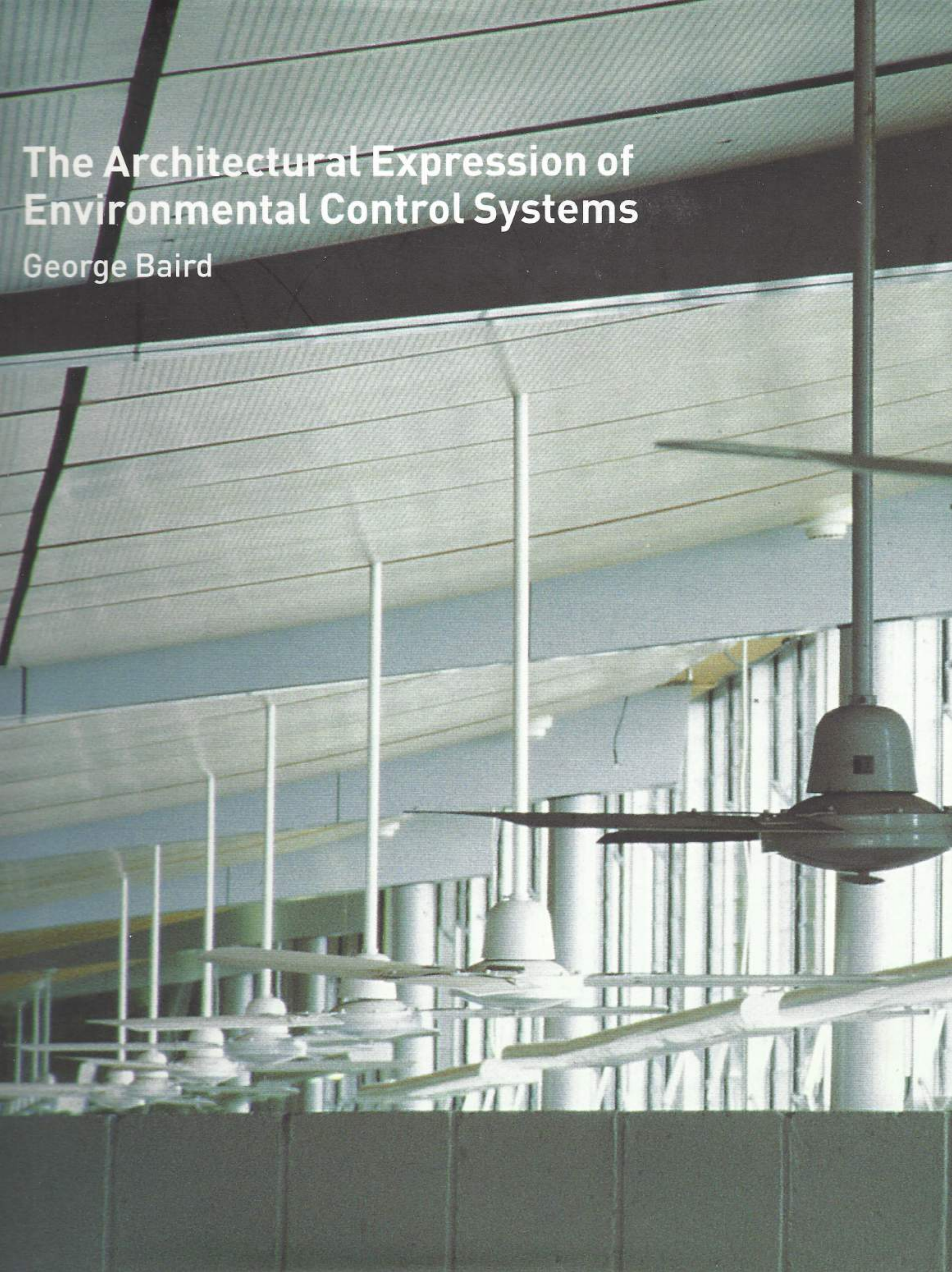
The Architectural Expression of Environmental Control Systems

George Baird



Contents

Chapter 7

Central Library, Phoenix, Arizona, USA

From the cold temperate conditions of central Europe, we now move to the hot dry climate of the city of Phoenix, which is the capital of the south-western American state of Arizona. The new Central Library building is just north of the city centre, where N. Central Avenue crosses over the I-10 Freeway tunnel. With a total area of ~26 000m^2 (280 000 ft^2) spread over five floors, the library is designed to house up to 1 million books. The first civic building completed (at a capital cost of just under US\$100 ft^{-2}) as part of a plan to revitalise the downtown area, was opened in May 1995.

The designers

The successful design team (of the 25 or so who expressed an interest in this commission) was led by local architect Will Bruder, whose small practice was based at New River in the desert just north of Phoenix; in collaboration with Ove Arup California's large office, a block away from the intersection of the Santa Monica and San Diego Freeways in Los Angeles – an intriguing contrast in size and location.

A graduate in sculpture from the University of Wisconsin at Milwaukee, and a student of Paulo Solari, Bruder had started his own practice in 1974. He had a well-established philosophy that building systems were basic to architecture – in his view 'real architecture is a balance between pragmatism and poetry'. Expressive integration of environmental control systems and responding to the local climate and surroundings were always high on the agenda, whether he was designing houses, offices or libraries (Bruder, 1998). In two earlier branch libraries for the city of Phoenix (at Mesquite and Cholla) Bruder had tested many of the ideas, including the expression of environmental control systems, which came to full fruition in the Central Library project (Khroyan and Schutt, 1996), where he was assisted by partner Wendell Burnette and associate firm DWL Architects.

Ove Arup California gave Bruder an 'exclusive' on this project. In other words, they were not involved with any of the competing teams. In addition, Bruder took the apparently unusual step of involving the engineers (Peter Budd was principal at the time) in the initial interviews with the client. In due course, the environmental engineering design was taken over by Alan Locke, a graduate of Napier College, Edinburgh, who had been exposed, at Arup's London office, to work on the Pompidou Centre and the Lloyds of London projects, and later, with Arup California, on the design of the Menil Museum and the Cy Twombly Gallery in Houston, Texas.

This was the first project on which the two practices had teamed up, together with environmental design specialists David Tait on solar design and Roger Smith on lighting.

Project background and the design process

The rapid growth of Phoenix has led to an expansion of its cultural and community facilities over recent years. The new Central Library is the flagship manifestation of what is a US$1.1 billion dollar programme. The site of the building is on the north edge of the Margaret T. Hance Park (or Deck Park), which itself is above the I-10 freeway tunnel. Central Avenue runs alongside the west edge of the site with only the sidewalk between road and building. Surrounded by the upper Sonoran Desert, Phoenix is at an elevation of ~330m and a latitude of 33°N. It experiences hot dry summers (1% design temperature of 42°C), relatively mild winters (1% design temperature of 3°C), and receives >85% of annual possible solar radiation (ASHRAE, 1997: 26.6–7; Burrelsman *et al.*, 1998).

The brief was to emphasise low capital and running costs (do not all briefs!) as well as the elimination of the operational inefficiencies of the existing library. The need for energy efficiency was implicit and the design had to be both flexible within its current envelope and capable of future expansion. But all this was to come later, following the selection of the design team. Selection in this instance was a professional hiring process involving an interview following an open invitation for expressions of interest, rather than by a design competition. For Bruder, the interview involved describing how he would approach the project, the vision and the methodology, and integral to the presentation was Ove Arup engineer Budd.

Will Bruder takes some pride in 'having that discipline not to preconceive' (Bruder, 1998). Having been selected to lead the design team his first action was to go on a 10-day study tour to Europe, taking with him his associate and co-designer Wendell Burnette, and Carleton Van Deman, president of DWL Architects with whom they had formed an alliance for the project. The aim of this tour was to study relevant buildings (not necessarily libraries at this stage). Included were work by Calatrava and Scarpa in Zurich; Pompidou, Institut du Monde Arabe, Cherelle House and Labrouste's Bibliotheque Nationale in Paris; a meeting with Herman Hertzberger in Amsterdam; Mackintosh's School of Art in Glasgow; and finally, in London, Foster's and Rogers' offices and tours of several buildings in which Ove Arup designers had been involved.

Following that, the design team conducted a series of public meetings with different interest groups in the Phoenix community, 26 in all, to assess their expectations of the building (students, minority groups, business users, historic concern groups, etc.). They then worked with the librarians and at the end of this process produced a 650-page brief of the building requirements.

The final step, 'before we went on the design journey' (Bruder, 1998) was for key members of the design team, the library management group and relevant city officials, to make a brief tour of recent central library facilities in North America – in particular, Dallas, Houston, Broward County Florida, Atlanta, and Toronto. In each case, members of the group played the (serious) part of a user trying to locate a particular piece of information or

a book, to evaluate how the building really worked in practice. A predesign process every bit as rigorous as what was to follow.

Although they had not previously worked together, 'the Arup team quickly realised that he [Bruder] and his collaborator Wendell Burnette believed in teamwork, bringing to the project great talent for investigating, examining, making decisions, and re-examining, all very quickly to meet not only schedules and budgets, but also ideals'. and 'Will Bruder believes in total team collaboration, and in the early design phases, not a single idea or suggestion passed unexamined. Many alternatives were considered and rejected before the final solution was agreed' (Bolin and Hamilton, 1996).

One of the early options considered was to build a concrete box with thick walls and minimal openings to the sun – the desert adobe house concept. This was analysed thoroughly by Arups, but eventually rejected on account of the lack of views out to the north and south. A trombe wall option was also considered for the south façade, but it too was rejected. Central core plans were considered and rejected on account of their restricted flexibility in terms of future changes in internal layouts. The breakthrough, according to members of the Arup group, 'came during a design team meeting when a plan emerged for a service zone on each side of a "warehouse for books"' (Bolin and Hamilton, 1996) – the so-called 'saddlebag' metaphor – resulting in a building with façades and roof that responded appropriately to the external environment.

Of course, this was the first project that Bruder and these engineers had worked on together, and according to Alan Locke of Ove Arup, who participated in the tour of recent libraries and visited some of Bruder's previous work, building up a relationship takes time and initially it was hard to read Will's mind. However, he recognised that Will 'wanted to make it perfect' and an excellent relationship was built up and has continued in further project work. He also recognised one of the advantages of working with an owner-architect (as opposed to a larger partnership) – that final decisions could be made more readily at the design team meetings (Locke, 1998).

As far as design team meetings were concerned, these were held weekly or fortnightly, at New River or South Sepulveda Boulevard as appropriate, with the design leadership coming from Will and Wendell. In the words of the former, 'we led ... the design effort, and it was our rigour in bringing this purity of integration to the occasion that everyone responded to', an integration that took place 'at the conceptual or even the pre-concept level, not at the schematic or the design development level'. In his view, 'technical issues are not about being crammed into a solution, they are about forming the solution' (Bruder, 1998).

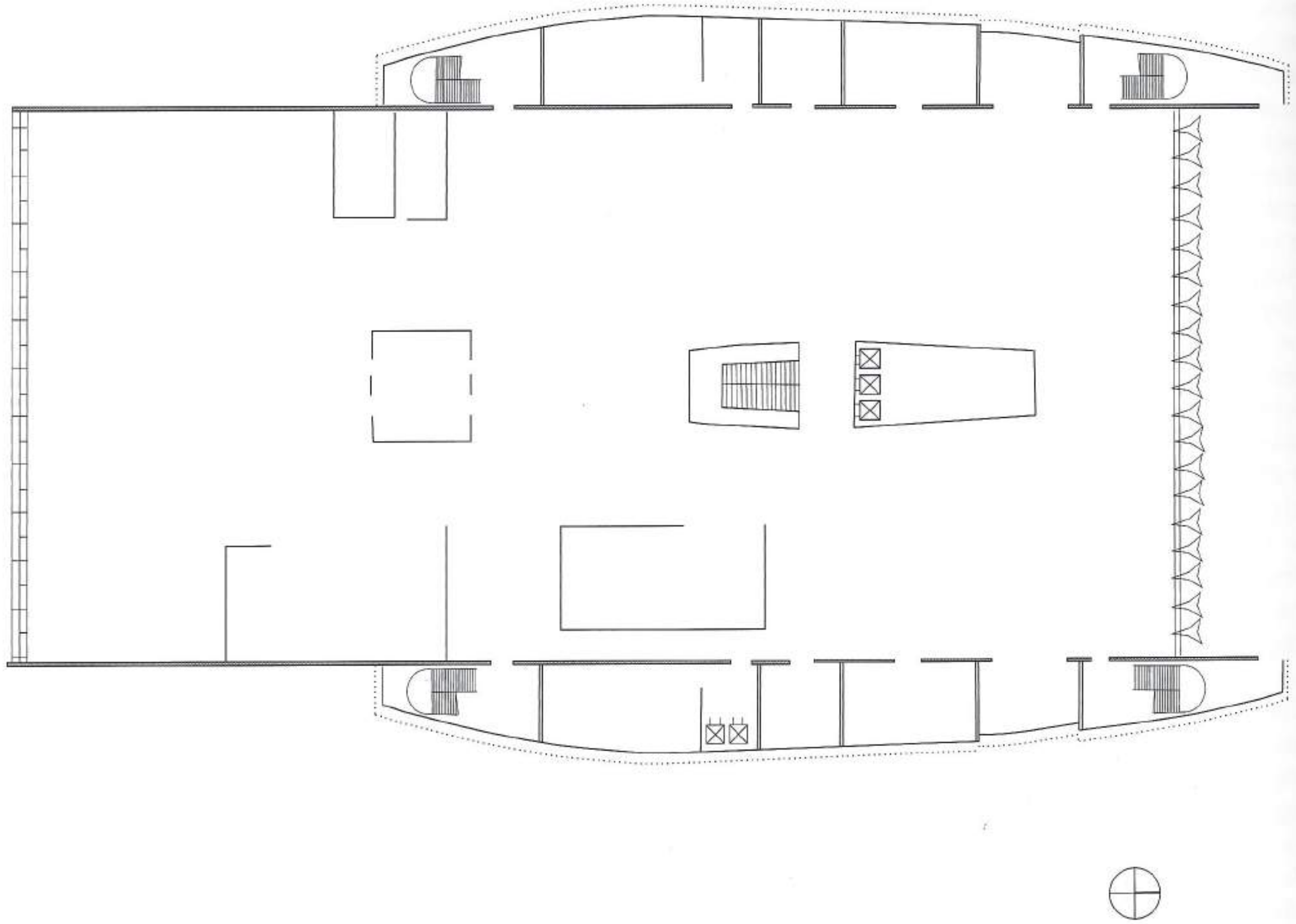
Design outcome and thermal environmental control systems

Much of the 26000m^2 floor area is contained in a five storey rectangular plan block. Levels 1 and 2 are ~66 × 107m and house the main lending and reference departments (Figure 7.1). The three ~66 × 80m upper levels (Figure 7.2) house administration (Level 3), special collections (Level 4) and the main reading room (Level 5) (Seal, 1996). The reading room (Figure 7.3) has a height of ~12m, all the other levels being a more conventional 3m. An atrium space (~32 × 8m), containing three elevators and the main stairs, is north of centre on the north–south axis of the block.

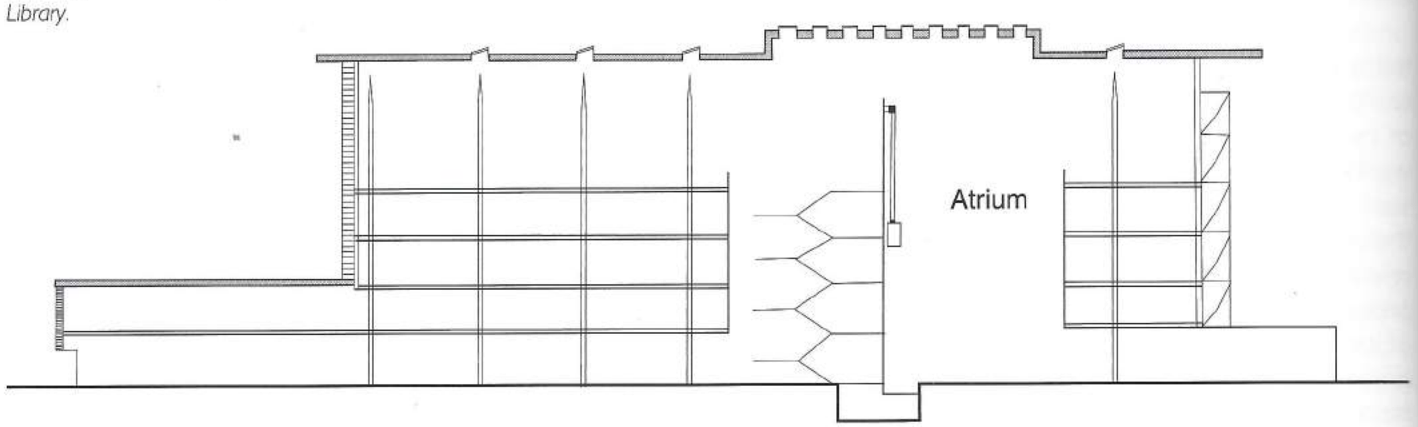
The so-called saddlebags are on, and completely cover, the east (Figure 7.4) and west (Plate 10) façades of the building, other than where Levels 1 and 2 jut out from the rest of the block over the I-10 Freeway tunnel. At ~8m wide at their maximum, these full-height, curved, copper-clad containers house the building's escape stairs, service elevators, rest rooms and mechanical services, leaving the rest of the floor plate substantially free of associated vertical ducting (Figures 7.1 and 7.3).

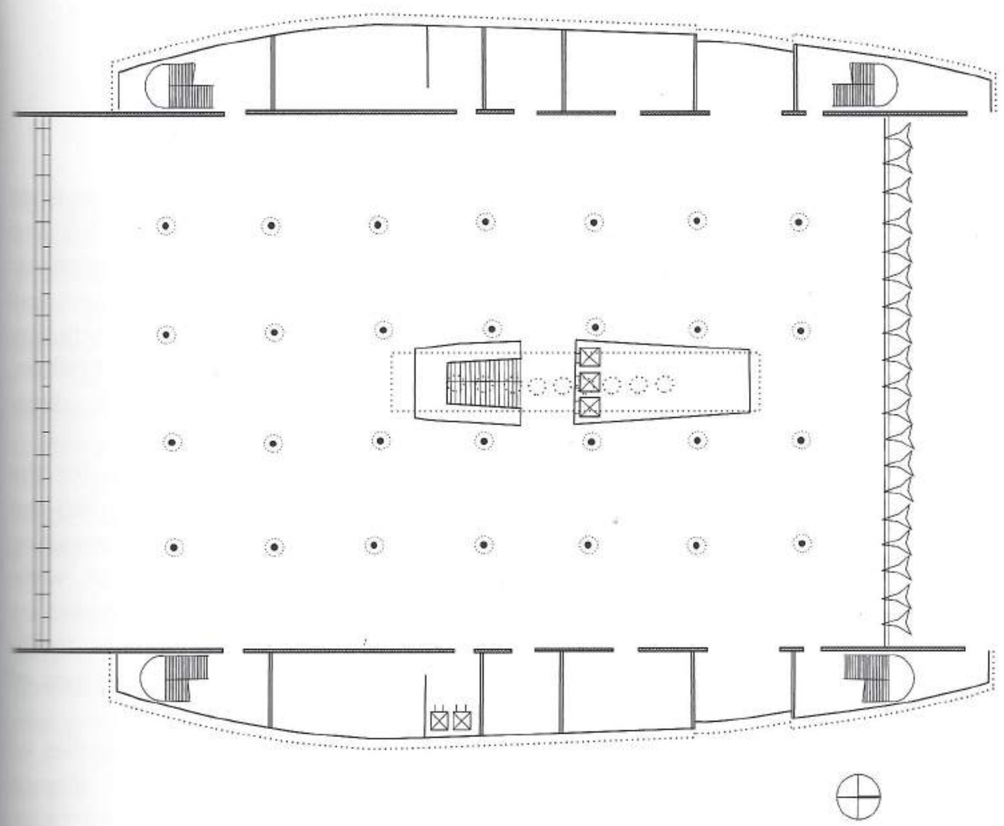
While the entire building is air-conditioned, significant steps have been taken in the design of the façades and roof to control the solar heat gain which is such a significant factor in this desert region. Given the latitude and climate of Phoenix, the likelihood of significant internal heat gains from lights and people, and a deep

7.1 *Plan of Level 2.*

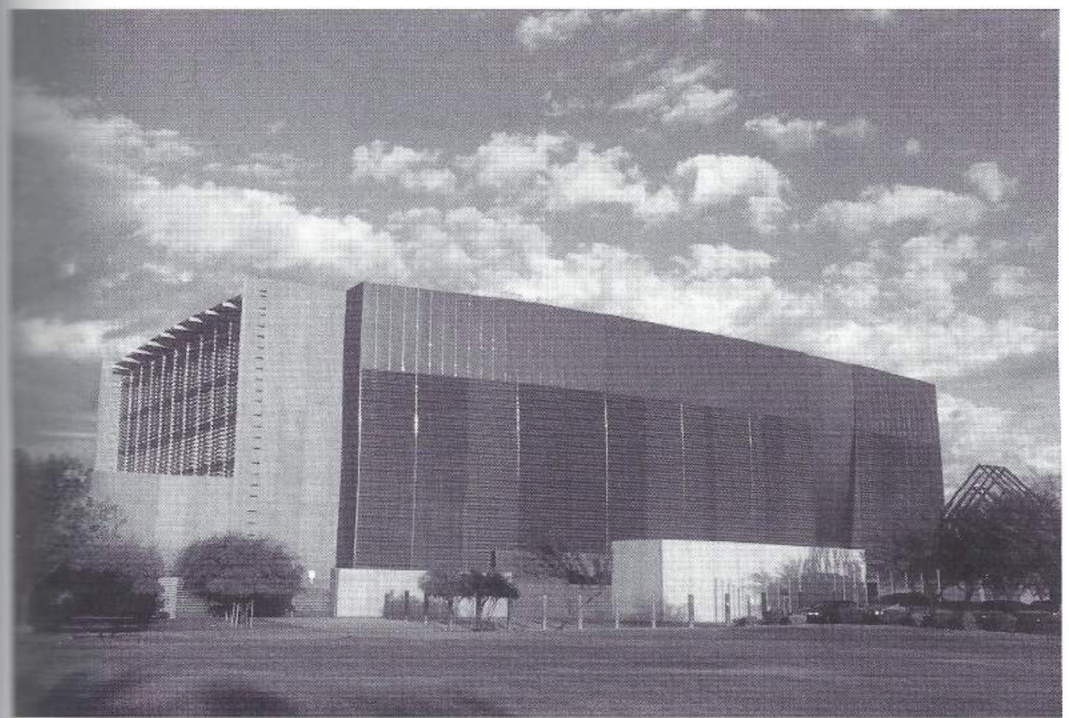


7.2 *Long cross-section of the Library.*





7.3 *Plan of Level 5, The Reading Room.*



7.4 *East façade Saddlebag and service yard.*

floor plan which precluded natural ventilation, coupled with a strong desire to keep energy costs to a minimum, the thermal environmental control strategy became one of reducing external heat gains, minimising internal heat gains and installing an energy-efficient HVAC system.

The HVAC system central plant is comprised of two gas-fired 400 ton (1407kW) absorption chillers in the Level 1 plant room at the bottom of the east saddlebag (Figure 7.5), with two 600 ton (2110kW) cooling towers in the adjacent yard. These supply chilled water as required to the main air-handling units (AHUs) located at each level in the saddlebags. There are four AHUs per floor, two in each saddlebag with capacities in the ~3.8–7.6m^{3}s^{-1}) range each (Figure 7.6), thus reducing the need for vertical air circulation and increasing the flexibility of the system to cope with changing circumstances.

Supply air ducts from the AHUs penetrate the concrete wall and run parallel to it in the so-called 'power bellies' before being ducted into the ceiling spaces in Levels 1–4 (Figure 7.7). Distribution into the spaces is via VAV units, which are equipped with electric reheat, and then 'through specially designed perforated ceiling panels' (Figure 7.8), designed and tested at the maximum and minimum flow rates to ensure adequate air distribution through the range of flow rates' (Bolin and Hamilton, 1996). In the case of the high-ceilinged Level 5, air distribution is via a raised floor system (Figure 7.9).

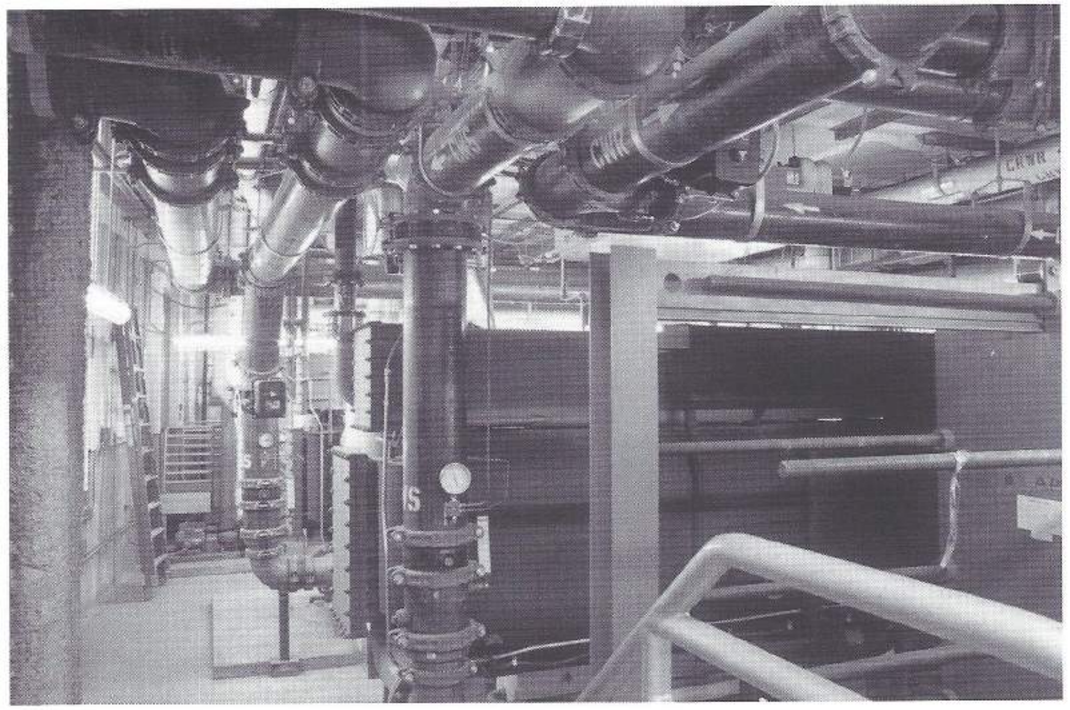
The passive environmental control systems for the library are incorporated in its walls and roof – with the aim of minimising solar heat gains but without eliminating visual contact with the outside environment. Thus, while the east and west façades are completely shrouded by the saddlebags, the north and south façades are totally double-glazed and the roof incorporates three types of skylight.

On the east and west, the reflective properties of the external copper cladding form a first line of defence against the year round morning and afternoon solar radiation (Figure 7.4). The depth of the saddlebags, naturally ventilated other than where stairs or rest rooms intrude, provides a second barrier, while internally, the 12-inch thick concrete wall panels give sufficient thermal time lag and reduction of the daytime heat gains (Figure 7.10).

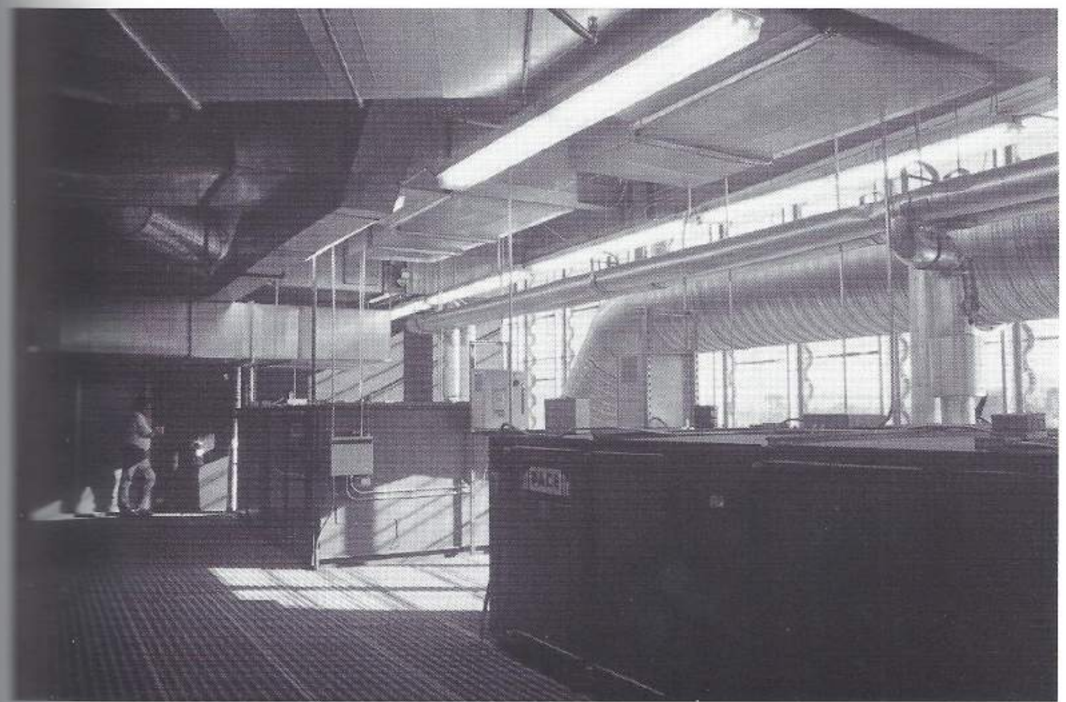
The fully glazed north façade is fitted with fixed external vertical shading. These take the form of Teflon-coated acrylic fabric sails and eliminate direct sun penetration between the spring and autumn equinoxes. The saddlebags jut out on each side of this façade and also provide useful shading during that half of the year (Plate 11).

The south façade is fitted with horizontal, externally mounted, aluminium louvres. These are computer-controlled to eliminate direct sun penetration, while maximising views and daylight (Figures 7.11 and 7.12).

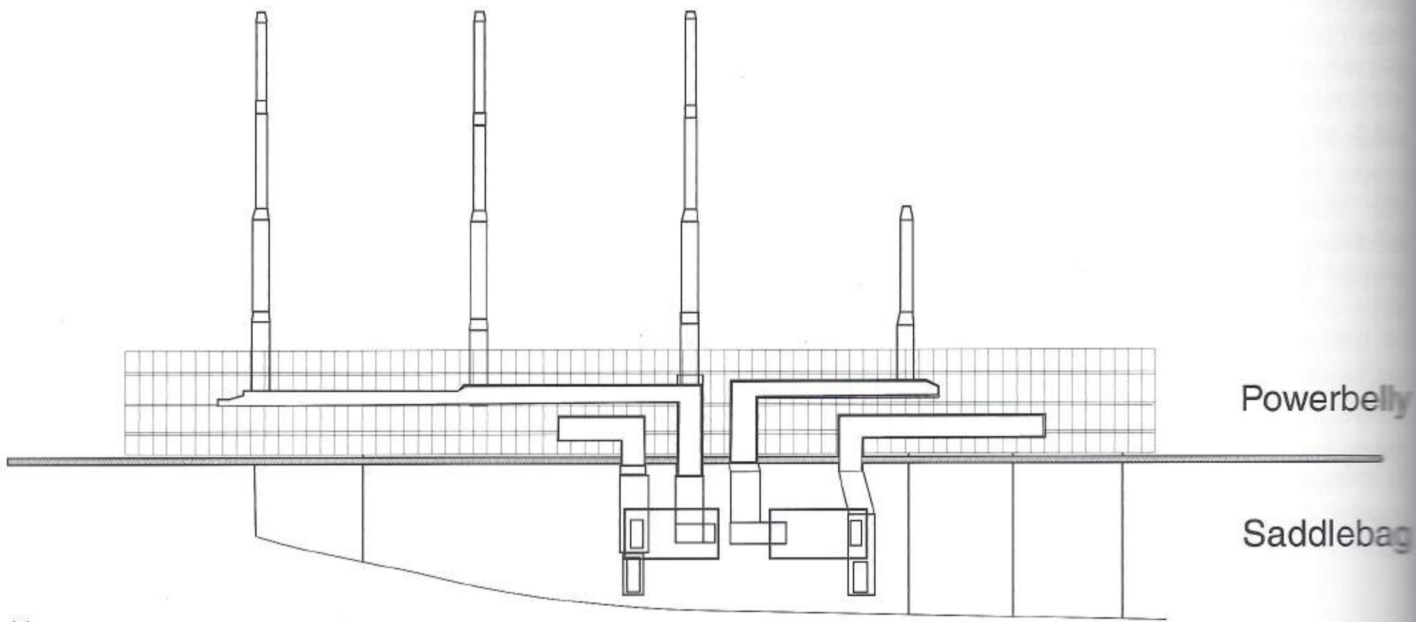
The roof incorporates three systems of environmental control, all of which impact to some extent on thermal conditions in the Level 5 Reading Room and the Atrium Space. The first and simplest of these are two 0.76m-wide strip skylights running along above the east and west walls, washing them with daylight at any time of the day (Figure 7.9) and with sunlight at solar noon. The second comprises the ~1.2m diameter skylights above the tops of the columns which provide support for the roof (Figure 7.13). The blue interlayer within one of the several sheets of glass which form each skylight has a 4-inch (100mm) hole cut such that at solar noon at the summer solstice, the sun shines directly onto the top of the corresponding column. Finally, the nine atrium skylights (Figure 7.13) are designed to diffuse maximum daylight into that space using a computer-controlled double louvre system – an upper set of reflective louvres tracks the sun and directs the appropriate amount of light downwards, while the lower set diffuses the light and eliminates direct glare to the space below (Figure 7.14).



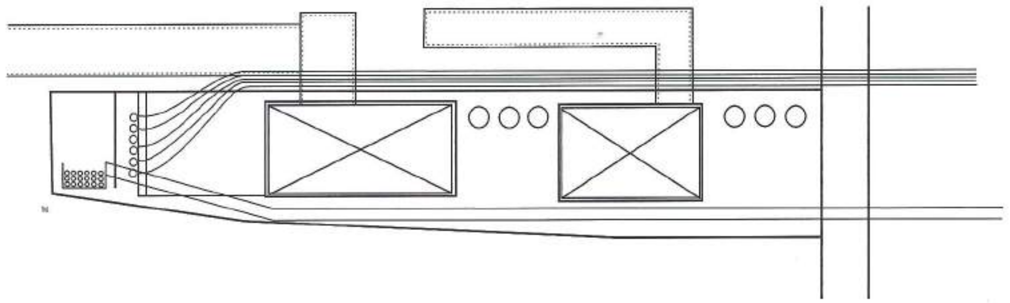
7.5 *Central Library, Phoenix – central Plant Room with absorption chillers.*



7.6 *Air-handling units in the east Saddlebag.*



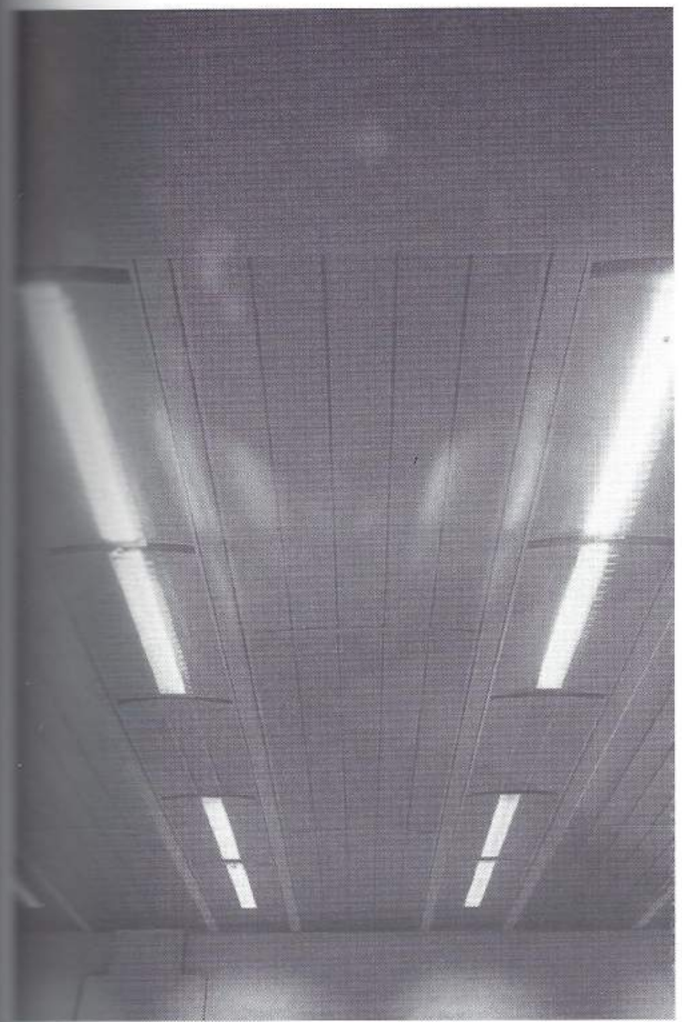
(a)



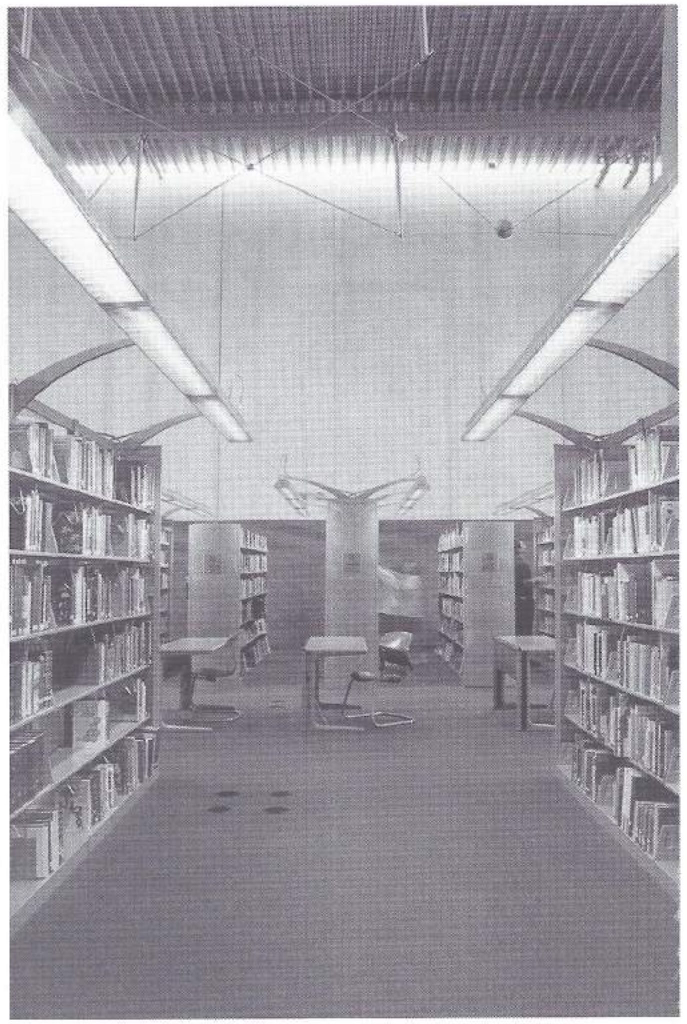
(b)

7.7 *Saddlebag air-handling units and the power belly services distribution system. (a) Plan; (b) section of the power belly.*

7.8 *Perforated ceiling air supply system.*



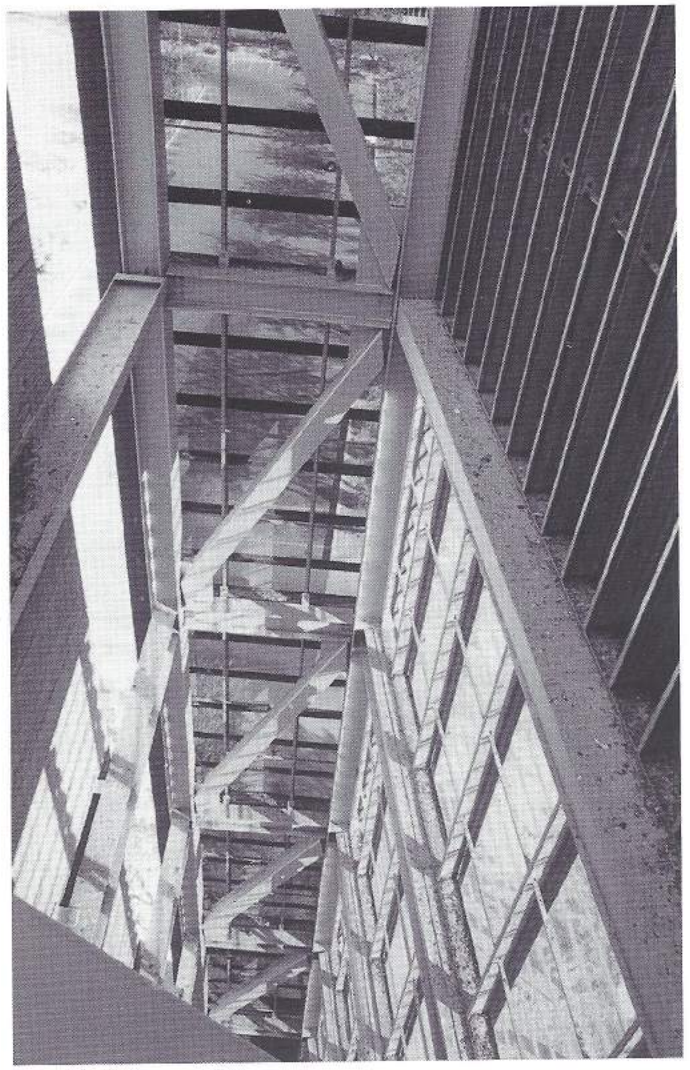
7.9 *Level 5, showing the floor air-supply diffusers and west wall daylit by a strip skylight.*



Expression of environmental control systems

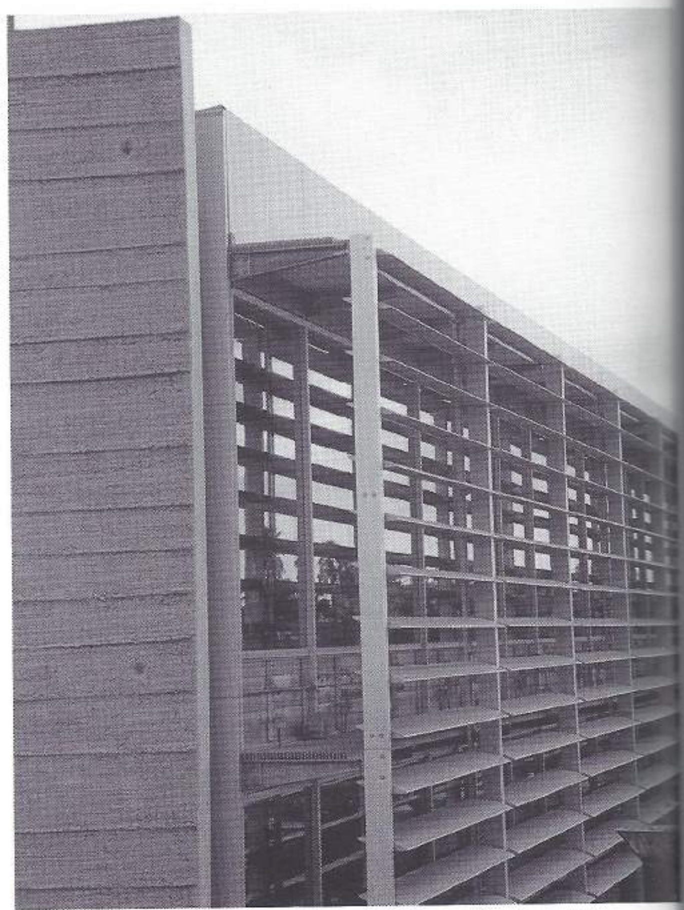
According to one writer, this is 'One of the most technically expressive buildings in America ...' Barreneche (1995), while another asserts that '... Bruder has managed to raise prosaic technology to the level of architecture by making it obey a formal order and by translating it into metaphorical terms corresponding to his concept of the public library as a late 20th-century popular institution' (Curtis, 1995). High praise indeed from the pages of *Architecture*.

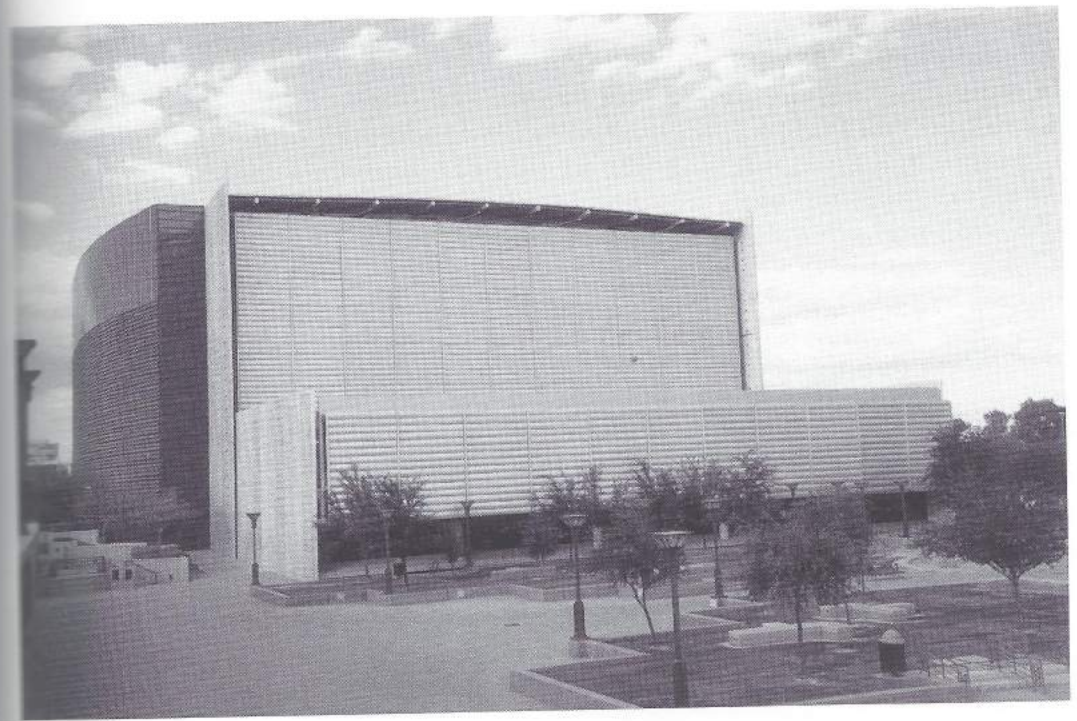
Outwardly an air-conditioned box, the library's orientation and the clearly articulated differences between its façades, belie such a simplistic description. The saddlebags shroud the east and west façades, clearly expressing their thermal environmental control function of limiting solar heat gain to these façades, which not only bear the brunt of the sun's intensity all through the summer months, but also are the more difficult to control. The fixed vertical



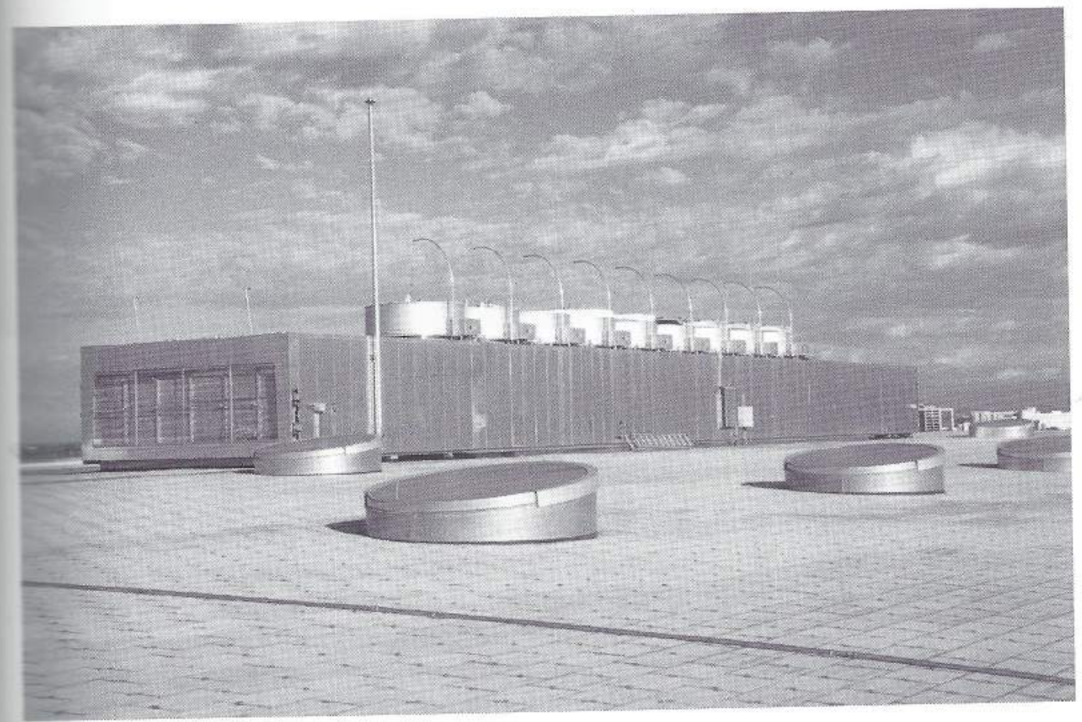
7.10 *View down into the saddlebag at the north-east corner.*

7.11 *External detail of the south façade louvres at Level 2.*



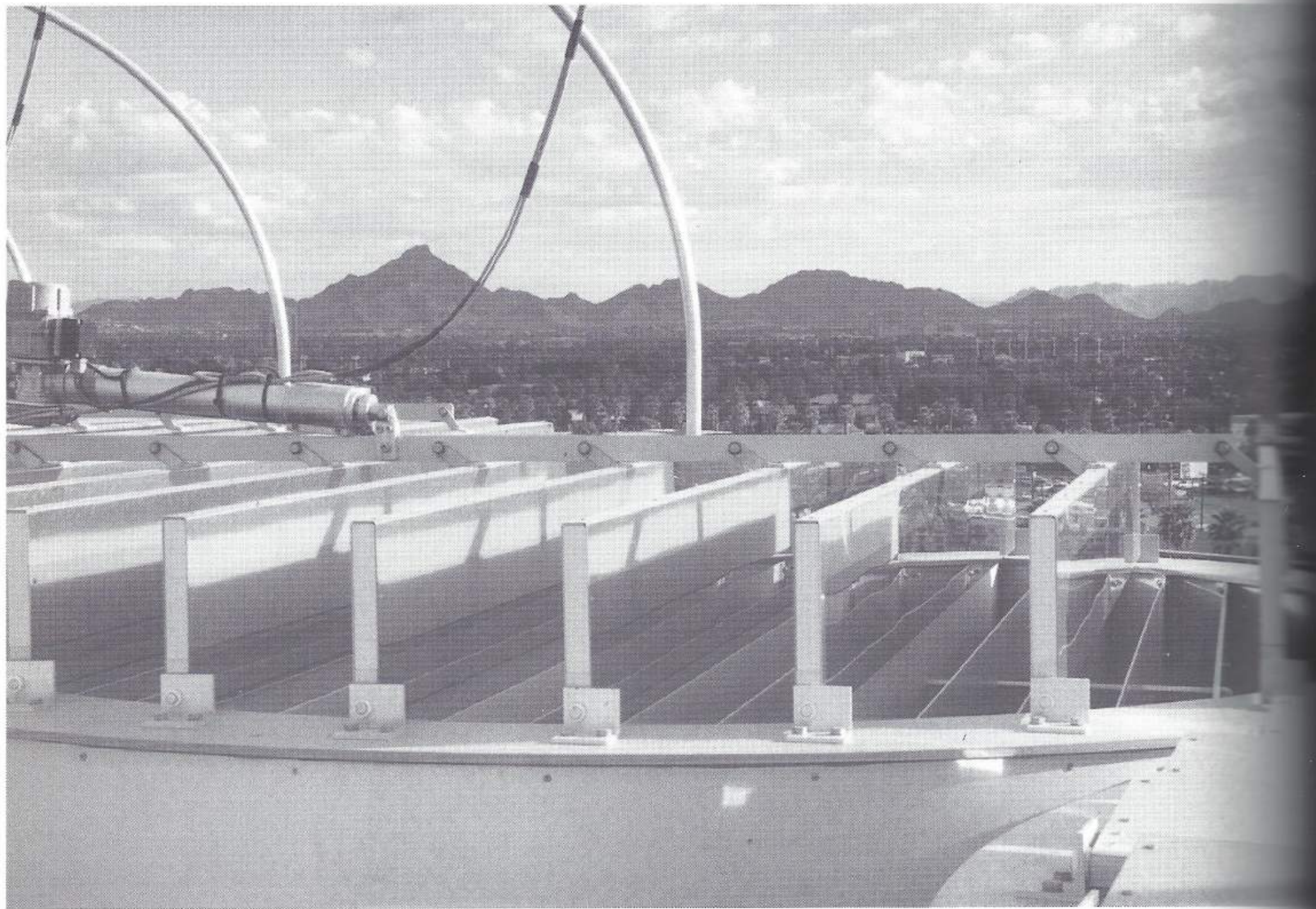


7.12 *South façade with the louvres in their closed position.*



7.13 *Skylights. The row on top of the metal-clad structure is above the atrium; the others are placed above the structural columns.*

7.14 *External detail of the louvre arrangement on one of the atrium skylights.*



shading on the fully glazed north façade, and the adjustable horizontal shading on the south, even to the use of fabric for the former and aluminium for the latter, speak directly, and appropriately, of their environmental control function – solar heat gain, daylighting and glare in this instance. The use of the saddlebags to house the main AHUs and vertical pipe runs, as well as other service areas, reinforces and also gives clear expression to their environmental control function.

In the words of the architect, 'it's obvious that the two sexiest things about this building are these saddlebags clad in copper and what was generated from that idea; and the mystical quality of the great reading room ... which is a testament to structural and mechanical and lighting integration' (Bruder, 1998).

With the main items of central plant housed within the saddlebags, the cooling towers tucked in behind the high walls of the service yard, and air distribution via perforated ceilings on Levels 1–4, there is little of the active systems directly visible to the casual observer other than the floor diffusers in the reading room. Whereas the mechanisms of the adjustable louvres on the south façade and the atrium skylights are discernible only to the careful observer, it is understood that high noon at the time of the summer solstice is celebrated appropriately in the Reading Room by a (presumably capacity) crowd of 1500–2000 people. The set of electrical transformers serving the building form an interesting sort of sculpture court at ground level on the west side of the building (Plate 10), but may eventually be screened by surrounding shrubs.

Performance in practice and lessons learned

Energy efficiency was an important criteria for this building and according to Bolin and Hamilton (1996), the design heating and cooling load predictions were 10% less than Arizona State targets.

A group of Arizona State University (ASU) students undertook a study of the efficacy of some of the passive systems, concluding that 'even though internal sources of heat are the primary issues in internal load dominated buildings, envelope design is still critical in extreme climates' (like that of Phoenix, presumably) (Burrelsman *et al.*, 1998). The study also conducted computer simulations comparing a system of fixed louvres with the adjustable ones installed on the south façade, and removal of both the circular and the strip skylights from the roof of the Reading Room. In no case were the computed differences more than a few percentage points – well within, one might reasonably assume, the margin of error of even the most reliable of computer models – but the study did assert that a system of fixed louvres on the south façade could be 'as effective and less troublesome'. The same study investigated the potential for using evaporative cooling in some zones of the building where close humidity control was not deemed necessary, concluding that such a strategy had the potential for significant running cost savings.

For Will Bruder, this project reinforced his conviction that the architect must accept the responsibility of leading the design team: 'to be the composer of the symphony, the choreographer of the dance' and that 'if you are challenging convention (even when in fact you are only going back to basics) you have to be prepared to be not just poetic about the intention, and win everyone's favour by the vision of your idea, but also be able to support it with incontrovertible technical rigour'. Alluding to a presentation he was about to make in relation to an upcoming major project, he described it thus,

> So it's our job now to present a system that does have the qualities that we promise, to back up the built reality; and we have to bring the data, accurately projected, of the kind of savings that will be generated by letting us have our way with this, and the benefits to the client organisation and their whole culture, if you will, by accepting it. And so it's the start of this journey, and we'll be going from a conceptual level of schematics, through design development, but now's the time we win the audience, and then what's important to do is listen to your clients with their agenda, you know, give the proposition a language and a potential that captures their imaginations, empowers them to be part of the team from the beginning, and then you go on a journey excitedly together. Because, you know, people just don't like the ordinary, and I think they are rather thrilled with the potentials that what we're talking about portend, both for the quality of environment that they'll provide and the energy savings and the responsibility to the larger global issues; I mean I think it can be a win–win for everybody, but it takes an almost evangelistic preacher attitude to empower, enlighten, and inspire these people to the cause. (Bruder, 1998)

At the time of the library project, the underfloor system of air distribution was relatively novel in the USA, so that Locke found himself in the role of educator (Locke, 1998). For this latest project, thermal mass cooling, night-time ventilation, and evaporative cooling strategies are being proposed, so he and his colleagues will no doubt find themselves in that role again.

More prosaically, the student studies confirmed the need for the design of the basic building form to reduce solar heat gain in such a climate, while at the same time reinforcing the KISS ('Keep It Simple, Stupid') principle and demonstrating that later individual detail design changes may only have a small impact on overall energy efficiency.

Finally, at the irritation level, how to keep the local bird life out of the saddlebags needs to be given some careful design consideration (Figure 7.10). (I promised Building Operator Bill Ruhule that I'd make that point!)

Acknowledgements

My thanks to Will Bruder and Alan Locke, whom I interviewed in connection with the design of the library, and to Doddie, Rob, Tim, Patrick and Karen of their respective offices who assisted freely with the arrangements. I also thank Bill Ruhule who gave me access to every part of the building, and waited patiently while I photographed its many features.

References

ASHRAE (1997) *ASHRAE Handbook: Fundamentals, SI Edition*, Atlanta: ASHRAE.

Barreneche, R. A. (1995) 'High heat, high tech', *Architecture*, 84: 107–13.

Bolin, R. and Hamilton, N. (1996) 'Phoenix Central Library', *Arup Journal*, 31: 3–7.

Bruder, W. P. (1998) Transcript of an interview held on 21 October, New River.

Burrelsman, T., De Villiers, B., Lewis, F. and Agarwal, P. (1998) *Vital Signs Project*, Phoenix Central Library [http://www-archfp.ced.berkeley.ed…kup/phoenix_lib/phoenix_home.html], November revisions.

Curtis, W. (1995) 'Desert illumination', *Architecture*, 84: 56–65.

Locke, A. (1998) Transcript of an interview held on 23 October.

Khroyan, S. and Schutt, J. with Hendricks, B. A. (eds) (1996) *The Evolving Bruder Libraries*, Mesquite, Cholla and Phoenix Libraries [http://www.public.asu.edu/~bah24/pictures/c–pict/evolve/index.html]

Seal, M. (1996) 'Scarpa in the south-west', *Architectural Review*, 199: 48–53.