RESPONSIVE ARCHITECTURE AND THE PROBLEM OF OBSOLESCENCE

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Abstract
Responsive architecture, a design field that has arisen in recent decades at the intersection of architecture and computer science, invokes a material response to digital information and implies the capacity of the building to respond dynamically to changing stimuli. The question I will address in the paper is whether it is possible for the responsive components of architecture to become a poetically expressive part of the building, and if so why this result has so rarely been achieved in contemporary and recent built work. The history of attitudes to- ward obsolescence in buildings is investigated as one explanation for the rarity of examples like the one considered here that successfully overcomes the rapid obsolescence of responsive components and makes these elements an integral part of the work of architecture. In conclusion I identify strategies for the design of responsive components as poetically expressive elements of architecture.

Keywords: *Responsive architecture; obsolescence; High Tech architecture; Archigram*

INTRODUCTION
The question I would like to address in this article is: Why haven't there been more examples like the Institut du Monde Arabe, buildings which propose a poetic purpose for responsive components in architecture (figure 1)? Part of the answer to this question, I believe, lies in the definition of 'high' and 'low' architecture in terms of rates of obsolescence and change, a distinction presented by Stuart Brand in terms of the capacity of the building to gracefully adapt to change in its surroundings over time. In Brand's book 'How Buildings Learn', 'low' architecture is associated with flexible responsiveness to change over time, in part due to the use of construction methods and materials with a relatively rapid rate of obsolescence and decay. The 'high' road for architecture puts a premium on permanence in buildings, and tends to avoid components susceptible to obsolescence and material deterioration. Those mechanical and electronic devices most susceptible to obsolescence are, in this schema, unsuitable for employment in 'permanent' structures except as 'peripherals' which claim a place outside the primary concerns of high architecture. This dissociation between technological innovation and culturally significant architecture has been challenged by occasional voices in the last century, notably Archigram in the 1960's and 70's, but persists in the strength of concepts and practices that exclude mechanical and electronic responsive devices from prominent inclusion in works of architectural significance.

In this paper I will first investigate obsolescence and the strict separation of high and low architecture as concepts that explain, in part, why the responsive components of architecture have seldom been granted an aesthetic purpose. I will then look at one example that tells a story of the architectural contribution of responsive building components, and suggests alternative ways of thinking about the elements of buildings that change over time in response to the environment. And finally, in conclusion I will extract strategies for future responsive buildings that aspire to the kind of expression found in these examples.

Figure 1: The South façade, Institut du Monde Arabe (Source: Peter Blundell Jones).

TYPES OF OBSOLESCENCE

The term obsolescence was first applied to buildings in early 20th century America to describe the rationale for razing solid, recently-erected structures to make way for new construction (Abramson, 2009, p. 157). In places like New York and Chicago land values exceeded the cost of new construction, necessitating frequent renovation and reconstruction in order to realize a sufficient return on investment. With changes in fashion and rapidly increasing requirements in terms of light, ventilation and other material comforts, frequent reconstruction was often a prerequisite for assuring a rental income commensurate with land values. In many urban areas of contemporary Japan the average building is valued at around 10% the cost of the land on which it's sited, resulting in an extraordinarily short cycles of demolition and reconstruction (Bognar, 1997).

The too close integration of ephemeral and relatively ‘permanent’ elements of the building was discussed as a factor contributing to obsolescence in Brand (1995), which proposed a model for understanding the various components of the building in terms of relative rates of change. Brand's model exists in multiple variations and continues to be widely applied as a way of understanding the role of dynamic elements in architecture. The concept of the building as a layering of elements, each with a different rate of change, was introduced by Frank Duffy (Duffy, 1990) as a way of explaining how the cost of accommodating change in buildings over their lifespan can amount to several times the original cost of construction. This concept was summarized and elaborated by Stuart Brand in his `shearing layers' diagram, which describes the relation between the components of a building as a series of concentric layers, each defined in terms of its expected lifespan. In this schema, `stuff', the furnishings and personal equipment that accumulate in buildings, has the highest level of obsolescence and a rate of change that varies from daily to monthly. `Site' describes the most intransient of building elements, the ground of construction, which is assumed by Brand to be essentially permanent; `structure' is the most durable aspect of the building itself, the part that persists over time. `Services', `space plan' and `skin' occupy the more transient zones on either side of the structural layer.

Brand's diagram is useful as a concise description of two types of change in buildings: the rate at which the physical materials of architecture wear out and the frequency with which changes in fashion dictate the reconstruction of existing infrastructure. The recognition of inexorable forces leading to obsolescence of entire buildings as well as building components has inspired a range of architectural responses. Cedric Price famously claimed that embracing obsolescence would bring a new kind of flexibility and social performance to architecture. Speaking of the concept of a Fun Palace, Price wrote ``Its stated and designed limited life will in itself enable the palace to be used in the particular mental behavior pitch reserved for immensely important impermanent objects of cherished social immediacy.'' (Price, 1968, p. 129). Every element of the Fun Palace was to have a limited lifespan, declared in advance: ``Nothing is to last for more than ten years, some things not even ten days''. (Price, 1968, p. 130).

This act of designing for obsolescence was proposed as a way of radically transforming the experience of architecture and was a strong influence on `High Tech' architecture such as the Centre Georges Pompidou (1977) of Renzo Piano and Richard Rogers in Paris which follows the spirit of the Fun Palace with its flexible environment consisting of temporary, re-arrangeable enclosures, ramps, escalators and walkways suspended from a space frame superstructure. The visible expression of independence between structure, services and skin was intended to increase flexibility and adaptation to change over time; in reality it often resulted in the appearance of flexibility.

Machine Anxiety

The concept of buildings as `machines for living in' is one of the potent legacies of modernism, although the fact that machines require an unprecedented level of maintenance was only belatedly recognized by advocates of the machine aesthetic in architecture. Automobiles, boats and airplanes can be distinguished from most buildings by their adoption of technologically advanced materials selected more for efficiency, weight and performance than for longevity and cost-effectiveness. As objects designed for motion, they are also characterized by a preponderance of moving over static parts, a quality that was sometimes translated into an architectural context through the introduction of mechanical devices that provide a precise, calibrated kind of flexibility designed to allow the building to adapt to everyday needs or unanticipated events.

Asked about the excessive maintenance required for his geodesic structures, Buckminster Fuller replied: ``If you build it like a machine, you must maintain it like a machine, not like a building.'' (Baldwin, 1997). Not surprisingly, building owners have often been unwilling to maintain the building in this fashion and the history of the building as machine has been plagued with failures. Brand (1995) is unapologetic in pointing out the failures of Fuller's geodesic domes: ``Domes leaked, always'' (p. 59). Le Corbusier's most ambitious attempts at integrating innovative technology were plagued by disaster, as in his Salvation Army building (1931-33) in Paris whose south-facing facade was originally constructed with no sunshades or operable windows, realizing the ideal of a `hermetically sealed' envelope expressed in Corbusier's writings.[i] During the first summer after opening it became clear that the `*mur neutralisant*' as built was insufficient to control interior temperatures in the south-facing rooms. Operable windows were added; even these were ultimately insufficient and the original planar glass facade was replaced with another that incorporated a concrete brise-soleil in 1952.

Technological failures can also result from innovative implementations of materials. The premature failure of the original cladding panels of Norman Foster's Centre for the Visual Arts in Norwich (1978) is thought to have been due to factors related to material incompatibility between the phenolic core and the aluminum panel (Stacey, 2001, p. 109). The glazed membranes of Le

Corbusier's Swiss Pavilion and Salvation Army building offer another example of a then new technology, the glazed curtain wall, whose early implementation was frequently problematic: the facades of both buildings required replacement less than 20 years after construction (Ford, 1997).

The history of modernism's technical failures had a chilling influence on the next generation of architects. As Antoine Picon states, ``In the years 1920-1930, from Le Corbusier to Perret, the perception of the modern environment is already oscillating between the intoxication provoked by its functional character -- source of an abstinence more authentic than the stylistic affectations of a system of beaux arts on the decline -- and the fear of breakdowns and obsolescence.'' (Picon, 2000, p. 78). The considerable interest among architects in the 1970's and 1980's with the topic of obsolescence and with designing for change was in part a reaction to the perceived failures of modernism, with its rigid vision for the integration of technology in buildings. Writing of Cedric Price's Fun Palace, Joan Littlewood states ``The ephemeral nature of the architecture is a major element in the design, making possible the use of materials and techniques normally excluded from the building industry. Charged static-vapor zones, optical barriers, warm-air curtains and fog-dispersal plants are some of the methods employed, together with vertical and horizontal lightweight blinds'' (Price, 1968, p. 132).

Significant in this last example is the assumption that components with a high rate of obsolescence are inappropriate for use in a building with pretensions to `permanence'. This is what Brand's diagram would have us believe, but this sharp line between the permanent and temporary elements of the building is more difficult to define in contemporary buildings that employ technology as a means of making the building more responsive to change in its environment.

High and low architecture

The relation between buildings that aspire to permanence and those that embrace the possibility of significant change over time is associated by Brand (1995) with a distinction between high and low architecture. 'High' architecture, what Brand terms 'magazine architecture', is disparaged as buildings that aspire to permanence and cultural significance while ignoring the needs of their users and the inevitability of change. 'Low' architecture is associated with the vernacular, everyday buildings that are open to transformation over time because no one is invested in their current configuration. Low architecture is epitomized by buildings that encourage reorganization and adaptation through their flexible approach to infrastructure and separation of systems.

This ability of low architecture to change over time is related to its separation of components with different rates of obsolescence. In Venturi (1972), part of what is admired about the Las Vegas strip is its separation of rapidly-changing iconographic elements from the structures behind them: ``The most unique, most monumental parts of the strip, the signs and casino facades, are also the most changeable; it is the neutral, systems-motel structures behind that survive a succession of facelifts and a series of themes up front.'' (Venturi, 1972, p. 34). This architecture celebrates the practicality of the solution as well as its playful reversal of expectations: the most ephemeral part of the building is also the most monumental, the aspect that defines the building iconographically. Venturi, Scott Brown and Izenour observe ``The rate of obsolescence of a sign seems to be closer to that of an automobile than that of a building'' (Venturi, 1972, p. 34): in this sense Venturi's concept of the decorated shed is consistent with the implication of continual reconstruction and maintenance implicit in patterns of urbanization in rapidly-growing global urban centers. As John Thackera writes ``[In Japan] buildings are designed in the expectation not that they will stand the test of time but that they will be torn down sooner rather than later and replaced by something more appropriate to the economic and technological demands of the future'' (Thackara, 1991). In this account low architecture is cheap, utilitarian, and sufficiently forgettable that its eventual replacement by new construction is unlamented.

Till (2009) builds on Brand's definition of high and low architecture, presenting high design as the enemy of an architecture that embraces the everyday needs of people, contingency, and the inevitability of change over time. Among the enemies named in Till's account are Le Corbusier, Norman Foster, Richard Rogers: 'magazine' architects who prefer the illusory and rigid image of perfection to the messy reality of constant change and reconfiguration over time. Architects whose decision to ignore the temporality of their buildings resulted in ``leaky roofs, rusting pipes, and awkward inflexibility'', they are criticized for short-sighted approach to design that ignores the necessity of adaptation over time in response to external change. Technology, in the form of the latest building gadgets and the use of the most sophisticated materials, is either an attempt to keep up with the Joneses in a building culture focused on the building as commodity or an attempt to superficially apply the appearance of progressiveness: ``Their commodity -- the design of buildings as objects -- has to signal its progressive tendencies so as to survive ... Progress is announced through the employment of ever-newer technologies (hence the conspicuous success of the high-tech movement in the external marketplace ...'' (Till, 2009, p. 85).

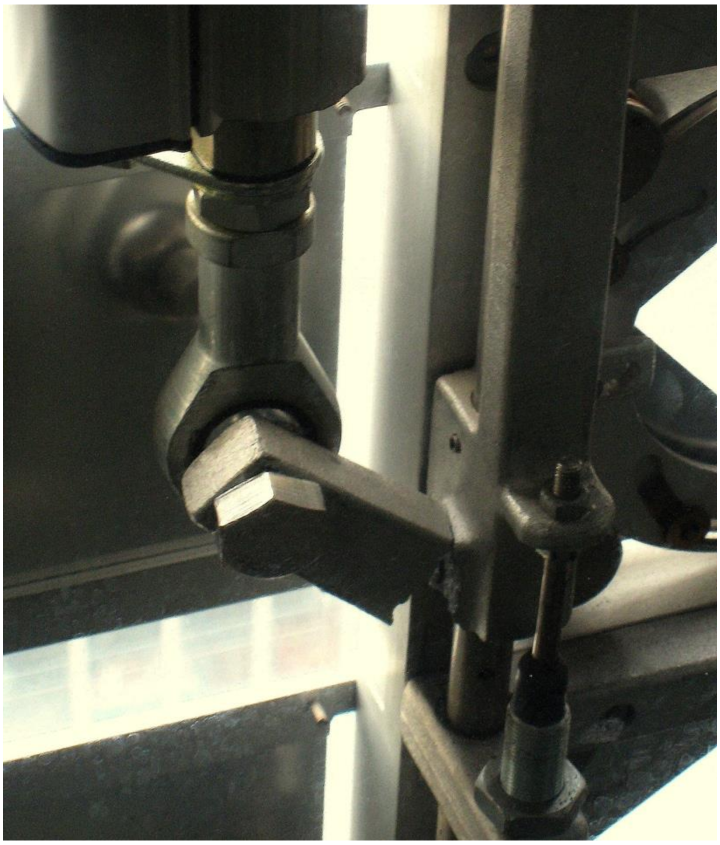

Figure 2: Institut du Monde Arabe, Mechanical diaphragms. Image showing damage to the arm that transmits the force of the motor to the diaphragm actuation mechanism (Source: Author).

Till and Brand present a compelling vision for low architecture as an adaptable architecture that anticipates change over time. Both agree in associating low architecture with low-tech: the avoidance of expensive and maintenance-intensive details which employ new materials and technologies as an integral part of the building. Applied to much responsive architecture of the past three decades, their critique has considerable merit. Buildings like Jean Nouvel's Institut du Monde Arabe, its south façade equipped with an array of mechanical diaphragms controlled by light sensors, promised a poetic experience of movement and change in response to the variable environment. Their reality has been something quite different: in the case of Nouvel's building maintenance of the responsive elements proved too difficult or expensive and the responsive, performative aspect of the façade was abandoned a few years after the building opened (figure 2). The building stands now as a reminder of one kind of obsolescence, the rapid deterioration of components whose use as an integral part of a significant work of architecture implied participation in a different order of persistence over time.

Responsive components occupy an awkward position between high and low architecture as defined by Brand and Till. On one hand, as expensive and 'high-tech' components they fall into the category of high architecture as practiced by Nouvel, Foster or Rogers. On the other, their rapid obsolescence and requirement for regular maintenance implies the kind of flexibility in anticipation of change over time that Brand and Till associate with low architecture. There is an alternate vision, one which imagines a hybrid architecture that mixes high-tech with rapid obsolescence in certain instances as a means of making culturally significant buildings that respond to change. This is one aspect of Archigram's proposals, and as one of the few built projects to emerge from this line of thought the Graz Kunsthaus suggests an alternate picture: one in which high and low elements are mixed in the creation of a significant work of architecture premised in part on the integration of 'high-tech', responsive components.

THE FAÇADE AS COMMUNICATIVE DISPLAY

The Kunsthaus in Graz of Peter Cook and Colin Fournier (2003) is a building with a complex relation to the concept of obsolescence and to the use of the facade as a responsive surface. The array of circular fluorescent tubes embedded in the facade are controllable via a software interface developed by new media design firm realities: united, who were also responsible for the design of the display hardware. The building is an interesting exception to the type of the media facade, and offers insights into the poetic potential of responsive building components (figure 3).

The media facade was part of the original concept for the building, although in a form that bears little resemblance to the final constructed version. In their competition entry Cook and Fournier described the building skin as a soft, semi-transparent surface animated at certain moments with hints of the activity within: ``Much of it is opaque, but from time to time there are revealing slivers of transparency or hints of the presence of action within. Strange things appear and disappear within the skin: signs, announcements, short sequences of film or images: glimpsed for moments, only to fade away'' (Ilsinger, 2003, cited in Edler, 2005). The skin is also described as a ``laminated fabric incorporating a mesh of tensile threads and compression ribs enabling it to span the width of the roof without intermediate supports ...''. (Ilsinger, 2003). This highly suggestive and poetic concept for the building skin was in the end too expensive and impractical to realize. As Peter Blundell Jones comments of the high-tech construction proposed in the competition entry, ``This Archigram rhetoric recalling the space race proved hopelessly optimistic, once again missing the point that buildings are large, so a cubic meter can only cost a fraction of a cubic meter of car, airplane, racing cycle, or computer.' (Jones, 2004, p. 52). The skin as realized represented a radical simplification of the original proposal, but one that retained a certain fidelity to the architects' vision despite its compromises. I will focus here on the aspects of the skin that relate to its performance as a surface for dynamic display.

The facade of the Kunsthaus does not employ the Brand's clear separation of elements based on rates of obsolescence: the skin is rather conceived as a layered assembly that tightly integrates multiple functions. Although realities:united were brought in as consultants on the media facade at a late stage in the design of the building as a whole, the concept for the animated display is remarkably well-integrated with the building skin. For the individual pixels of the display Jan and Tim Edler selected the low-tech solution of circular fluorescent tubes with individual ballasts which permit the brightness of each pixel to be varied at a rate of 18 frames per second. The low cost per pixel allowed the display surface to be extended across a significant portion of the facade. Such a large display would not have been possible with LED's given budget limitations, so display resolution was sacrificed in favor of creating a surface at the scale of the building. The fluorescent tubes are sandwiched between transparent heat-formed acrylic panels that follow the building's curved form, and an underlying opaque weather barrier visible in the gaps between the panels. Because the fluorescent bulbs are not clearly visible behind the acrylic panels except when illuminated, and because the edges of the display surface are irregular and follow the contours of the building, there is an ambiguity about where the display surface stops which enhances the sense of integration and the perception that the entire building surface is animated by the BIX (big pixel) display.

Figure 3: Kunsthaus, Graz. (Source: Peter Blundell Jones).

In addition to designing the hardware of the BIX facade, realities: united were commissioned to build a software interface that facilitates the creation of content for display on the building. In a series of curated exhibits, designers have been invited to use this tool to create content for the facade, whose round pixels can be fluidly animated with patterns visible from many points within the city. The software allows the designer to view an animated sequence mapped to the building's 930 fluorescent pixels from multiple vantage points within the city. In a published discussion of the facade, realities: united principal Jan Edler has written that it was important to distinguish this facade from the concept of the media facade as a form of advertising. This he describes in terms of the distinction between a billboard that displays messages that have nothing to do with the building and its function (i.e. advertising) and messages that are in some way closely related to the building and the activities taking place within: ``... a majority of such installations broadcast global advertising messages, thereby denying any form of relation between the specific building and its outer appearance. The surface of the building becomes separated and alienated from its inner programmatic structure ...'' (Edler, 2005, p. 152). It is precisely this expression of the interior on the facade that was imagined by the architects in their competition entry, with its glimpses of the building's inner world projected onto the outer surface. The realization of a partially transparent skin was eventually found to be impractical given budgetary constraints, and the fully opaque skin with an outer layer of animated lights across its surface does bear a family resemblance to Venturi's concept of the sign as a total separation of interior program and exterior display. The openness of the facade's control software leaves open, though, the possibility of a display that responds to sensor data capturing activity within the building, a use that would come closer to the poetic vision of the architects than animations with no relation to the building and its interior.

The building's relation to its own obsolescence is not straightforward. The facade was originally conceived by the architects as a multi-functional laminated fabric: ``The laminate consists of a mylar film incorporating anisotrophic carbon threads and kevlar/Nomex aramid honeycomb struts for compressive strength… Fluids, fibreoptic cables and other infrastructure elements are channeled through the fabric by means of laminated bladders.'' (Ilsinger, 2003, cited in Jones, 2004). When this method proved prohibitively expensive a more conventional layered assembly was proposed: rather than an expensive, high-tech solution integrating multiple functions in a single fabric membrane a more pragmatic but still complicated solution was chosen that sandwiches the fluorescent bulbs between the acrylic panels and a waterproof plastic membrane consisting of sealed PVC panels. The advantages of such a layered assembly includes easier replacement of each element of the facade as required by material deterioration or changes in fashion. The fluorescent tubes were chosen over a more expensive solution such as LED's, with the trade-off of the necessity of more frequent replacement.

CONCLUSION

The Graz Kunsthaus presents an example of responsive building components conceived as an integral part of a culturally significant work of architecture. In this way, the building suggests an alternative paradigm for understanding the relation of such responsive components to the building as a whole. I have suggested several reasons why examples like this are as rare as they are including the perceived incompatibility of automated mechanical components, with their accompanying threat of early obsolescence, and the permanence associated with 'high architecture'. To this could be added numerous other obstacles including poor warrantees on responsive components, high insurance costs, and the question of who is to blame when something goes seriously wrong (Kroner, 1997).

The Kunsthaus illustrates the degree of care in design that has been applied to responsive, moveable components of buildings in the recent past. In the following, I will summarize several observations that suggest why responsive components are not often treated with this level of care in contemporary buildings. These observations can also serve as strategies for the design of future responsive components that aspire to become poetically expressive elements of culturally significant works of architecture, Brand's 'high road'.

Use simple, low-tech elements whenever possible: The fluorescent bulbs used in the Graz Kunsthaus were cheap, long-lasting, and resistant to obsolescence because they represented a new use of a well-established and stable technology. As Jan Edler of realities:united writes of the facade: ``By using the fluorescent light rings, i.e. an 'outdated' technology, the BIX display meets the architectural demand of constancy'' (Edler, 2005, p. 158). The choice to employ large fluorescent bulbs resulted in a radically low resolution display, but also afforded the possibility of covering a significant area of the building's surface, achieving a greater level of integration between the dynamic display and the building. Had the display been created using contemporary, relatively high-resolution media wall display technology the size of display possible with the same budget would have been nearly 100 times smaller (Edler, 2005, p. 155).

Consider software design as an area for innovation: Responsive building components have a physical aspect consisting of the actual hardware with its motors or display elements and embedded computer circuitry; and a digital aspect consisting of the software that determines how the hardware will perform in response to sensor data. This software is generally less expensive to produce and more readily replaced when it fails than the responsive hardware, particularly when the latter is employed at the scale of the building (as in the Institut du Monde Arabe or the Graz Kunsthaus). The control software designed by realities: united allowed the public to design animated sequences for display on the Graz Kunsthaus, which is representative of a distinctly new type of building, one whose design involves the creation of digital content and/or an interface for creating that content. In this relationship between digital content and hardware it is the content that leads: the Kunsthaus display hardware is by comparison inexpensive, easily replaced, and incidental.

Anticipate the possibility of failure: One remarkable aspect of the Institut du Monde Arabe is the extent to which its responsive diaphragms continue to function despite the failure of their mechanical moving parts. It is most likely a happy accident that the diaphragms continue to act as effective daylight diffusers and potent symbols despite the fact that their responsive mechanism is no longer functional. Still, this example highlights the importance whenever employing new and relatively untested technology as an integral aspect of a building to consider the impact on the building in terms of performance and poetics if the technology were to fail.

Anticipate the necessity of maintenance: The decision to make responsive components an integral and permanent part of a building of cultural and civic importance involves a commitment to regular maintenance over a significant period of time. The 'permanence' of the such a building's responsive components lies in the persistent will to replace the building's physical and digital components as required by obsolescence or failure: as Stuart Brand pointed out, this is a kind of permanence that is facilitated by a layered and modular approach to construction. Edward Ford has argued that although the conception of the wall as a layered assembly requires greater maintenance than a masonry wall, it also offers increased performance and ultimately greater longevity (Ford, 1997, p. 6). In an analogous fashion, the responsive components of architecture have the potential to become `permanent' elements of the building through the decision to design its components for regular replacement.

I have considered the extent to which the integration of responsive components in buildings requires a re-assessment of the significance of obsolescence as a model for understanding architecture. Each of the strategies listed above presents one method for achieving hybrid architecture with low and high elements. The introduction of mechanisms that anticipate movement and change implies a shift in the understanding that the most permanent elements that *define* the building. This is particularly the case when these dynamic components become central to the symbolic and aesthetic conception of architecture. As more buildings are defined by their integration of responsive components, it will become necessary to rethink the relation of the building itself to time and to accept as commonplace the idea that the most ephemeral and rapidly-obsolescent of building components can become an integral part of the work of architecture.

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[i] For example, in the essay `Techniques are the very basis of poetry' (Corbusier, 1991) he writes: ``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 degrees. The house is sealed fast! No dust can enter it. Neither flies nor mosquitos. No Noise!."

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