
The Story of Comfort Air Conditioning

Part-4 Air Conditioned Office Buildings 1979-2000

Text
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He had been eight years upon a project for extracting sun-beams
Out of cucumbers, which were to be put into vials hermetically
sealed, and let out to warm the air in raw inclement weather.
“Gullivers Travels, (Voyage to Laputa),” Jonathan Swift, 1726.

4.1 The Prestige Office Development

By the 1980s, architects and air conditioning designers were looking for ways to reduce dependency on mechanical cooling as a means of achieving satisfactory environmental conditions in offices. Passive architecture, minimisation of internal heat loads, thermal storage, heat recovery and natural ventilation were often among the possibilities considered. However, in spite of the trend to reduce or do away with mechanical cooling altogether, there were still projects where air conditioning proved to be essential. Typical, was the major prestige development. The following examples include the air conditioning solution adopted for one innovative high technology building in Hong Kong, the refurbishment of what was London’s tallest office when originally built, and the commercial “tried and tested” approach used in the successor to the title of London’s tallest building. While these illustrate the dawn of a new era of air conditioning -more detailed analyses of the role of the building envelope, the comparison of energy usage and costs-in-use, the rigorous testing of equipment, standardisation of layouts, and widescale use of factory prefabrication -they only signal that in these instances, air conditioning had not yet fallen from grace.

1986 Lloyds, Leadenhall St, London

This new Lloyds building stands on the site previously occupied by its famous neo-Roman style 1928 building. (A new Lloyd’s building in Lime Street was one of London’s first major comfort air conditioning installations in 1957 and is described in Sect.3.2.) The new Lloyds [4.1] has proved to be one of the capital’s most controversial buildings and echoes the design of the Pompidou Centre (Renzo Piano and Richard Rogers, 1976) in Paris, where the services are an exposed feature on the outside of the building. The Lloyd’s externally located services have, unfortunately, suffered from a variety of problems.
The design of the building has been vividly described

“Despite its agitated profile, Lloyds is a simple rectangle in plan. It reverses the conventional core arrangement for office buildings, moving lifts, fire stairs and lavatories to the exterior wall in order to make way for a dramatic twelve-storey-high barrel-vaulted atrium at the centre. This arrangement of ‘servant and served’ spaces is a tribute to Louis Kahn (Richards Laboratories, University of Pennsylvania, 1961) and more distantly to medieval castles.”

Lloyd’s facade incorporates a triple-glazed system, where the outer skin is double-glazed with a gap between this and the inner single skin. Warm air from the room is extracted into the ceiling, picking up heat from light fittings, and discharged down through this gap to warm the cavity in winter, before returning to the air handling unit. Le Corbusier used a similar system for the Salvation Army Hostel in Paris in 1933 (Sect.2.7), employing “le mur neutralisant” (neutralising wall); perfect in winter, but a disaster in summer, the refrigerating plant having been omitted to reduce costs.

An interesting feature of the air conditioning design was an early use of CFD (computational fluid dynamics) in analysing air flows and temperatures from a comfort viewpoint within the Lloyd’s building tall central glazed atrium. It was necessary to determine whether cold air from the glass walls and roof would drop onto the open dealing floor at the base of the atrium, or whether the rising warm air from the open floors at the bottom would cause sufficient stratification to counteract it. A CFD model indicated the falling and rising streams met above the occupied zone, and would cause a circulating current which would not effect the temperature or air movement in the occupied spaces; the space was found to perform as predicted.

A central energy plant minimises building energy consumption. Refrigeration comprises two 1500 kW screw chillers with double-bundle condensers and one 1200 kW standard screw machine. Heat reclaim coils are fitted in the exhaust ventilation systems. Rejected heat is stored and withdrawn from the sprinkler storage tanks, used as thermal reservoirs.

1986 Hongkong Bank Headquarters, Hong Kong

The 1935 headquarters was, in its day, described as “the tallest building between Cairo and San Francisco,” and the first major (office) building in Hong Kong. The design brief for the new headquarters was to create “the best bank building in the world.” The result design was a 46-storey steel frame building 179 m high of 100,000 m$^2$ floor area. The architect envisaged extensive use of glass and the final design is virtually 100% glazed on the major facades which look north and south providing possibly the most sought-after views in Hong Kong. A key requirement of both building and services was that it should be “state of the art,” and this required that the air conditioning designers J Roger Preston & Partners carry out extremely detailed analyses of alternative forms of building envelope to check comfort levels and energy requirements.\(^1\)
Numerous glazing and shading options were considered and this work recalls similar studies carried out for the UN Building in New York some thirty years earlier, but without the benefits of computer simulation. The Hong Kong studies found that the solar design loading under a “high diffuse” condition was approximately twice that under conditions of maximum direct gain. As a result, the final design for the offices [4.2] uses a profiled ceiling to maximize the view out and external sun shades to significantly reduce the impact of solar radiation. The glazing option selected was a clear outer pane, a grey tinted inner pane and perforated mid-pane blinds. Further investigation found that it was just possible to omit the blinds to the north facade and use photoelectric switching of artificial lighting, taking advantage of the higher daylight factors and in the process reducing internal gains.

The air conditioning system solution adopted uses four modular, factory-prefabricated, combined toilet and air handling plantrooms at each office floor level [4.3]. The scheme combines a constant volume perimeter supply (scheduled supply temperatures) with a constant temperature variable air volume system to internal zones. The selection of central cooling plant led to detailed cost-in-use analyses on how to handle the heat rejection of the target cooling load of 12,500 kW. These showed that both evaporative and air-cooled systems would require some 2500 m² of prime floor area at high level, require significant vertical riser space, and consume 30% more electrical energy than a cooling scheme taking seawater from Hong Kong Harbour. An existing sea-water connection to the 1935 building was inadequate. The new system required a 350 m long tunnel, some 70 m underground. To overcome the corrosive nature of the harbour sea water, the condenser water heat is rejected to the seawater through titanium plate heat exchangers, of proven reliability in Hong Kong. There are six refrigeration machines, four providing cooling only, the remaining two operating in heat pump mode and available to deal with a short, but often sharp, and winter heating season [4.4].

1992 One Canada Square (Canary Wharf Tower), London 5, 6, 7
The centrepiece of the rejuvenated area of London’s Docklands known as Canary Wharf, where the developer has created a new business district within the City, is the 50-storey, 244 m high tower [4.5] called One Canada Square With over 160,000 m² of office accommodation it took the title of the tallest building in the UK. However, despite the modern architectural form, the decision was taken that the air conditioning designers should rely on tried and tested principles, partly over fears of the ability and lack of experience in the UK with this height of building. The shell and core scheme [4.6] uses two air handling plantrooms at each office floor level supplied with primary preconditioned air from two central risers with fresh air plants located above the lobby serving upwards to the 28th floor, and on the 51st floor serving downwards to the 29th. At each office level, the tenant fitting out was designed to use fan-assisted terminal VAV systems for perimeter and interior zones, the former being augmented with staged electric heater batteries as required. Six 3500 kW chillers using R11 refrigerant operate in conjunction with cooling towers on the 50th floor. The air conditioning installation has been described as “belt and braces” and “almost bereft of innovation,” but the cost savings using this approach reveal a saving reported as some 20-30%, largely on the basis of UK over-engineering, and its design and procurement consequences
1997 NatWest Tower, London (Refurbishment)

When the 52-storey, 183 m (600 ft) high office tower \([4.7, 4.8]\) for the National Westminster Bank (Richard Seifert & Partners) was completed in 1981 it took the title of the tallest building in the UK and the world's tallest cantilevered building.\(^5\) In London heights had previously been restricted to 122 m (400 ft). The plan is like a cloverleaf, representing Nat West's logo, with three individual leafs of offices cantilevered off a central concrete core. With a total floor area of 71,250 m\(^2\) but a net usable floor area of only 40,000 m\(^2\) the layout provided 56% area for offices to the 44% occupied by the core, which is extremely poor by present standards. The services in total occupied 17% of the building area. The exterior indentations in the plan means that the climatic zones are not well defined and do not coincide with the physical layout. To complicate matters, each zone has windows facing in exactly opposite directions. If this was not difficult enough for the air conditioning designers, full height windows increase the magnitude and fluctuations in heat gain and loss. An unrelated point of interest is that 5 double-deck elevators were provided.

The original air conditioning system was a perimeter 4-pipe induction system with secondary induced air bypass control units (with the water flow running “wild”) with a VAV system for the office core. The 3200 induction units were recessed into the floor, thus adding about 4% to the usable office space. The design used three intermediate floor plant rooms, with refrigerating plant (4 x 3500 kW chillers, one being a standby) and boilers in the basement, and roof-mounted cooling towers. A certain amount of off-site prefabrication of the piping systems was carried out.

The air conditioning design had the merits of simplicity and relatively low capital cost but control was achieved at the expense of heating and cooling energy mixing losses. This original scheme for the building itself took some 16 years of work and controversy from inception to completion, the construction period finally occupying some 7 years.

After the cladding of the building was severely damaged by the blast from a nearby terrorist bomb in April 1993 the decision was taken to embark upon a major refurbishment of the tower. The architect working with the original air conditioning designers faced a number of unusual challenges. It was necessary to increase the allowance for heat gains from office equipment from the 1981 value of 5.3 W/m\(^2\) to the much higher 30 W/m\(^2\). The decision was taken to incorporate Antisun double glazing into the new facade improving the tower’s U-value of about 0.9 to 0.45 W/m\(^2\)K.

The new design \([4.9]\) for the air conditioning uses 2300 ceiling-mounted fan coil units. replacement cooling towers, refurbished air handling plant rooms and three replacement centrifugal water chillers running on the more environmentally acceptable R134a refrigerant.\(^8,9,10\)
This time, with on-site space at a premium, it was decided that the services would be almost totally prefabricated in an off-site factory some 140 miles away. (Fab Shop). The contractor (Crown House) arranged to prefabricate all of the services in the form of complete modules, comprising piping, ducting, fan-coils and cable trays. To achieve this, the contractor worked initially by laying out a full-size replica of a tower floorplate on the floor of the factory. Two types of services module were produced a Bulkhead Module which carries piping and ducting around the outside perimeter of the core, and a Run-Out Module containing fan-coil units, piping and controls, all cabled up, pre-tested and pre-insulated. The programme required modules to be installed at the rate of 45 per week (one floor per week) using four fitters per floor, instead of the usual eighteen. This arrangement required the prefabrication and installation of 1560 service modules over a 43-week contract, with no storage, minimal second fix, and a significant reduction of trades on site. Quite a change in the way of doing things since the 1970s.

1987 NMB Bank Headquarters, Amsterdam
This building is exceptional for when completed it was acclaimed as being the lowest energy consumption building in the world. The primary energy consumption is 96 kWh/m² per annum for an overall office space, contained in “ten office clusters”, of 46,800 m². The design of the building is unusual to say the least. When viewed externally [4.10] the facade, which uses “reclining and oblique forms,” looks like the reflection in a distorting mirror. The use of this segmented form “offers each cluster the optimum sun path orientation, into areas where the staff is located. It also breaks up the wind impact, and therefore reduces energy consumption.”

The structural facade of the building is a thermal sandwich comprising of 180 mm brick, 30 mm airspace, 100 mm insulation, and 180 mm internal concrete facing. The air conditioning, or perhaps we should say environmental control, designer has produced an imaginative and energy efficient scheme. This provides, to borrow the words of Reyner Banham, “a well-tempered environment.” The large office spaces are simply ventilated. The double-glazed, opening windows have internal blinds with local adjustment and external motorised blinds that operate at external temperatures above 16°C. They also have a control link to the under-window radiators. The top window section has fixed deflecting louvres to reflect light onto the profiled ceiling surface.

The system works as follows. Within each of ten rooftop clusters [4.11], recirculated office air mixed with a small amount of fresh air is warmed by a shaped passive solar collector and thermal wheel combination. Further heat is added as necessary from four 25,000 litre water tanks contained in heavily insulated concrete bunds beneath the building’s energy centre. These tanks collect and store waste heat from the gas/oil turbine electricity generating system, from condenser heat rejected by the refrigeration machines, and even from the lift machinery. Rain-watered plants contribute to control of internal oxygen content and humidity (no artificial humidification is provided). In addition, the thermal storage benefits of the mass of concrete are used to advantage. In summer, cooler night air is flushed through the building, removing excess heat which has been stored in the structure during the day.
4.2 The Interactive Building Facade

During the 1980s, a major change in the design of a number of buildings was the emergence of the dynamic or interactive facade. “Curtain walls had grown out of the window industry relying upon cheap power to condition the interior. Now the facade is a mediator between energy flows of many kinds with much innovation and research going into this area.”

Goals were set to maximise the desirable attributes of this new office block facade: natural ventilation, natural lighting, good views out for occupants (preferably through clear glass), and energy efficiency. Studies embraced translucent insulating materials, photovoltaic solar cells, photovoltaic cladding systems, shading systems, the lightshelf, ventilated twin-glass wall facades, and “smart” materials.

The lightshelf provides fixed shading to control heat gain and glare whilst reflecting daylight into the interior of the space. This rediscovered idea is in use at the Inland Revenue Building, Nottingham [4.12] and at Portcullis House [4.13, 4.14] (the new Parliamentary Offices) in London.