8.10 Metal Windows & Curtain Walling

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Some reference has been made above to cast iron windows, a type going back to the eighteenth century, and to folded zinc glazing bars, but here we are concerned with the more technically innovative types of the later nineteenth and the twentieth centuries. At a domestic scale it was the metal and glass louvre window which had the greatest impact in Australia, but this is a distinct topic, and will be discussed below. Apart from louvres, a new generation of metal windows seems to emerge in Britain, perhaps in about the 1860s, when sashes and frames cast in one piece began to be replaced by those assembled from rolled wrought iron Ts and angles, in the manner which was to become the norm for metal windows in the twentieth century. Burt & Potts of Westminster seem to have been the pioneers of this type, and Thomas Hardy sketched it in his notebook, which dates from the decade 1862-72.[1] In the C B Fairfax house at Double Bay, Sydney, metal casements by Burt & Potts were used, containing 'ornamental quarry-lead glazing', and were presumably the choice of the English architect of the house, Maurice Adams.[2]

a. steel windows & the fenestra joint

Steel sashes and casements by Crittalls of England were being advertised in Melbourne by 1908,[3] but earliest identifiable use of steel windows in Australia seems to be in the operating theatres at the Melbourne Hospital in 1910-13, and these were imported from Henry Hope and Sons of Birmingham.[4] Hopes had risen to importance on the strength of the new demand for steel windows in commercial and public buildings, and are said to have been the only substantial firm in Britain manufacturing windows of this type, though if this was really the case it is unclear why Crittalls did not penetrate this market. Hopes' catalogue of 1912 illustrates the use of their windows throughout

1 Thomas Hardy [introduced C J P Beatty], *The Architectural Notebook of Thomas Hardy* (Dorchester [Dorset] 1966), p 72 [the second of two pages so numbered].
2 *Australasian Builder & Contractor's News,* 10 September 1887, p 286.
3 *Cazaly's Contract Reporter,* XXIV, 25 (23 June 1908), p 97.
4 Shop drawings in the Melbourne University Archives, cited in Nigel Lewis & Associates, *Queen Victoria Medical Centre* (South Yarra [Victoria] 1985), p 103.

Britain, and in Toronto, Montreal and Princeton.[5] Until well after World War II these metal windows were a specialist product for major buildings, quite irrelevant to the domestic scene. In 1949 D V Isaacs and J W Drysdale reported that the shortage of timber in Britain had resulted in attempts to make good but cheap metal frames, but without success so far as they could tell, notwithstanding the earlier history of firms like Crittalls and Hopes. Even more surprisingly, prefabricators in the United States were importing metal windows from British makers, including one model with a frame of die-cast aluminium.[6]

In 1914 steel framed windows of both the casement and the pivoting types were used at Read's store, in the Melbourne suburb of Prahran.[7] By now, though their operations were doubtless at a humbler scale than those of the British makers, there seem to have been at least three Australian suppliers of steel windows. 'Waterloo' steel window frames were available in Melbourne,[8] possibly by Wormwald Bros, and Wormwald Bros certainly manufactured wired glass windows in hollow metal or steel frames.[9] Dobson Franks Limited of Melbourne, Sydney and Brisbane, had opened their own Bangor Steel Window Works, also at Waterloo, by 1912,[10] and they advertised that they manufactured steel windows of every description. However there is no indication that they used the name 'Waterloo', and in fact they were soon using the brand 'Simplex'.[11]

Dobson Franks 'controlled' the 'Fenestra' joint, in which one bar was more or less threaded through the other rather than mitred, requiring only 20% of the cross-section to be lost rather than the 50% of a mitred joint.[12] This joint was probably made or marketed under some sort of licensing or agency agreement with Crittalls of England, who seem to have owned the rights. In the same way, Standard Steel & Radiation Limited of Toronto, Canada, marketed the Fenestra steel sash as well as being agents for Crittalls, though their catalogue does not explicitly link the two.[13] 'Fenestra' (Latin for 'window') was also the brand name of the Detroit Steel Products Company of Michigan, but their advertising contains nothing to suggest the use of this joint.[14]

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5 *Henry Hope & Sons Ltd* [Hopes' catalogue of metal windows] (Birmingham 1912), described in Hugh Pagan Ltd, *Architecture Catalogue No. 21* (London 1994), pp 51-2.

6 D V Isaacs & J W Drysdale, *Building Technique and Building Research* (Sydney 1949), p 47.

7 Allom Lovell & Associates, *Former Read's Store, 325 Chapel Street, Prahran* (Melbourne 2000), pp 61-2.

8 C E Mayes, *The Australian Builders & Contractors' Price Book* (8th ed, Sydney 1914), p 169.

9 Mayes, *The Australian Builders Price Book* (1914), advertisement p 20.

10 *Salon,* I, 1 (July-August 1912), advertisement p iv.

11 *Building,* 12 September 1919, inside cover.

12 Mayes, *The Australian Builders Price Book* (1914), advertisements, pp 37, 169. For much more detail see the text, p 167, and W F Crittall, *A Metal Window Dictionary* (Braintree [Essex] 1953), p 19.

13 Steel and Radiation Limited, *Steelcrete' Expanded Metal and 'Klutch Bar' Concrete Reinforcement* Toronto, no date [c 1910]), pp 143-5.

14 *Sweet's Architectural Catalogue* (17th ed, New York 1922), pp 828-831; Detroit Steel Products Co, *Fenestra: Blue Book of Steel Casement Windows* (Detroit Steel Products Company, Detroit no date [c 1935]).

Crittalls were the leading international makers and established their own Australian operation in about 1925, with a factory in the Melbourne suburb of Sunshine.[15] They used the Fenestra joint, and finished their iron sashes in 'Zincspra', which involved pitting the surface by sandblasting, and then 'shooting' zinc onto it. They also made windows in bronze, costing about twice as much as steel. Their Melbourne agents in the 1920s were Harrisons, Ramsay Pty Ltd.[16] In 1922-3 the Herald Building in Melbourne reportedly used thirteen thousand superficial feet [about 1300 m^2] of steel window frames, mainly from Fitzroy and Brunswick,[17] though the manufacturers are not identified. At about the same time the Capitol Building in Swanston St, Melbourne, by Peck & Kemter in association with W B Griffin, was fitted with 'Analite' steel framed pivoting sash windows.[18]

After World War II, K M Steel Products of Richmond, Victoria, were probably the leading suppliers of domestic steel windows, and had distributors in all states,[19] but Crittalls continued in operation at Sunshine, also with agents in all states,[20] and there were a number of other makers in the east,[21] notably J Connolly Ltd of Sydney, makers of 'Air-Vue' steel window frames.[22] Non-ferrous metals were also used. By 1952 Connolly was using steel, bronze and aluminium.[23] Aquila, of Melbourne and Sydney, also made windows and doors in both aluminium and bronze.[24] By about 1959 Aluminium Industries of Sydney made an aluminium 'window-wall panel', perhaps intended to be equivalent to the timber Stegbar Windowall, and claiming to be an application of the curtain wall technique used in large buildings.[25]

b. reversible windows

Dobson Franks, apart from the products mentioned, also made 'Marks' Patent Reversible Casements', which could be turned entirely inwards for cleaning purposes.[26] This was one of the inventions of Harry Marks of Toowoomba, whose 'Austral' or 'Magic Balance' window has been discussed above, and we know what it is like solely because Morag Papi has reported what must be

15 *Australian Home Builder,* 16 March 1925, pp 20-21; *Bulletin of the University of Melbourne Architectural Atelier* (Melbourne 1929), p 6.
16 *Australian Home Builder,* 15 April 1927, p 12.
17 *Herald,* 26 February 1912, New Building Supplement, p 1.
18 *Australian Home Beautiful,* November 1948, p 14.
19 *Australian Home Beautiful,* November 1948, p 14.
20 *Australian Home Beautiful,* June 1955, p 72. See also F W Ware & W L Richardson [eds], *Ramsay's Architectural and Engineering Catalogue* (Melbourne 1954), §21/9.
21 F W Ware & W L Richardson [eds], *Ramsay's Architectural and Engineering Catalogue* (Melbourne 1949), §21, passim.
22 H L Divola, *Truth Home Plan Book* (Sydney, no date [c1951]), p 50.
23 *Building: Lighting: Engineering,* 24 November 1952, p 27.
24 Divola, *Truth Home Plan Book*, p 20.
25 Master Builders' Association of New South Wales, *Guide Book to Parade of Homes* (Sydney no date [c1959]), p 20.
26 Mayes, *The Australian Builders Price Book* (1914), advertisements, p 37. For much more detail see the text, p 169.

examples of it at Marks's St James's Parish Hall, Toowoomba, of 1910. It is a single sash designed to pivot horizontally on spindles at the top and bottom. At the top and bottom of the window frame a track projected at right angles from the centre so that the sash could be pushed outwards and clear of the opening, with the spindles running along the tracks. The sash could then be rotated to any angle, or turned right around to face inwards for cleaning.[27] The surviving examples are not operable, but it is not difficult to envisage a number of problems likely to have occurred in practice.

The Australia Hotel, Melbourne, in 1938-9 had Fisk soundproof windows extending nearly twenty metres along the Collins Street frontage. In these windows there were three sets of glazing spaced about 100 mm apart, the inner one open at the centre, the middle one at the bottom, and the outer one at the top, and the reveals lined in sound absorbent material.[28]

c. origins of the curtain wall

In broad terms, the principle of the curtain wall is that it is neither a load-bearing component of the building nor a system of infill within the framing elements, but a screen hung over the face of the structural frame. The idea of a glass non-wall possibly has its roots in the eighteenth century writings of Marc-Antoine Laugier, but for practical purposes it came into existence in the walls of greenhouses and conservatories during the second quarter of the nineteenth century, though such walling was not even considered at that time as an option for serious buildings. The situation was changed to a degree by the Crystal Palace, London, of 1850-1, which was seen by at least a minority of commentators as a contribution to serious architecture. In this sense it paved the way for the later curtain wall, though David Yeomans has argued that there is no substantial connection between the one and the other.[29]

Various prefabricators of the mid-nineteenth century made buildings of frames clad in cast iron panels, usually of quite elaborate architectural design, and these - though substantially opaque - are technically curtain walls. The British manufacturers were mainly in Glasgow, and produced only one or two buildings over three storeys in height, but in New York James Bogardus, and a little later Daniel Badger, specialised in quite large cast iron clad structures. From the mid-nineteenth century until the present there have also been many industrial and other architecturally unpretentious buildings with continuous claddings of materials like corrugated iron, which technically can be described as curtain walling. However, for reasons of aesthetic prejudice, more than anything else, these buildings are always excluded from any discussion of the curtain wall. In the twentieth century the term has been applied to walls of

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[27] Morag Papi, *James Marks and Sons, Architects, Toowoomba* (no place or date [?Brisbane]), p 20.

[28] *Hotel Australia Melbourne, 1939* (Melbourne 1939); 'Hotel Australia, Collins Street', *Journal of the RVIA,* XXXVII, 7 (September 1939), pp 191-201.

[29] David Yeomans, 'The Origins of the Modern Curtain Wall', *APT Bulletin,* XXXII, 1 (2001), p 13.

brick or stone, when carried off the structural frame rather than being load bearing,[30] but subsequently, in common architectural parlance, it has become confined to continuous metal frame walls filled principally with glass. In the United States there were concerns about even masonry walls which were supported off the frame, one reason being that it was the masonry, rather than any form of bracing, which was seen as resisting wind loads. An article of the 1890s demanded that 'the outer walls of fire-proof buildings should be real, instead of masonry-veneer, walls, capable of supporting themselves.'[31]

The French engineer Gustav Eiffel used a substantial curtain of glass of a more self-consciously designed ornamental type in the entrance building for the French International Exhibition of 1875 French exhibition building. In the Galerie des Machines of the 1889 Exposition Universelle the architect C L F Dutert covered the entire end of the building in a much plainer glass wall. Pevsner identified Bernhard Sehring's Tietz Department Store, Berlin, of 1898, as a primary example in which the main part of the façade, between flanking masonry bays, was of glass with 'the thinnest iron verticals and horizontals'.[32] It was neverthless presented like a large window in a façade, rather than a building cladding system.

A good case has been made for the Steiff toy factory building at Geingen, Germany, of 1903, as being the first curtain wall in the normally understood sense - continuous, multi-storey, and cladding a regular industrial building.[33] Surviving examples include the Samaritaine store in Paris of 1905[34] and the Boley Building, Kansas City of 1909.[35] At the Fagus Factory in 1911 Walter Gropius used sections of glass curtain walling which ran through three storeys height, but were articulated laterally by recessed brick pilaster strips. At the Werkbund Exhibition at Cologne, of 1914, Gropius's 'Fabrik' office building had a pair of dramatically projecting spiral staircases encased in sheer glass semi-cylinders. Finally, the workshop of the Bauhaus at Dessau, of 1925-6, had an extensive area of continuous curtain wall glazing, three storeys in height and continuing around corners. Meanwhile an even more remarkable example had been built in the United States in 1915-17: Willis Polk's Hallidie Building, San Francisco, despite two sets of external stairs and four bands of decorative iron hanging like valances, includes a large area glass in a uniform grid of metal framing of a very advanced character.[36]

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30 C P Sorenson, *Curtain Walls* (Sydney 1959), p iii.

31 Birkmire, *High Office Buildings* (4th ed), quoted in Joseph Siry, 'Adler and Sullivan's Guaranty Building in Chicago', *Journal of the Society of Architectural Historians,* LV, 1 (March 1996), p 19.

32 Nikolaus Pevsner, *The Sources of Modern Architecture and Design* (Thames & Hudson, London 1968), p 96.

33 Anke Fissabre & Bernhard Niethammer, 'The Invention of Glazed Curtain Wall in 1903 – the Steiff Toy Factory', in K-E Kurrer et al [eds], *Proceedings of the Third International Congress on Construction History* (3 vols, Brandenburg University of Technology, Cottbus 2009) II, pp 595-602.

34 Yeomans, 'Origins of the Modern Curtain Wall', p 13.

35 Yeomans, 'Origins of the Modern Curtain Wall', p 14.

36 Barry Russell, *Building Systems, Industrialization, and Architecture* (London 1981), p 54.

d. industrial glazing and skylights

Generally, formal architecture in the English-speaking world ignored these mostly Continental aberrations. The Hallidie Building has been claimed to be the first example of curtain walling in its specialised sense,[37] but large areas of glazed walling had already become common in industrial applications. As early as 1901 Mellowes & Co of Sheffield advertised their 'Eclipse' glazing, not only for roof lighting, but for 'vertical glazing for screens, works, windows, &c.' Grover & Co's 'Simplex' lead glazing was likewise used vertically, as well as for skylights and general industrial applications.[38] In 1936 Grovers still mentioned vertical applications in their advertising, but most other British makers explicitly confined themselves to roof glazing. The exception was Heywood & Co (not to be confused with their competitors, Haywards), who illustrated a factory with not only the roof but the greater part of a long wall clad in their patent glazing.[39] The machine room of the Dunston Power Station in north-east England, built some time before 1937, was one of the more prominent uses of a patent glazing system,[40] and feature elements like glazed spiral staircases appeared in some of the more innovative industrial complexes under the influence of Gropius.

In the United States the Mesker Bros Iron Co, previously known for metal shopfronts and pressed steel cladding, was advertising an extensive range of steel windows in an undated catalogue, perhaps about 1930. These included systems capable of creating continuous wall glazing, as was illustrated in an extensive area of glass at the Union Station, St Louis, Missouri, and in what seem to be three storeys of the George J Fritz Foundry and Machine Co in the same city.[41] In the latter case, however, some horizontal articulation at the floor levels suggests that this was not quite a true curtain wall, though it was certainly much closer to it than anything in the company's advertisement a few years earlier.[42]

The glazing bars developed for skylights form a part of the development of industrial curtain wall systems, and these were available from the 1920s in specialised forms, such the 'Deluge', produced by Florant & Co of Melbourne.[43] Proprietary and patent systems suitable especially for industrial buildings developed from the 1920s, and by 1950 there were many built examples and the detailing was widely published by manufacturers such as Aluminex. Aluminex Sidewall Glazing was patented throughout the world, available in both single and double glazing, and was said at this time, to be 'now extensively used for larger stretches of wall glazing in factories, offices,

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37 Yeomans, 'Trade Literature Sources', p 3.

38 J E Sears [ed], *The Contractors,' Merchants,' and Estate Managers' Compendium and Catalogue* (15th ed, London 1901), pp 274-5.

39 J E Sears & J E Sears [eds], *The Architects' Compendium and Annual Catalogue* (London 1936), pp 274-5.

40 McGrath & Frost, *Glass in Architecture and Decoration* (1st ed), p 260.

41 Mesker Bros. Iron Co., *Steel Windows* (St Louis [Missouri], no date [c 1930]), especially pp 1 & 2.

42 *Sweet's Catalogue* (1922), pp 844-847.

43 *Australian Homes* (Melbourne 1927), p 136.

bus stations and aircraft hangars', and to be suitable for every type of large industrial building.[44] It was not this, however, but the emerging concept of the crystal skyscraper, which gave the idea of the curtain wall such a glamorous image amongst architects in the 1950s.

e. the curtain wall æsthetic

The crystalline concept was developed in the early part of this century in the publications of Paul Scheerbart and Bruno Taut, and the designs of Taut and of Mies van der Rohe. Scheerbart published his *Glass Architecture* in 1914, the same year that Taut designed the famous glass house at the Werkbund exhibition, and Taut's own *Alpine Architecture,* of 1919 included fantastic designs in glass. These idealistic schemes reflected a purer curtain ideal than Gropius's practical experiments between 1911 and 1926, mentioned above. Mies van der Rohe produced a scheme for a prismatic glass skyscraper as a competition entry in 1919, and another in 1922 for what is described as a polygonal plan, but is in fact an undulating free form. Both had sheer vertical envelopes of continuous glazing.[45] These are especially relevant because of the architect's role in some of the major American curtain wall projects in the post-war years.

A number of examples now followed. One was the Van Nolle Factory at Rotterdam, of 1928-30.[46] In Slovakia the City Savings Bank in Bratislava, by Juraj Tvarozek in 1930, was a conventional office block-type building with a curtain fall across the façade and one return side, though it was coloured and articulated to express strong horizontal spandrels.[47] In 1932 the Daily Express Building, London, by Ellis & Clarke in association with Sir Owen Williams, had spandrels clad in toughened black Vitrolite.[48] Le Corbusier & Pierre Jeanneret's La Cité de Refuge at Ivry, Paris, of 1929-33, had a sheer curtain of glass across the facade; Eskil Sundahl's Homsburg Bus Garage at Stockholm of 1933 was a huge segmentally arched barn with a glass wall sealing the entire end elevation; and Victor Bourgeois's Restaurant Leopold II at the Bruxelles Exposition Internationelle of 1935 had a curved glass wall of at least eight or nine metres high to the dining area.[49]

In 1938 at the Peter Jones department store in Sloane Square, London, by William Crabtree in association with Slater & Moberley and C H Reilly, which had a complete curtain wall of a sinuous design. Even this, supplied by

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44 F R S Yorke [ed], *Specification 1950* (London 1950), pp 869-70. Also Evelyn Drury et al [eds], *Architects', Builders' and Civil Engineers' Reference Book* (London 1950), pp 351-3, illustrating the Brabazon Hangar, Bristol, and other examples.

45 Werner Blaser, *Mies van der Rohe* (London 1972 [1965]), pp 12-15.

46 David Yeomans, 'Trade Literature Sources in Design History', *CHS Newsletter,* 52 (January 1999), p 3.

47 Matús Dulla et al, 'Slovakia's First Curtain Wall', *Docomomo,* 15 (July 1996), p 4.

48 Arnold Whittick, *European Architecture in the Twentieth Century* (New York 1974), pp 253-5; McGrath & Frost, op cit, p 264.

49 Raymond McGrath & A C Frost, *Glass in Architecture and Decoration* (1st ed, London 1937), pp 265, 255-6, 215.

Thomas Hope's of Birmingham, is not accepted by Yeomans as a true curtain wall.[50] However, in Scotland the façade wall of St Cuthbert's Co-Operative Association Department Store, Edinburgh, of 1937, by Thomas Marwick & Sons, was a simply gridded curtain of clear glass, passing unequivocally across the face of the structural grid.[51] After World War II Frank Lloyd Wright designed the Laboratory Tower of the Johnson Wax Company at Racine, Wisconsin, in 1949. This was a radical structural concept, a skyscraper with the frame hung out from a central steel and concrete core, and it was largely clad in glass.

In 1950 there came the fusion of the two ideas, the new concept of the glass-walled skyscraper, and the already well established idea of a continuous glass walling system, as developed by Aluminex and others. While vertical patent glazing could be regarded as a sort of industrial curtain wall, the characteristic of the fashionable post-war architectural curtain walling was the use of extruded or rolled mullions spanning between floors in the vertical direction.[52] The critical building was the United Nations Headquarters, New York, essentially an amalgam of designs by Le Corbusier and Oscar Niemeyer, developed under an advisory a committee including Le Corbusier, Niemeyer and S G Markelius, executed by Wallace K Harrison of Harrison & Abramowitz, and completed in 1950.[53] This was immediately followed by Mies van der Rohe's Lake Shore Drive Apartments, Chicago, completed in 1951, and by Lever House, New York, by Gordon Bunshaft of Skidmore, Owings & Merrill, completed in 1952. Lever House was the building most directly influential in Australian examples such as the ICI buildings in Melbourne and Sydney.

f. Australian examples

Australia had numerous early curtain walls in the general sense of nineteenth century glass greenhouse walls, cast iron façades, and corrugated iron cladding. It also had what Donald Johnson has claimed was possibly the first curtain wall in the world,[54] meaning the term in the more limited modern sense. This was the facade wall of W B Griffin's Leonard House, 44-6 Elizabeth Street, Melbourne, of 1923-4, and was a curtain wall in the modern manner - containing a good proportion of glazing, and with a frame of rolled or extruded metal sections expressed as being continuous through the height of a number of floors. As Robin Boyd described it, 'Solid side piers held a single vertical panel composed of fixed and opening glass panes and a

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50 Yeomans, 'Trade Literature Sources', p 4.

51 Suzanne Ewing, 'An Early Curtain Wall in Edinburgh', *Docomomo,* 15 (July 1996), pp 16-17. See also Yeomans, 'Origins of the Modern Curtain Wall', p 13, ref *Architectural Review,* LXXXI (1937), p 65,

52 Raymond McGrath & A C Frost, *Glass in Architecture and Decoration* (2nd ed, London 1961), pp 164-5.

53 Victoria Newhouse, 'Harrison & Abramowitz', in Adolf K Placzek [ed], *Macmillan Encyclopedia of Architects* (4 vols, New York 1982), II, pp 324-5; Elizabeth Harris, 'Oscar Niemeyer', in ibid, III, pp 301-2.

54 D L Johnson, *The Architecture of Walter Burley Griffin* (South Melbourne 1977), p 109.

square cement device which marked floor lines ...'[55] Another early Melbourne example was Barnett's Building (the Weber & Rice Health & Strength College) at 164 Bourke Street, by Seabrook & Fildes in 1937-8. Here, however, there were full width horizontal spandrels in fluted sheet iron, so that the framing was not expressed as a continuous vertical system.[56] A critical example, which was reported even in the United States, as the McPherson Building, Melbourne, of 1936. It was not a curtain wall, but it had continuous horizontal glazing uninterrupted by the structural columns, which were set in behind it. The glazing, which curved at one end, was supported on 'slender but extraordinarily strong sections of Birmabright'.[57]

From this point one can make sense of local examples if one distinguishes clearly on the one hand the curtain wall used either as a panel in a facade, or as a feature like the cladding of a corner staircase, from, on the other, the crystalline glass-clad skyscraper, complete in three dimensions. Not only is the latter a specific paradigm in the minds of architects, but it introduces the technical problems of wind loading and wind-driven rain which tend to be unimportant in the other category. South Australia seems to have been important in the pioneering of both categories. For example the Southwark Brewery building at Hindmarsh of 1952 has an extensive rectangle of glazing, of about two-storeys height, let into the segmental end of the building, and not broken by substantial vertical members.[58] Another panel of curtain walling set into a facade was that of the monastery and chapel of the Fathers of the Blessed Sacrament, Sydney, converted from a George Street furniture store by D T Morrow & Gordon: here the glass wall extended about three storeys high.[59]

At least three industrial building complexes around Melbourne had significant elements of curtain walling. In 1953 Hugh Peck & Associates designed the Chesebrough building at Clayton, with a projecting semicircular stairwell, probably two storeys high, clad in sheer glass.[60] Also in 1953 Buchan Laird & Buchan's Administration Building at the Shell Refinery, Corio, had a face of two-storey curtain walling, though it was horizontally divided into bays in a manner similar to the Nicholas Building (below).[61] In 1954 Hassell & McConnell designed the administration block for Kirstall-Repco Pty Ltd at Clayton with a horizontal facade of about two-storey height (though whether two storeyed in reality I cannot say), with vertical divisions articulating the glass wall into six bays. It was 'distinguished by the fine details' of the architects,[62] but was not so dramatically designed and sited as was the

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55 Robin Boyd, *Victorian Modern* (Melbourne 1947), p 26.

56 *Journal of the Royal Victorian Institute of Architects*, XXXVI, 4 (September-October 1938), pp 129-130; *Age,* 20 September 1938, cutting in RVIA Press Cuttings 1938-9, State Library of Victoria; Boyd, op cit, p 54.

57 'Australia Shows Way to Modernism: Melbourne Building Good Example of Trend', *Architect and Engineer,* May 1936, pp 31-2 & 52.

58 *Cross-Section,* 5 (1 March 1953), p 2.

59 *Cross-Section,* 12 (1 October 1953), p 3.

60 *Cross-Section,* 9 (1 July 1953), p 4.

61 D C Ward et al, *Guide to Victorian Architecture* (Melbourne 1956), p 28.

62 *Cross-Section,* 17 (March 1954), p 1.

Nicholas Building two years later, which was otherwise similarly articulated. Again, Frank Heath's Doring Implements factory on the Princes Highway, of 1954, had a very crystalline two storey curtain wall divided into bays, and also a dramatically projecting transparent block of the same height.[63]

Curtain walls not divided into bays tend to be somewhat later. Apart from the normal run of industrial buildings and the slightly later city office blocks, there were three very dramatic uses of curtain walling in Melbourne. In August 1953 Bates, Smart & McCutcheon's design for Wilson Hall at Melbourne University was published, with a sheer wall of glass, 36 metres long by 14.5 high, on the east side, completed in mid-1955.[64] The next industrial example was even more dramatic, the boiler and turbine house of Australian Paper Manufacturers at Fairfield of 1954-5, by Mussen, Mackay & Potter. This was a volume equivalent to a four or five storey building, consisting of glass and aluminium hung on a steel frame, wrapping right around the building in a strikingly simple and clean manner.[65] The third example was the Olympic Swimming Pool of 1955-6, by Kevin Borland, John & Phyllis Murphy and Peter McIntyre, with great glass walls closing the ends of the structure.

A small example, two storeys high, but continuous over a width of at least two normal bays, was E F Billson's Paton Advertising building in Albert Road, South Melbourne, of 1956.[66] The General Motors Holden complex at Dandenong, by Stephenson & Turner, about 1956, had a row of three large buildings expressed consistently as boxes wrapped in glass (although the corner of the frame was expressed, thus separating the glass planes).[67] The same architects followed with Unilever House, Macquarie Street, Sydney, in 1967, and Building No 1, British Nylon Spinners, Bayswater, Victoria, in 1958.[68] In Sydney the Qantas Building was remarkable for having a curtain wall follow a sweeping curve in plan, in a sort of homage to the Peter Jones Store in London . Somewhat comparable with the APM Building in Melbourne was the Tennyson Power Station in Brisbane of 1955-6, with its multi-storey curtain wall panel.[69] The first curtain wall in Perth was that of the State Insurance Office, George Street, built in 1956 to the design of Hobbs, Winning & Leighton.[70]

The term 'curtain wall' itself is not used at all in reports of early examples in Australia - which makes it harder to identify them - but it seems to come into currency in the later 1950s, just as the associated technical problems were becoming manifest. The use of aluminium extruded components was critical in the development of the curtain wall, especially in Australia.

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63 Ward, *Guide to Victorian Architecture,* p 30.
64 *Cross-Section,* 10 (1 August 1953), p 2; 33 (1 July 1955), p 2; 53 (l March 1957), p 4.
65 *Cross-Section,* 24 (1 October 1954), p 1; Ward, *Guide to Victorian Architecture,* p 29.
66 Ward, *Guide to Victorian Architecture,* p 35.
67 *Cross-Section,* 51 (1 January 1957), p 1; *Architecture and Arts,* 47 (July 1957), pp 34-5.
68 *Cross-Section,* 46 (1 August 1956), p 2.
69 *Cross-Section,* 28 (1 February 1955), p 3; no 47 (1 September 1956), p 1.
70 *Cross-Section,* 46 (1 August 1956), p 2.

g. the curtain-walled skyscraper

The first Australian city building of the crystalline skyscraper type was the slab-like State Savings Bank of South Australia at Hindley and Bank Streets, designed by Caradoc Ashton, Fisher, Woodhead & Beaumont-Smith in 1953. This was to have a glass wall ten storeys high and 64 metres long, and was intended to be built in 1954, using 'sealed edge hollow glass'.[71] A squatter but even more crystalline concept was the Red Cross Blood Bank Centre in Perth, by F G B Hawkins & Desmond Sands in 1953. This consisted of two rather cubic blocks, four storeys high, linked by a service core, and apparently clad in glass on three sides. 'Its plan is as clean and clear as its glass walls' commented *Cross-Section.*[72] In 1954 it was announced the MLC Insurance were building investment office blocks in most of the state capitals and some provincial cities, all being designed by Bates, Smart & McCutcheon and all, at least of the three illustrated, having glass curtain walls (varied with a sunbreaker grid in the case of Brisbane).[73] The Adelaide block was the guinea pig of the group of curtain walled designs by Bates Smart,[74] and it proved to have serious problems, as will be discussed below.

The first curtain wall design for central Melbourne was possibly the Alliance Assurance Co building, 408-10 Collins Street, by A C Leith, Bartlett & Partners[75] with Alan Love in charge. It had been proposed in 1950 to build to six storeys on this site, but then a limit height building was decided upon,[76] and it appears that this was first designed in 1952, though it then advanced slowly. Whether or not planned with a glass wall at the outset, this was certainly the intention by February 1955, when it reported that it would have a double skin all glass front.[77] This was designed as a continuous aluminium frame, double glazed to reduce street noise, and using heat-resistant glass.[78] The aluminium and glazing subcontractors were the Bronze Window Frame Co Pty Ltd of Oakleigh ('Albron'), and Silverwood & Beck Pty Ltd.[79] By the beginning of 1957 it was complete, and was described as 'surely the most attractive glass front yet in Melb streets'.[80]

The first generally recognised post-war example of a city curtain wall, because it was finished before the Alliance Building, was J A La Gerche's Gilbert Court at 100 Collins Street, of 1954-6,[81] which straddles the two categories defined above. It is a facade wall, but it covers the entire facade

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71 *Cross-Section,* 11 (1 September 1953), p 3.
72 *Cross-Section,* 13 (November 1953), p 3.
73 *Cross-Section,* 18 (1 April 1954), p 1.
74 *Cross-Section,* 55 (1 May 1957), p 1.
75 Ward, *Guide to Victorian Architecture,* p 36.
76 *Architecture and Arts,* 42 (February 1957), p 29.
77 *Cross-Section,* 28 (1 February 1955), p 1.
78 *Architecture and Arts,* 42 (February 1957), p 29.
79 *Architecture and Arts,* 42 (February 1957), pp 37-8.
80 *Cross-Section,* 52 (1 February 1957), p 1.
81 *Cross-Section,* 18 (1 April 1954), pp 2-3; 33 (1 July 1955), p 2; Ward, *Guide to Victorian Architecture,* p 36.

rather than being framed or limited in the manner of Leonard House and the Barnett Building. It is clad in aluminium with heat-resisting glass, which in technical terms was not especially novel even for Victoria, but it suggests the aesthetic of the United Nations Building. Gilbert Court was followed immediately by Hosie's Hotel in Flinders Street, of 1954-5, designed by Mussen, Mackay & Potter,[82] and by the much smaller Pharmaceutical Guild building in St Francis Street of 1954-, by Cowper Murphy & Appleford.[83] The former had extensive areas of curtain walling, especially to the south (but only really clearly expressed in the inset panel to the east), while the latter was in the older tradition of a curtain panel let into a masonry facade, though in this case the panel was a full six storeys high, and paralleled by an adjoining six storey strip to light the stairwell. Many others followed, for twenty-nine major city projects were put up in 1955-8,[84] and a number had curtain walls. La Gerche followed Gilbert Court almost immediately with his design for Royston House in Exhibition Street, a ten storey building with slightly zigzagging front of glass and aluminium, designed in 1954[85] but perhaps not proceeded with. Afterwards he was responsible for another curtain wall, at the Coates Building in Collins Street, near Gilbert House.

Bates, Smart & McCutcheon, with R J Bonaldi as project architect, designed the first curtain walled building lit from all four faces, Hume House (later Sedgwick House) at 177-185 William Street, of about 1955-7.[86] The contractors for the aluminium curtain wall were Overseas Corporation (Aust) Ltd, and it used heat-resisting glass.[87] The form of the walling at Hume House was said to be much the same as the same architects' MLC Building at North Sydney, of 1955-7,[88] but its appearance was a basket-weave pattern of green, mauve and light brown glass.[89] Bates Smart & McCutcheon also designed the ICI Building of 1955-8,[90] and the MLC Building in Victoria Square, Adelaide, of 1957. The latter was done in association with the local form of Cheesman Doley & Partners,[91] and was Adelaide's first post-war skyscraper, of twelve storeys, with a curtain wall presumably similar in detail to that at North Sydney. The ICI was the first complete crystal skyscraper in Melbourne, not only because it was clad in glass curtain walling on all four faces, but because it was the first to exceed the established height limit of 132 feet (40 metres). The curtain wall was by Overseas Corporation, as at Hume House.[92] Also of this period is Chelsea House in Flemington Road,

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82 *Cross-Section,* 18 (1 April 1954), p 2; 33 (1 July 1955), pp 2-3; Ward, *Guide to Victorian Architecture,* p 37.
83 *Cross-Section,* 18 (1 April 1954), pp 2-3.
84 Igor Martek, 'Tall Office Buildings in Post-War Melbourne (BArch Research Report, University of Melbourne 1985), p 5 and map following p 15.
85 *Cross-Section,* 26 (1 December 1954), p 1.
86 *Cross-Section,* 52 (1 February 1957), p 1.
87 *Architecture and Arts,* 44 (April 1957), pp 21-3; also 51 (November 19657), pp 32-3.
88 *Cross-Section,* 60 (October 1957), p 2.
89 Martek, op cit, p 58.
90 *Cross-Section*, 34 (1 August 1955), p 1; *Architecture and Arts,* 45 (May 1957), p 26.
91 Susan Marsden et al [eds], *Heritage of the City of Adelaide* (Adelaide 1990), p 174.
92 *Architecture and Arts,* 45 (May 1957), p 22.

North Melbourne, of 1957, a surprisingly assured crystal box by the young Harry Ernest.[93]

It was now that A F Agnew & Co, to date manufacturers of louvres, developed their own curtain walling system, which was used in the Florence Bartley Library, King's Cross. The building won the 1959 Sulman award,[94] but it is unlikely that the Agner system had much success, because the tide had now turned against the curtain wall.

h. technical problems

It is likely that the specific forms of walling used in Australia derived from published details of overseas examples and, more particularly, trade literature put out by the glass suppliers and window manufacturers. Some of the standard materials and components (especially sealants and double glazed units generally) were inadequate for the extreme conditions to which they were subjected, and designers failed to appreciate the difficulty of resisting wind-blown rain in exposed situations, or the amount of heat which might be mopped up by large areas of glazing. Moreover, window merchants were not alive to the need to design framing members as beams, so as to resist wind loading, until one Melbourne firm, Ullin Engineering, pioneered the structural design of these members.[95]

Overseas, the first major technical problem to be dealt with was that of wind-driven rain. It came to be accepted in Britain that it was best to assume some degree of penetration, and to arrange for the water to be effectively drained away. In the United States action was initiated by the failure of glazing in the first section of the General Motors Technical Centre, Detroit, soon after its completion in 1951. General Motors drew upon their experience of windscreen glazing to develop, in collaboration with the architect, a system of weather strips or gaskets of neoprene, which were installed by 1953.[96] Such gaskets, replacing the older sealing compounds, were quickly adopted in other countries.

Neoprene was a synthetic rubber based upon a methylated unsaturated hydrocarbon,[97] developed by Dupont during the 1930s. Its rival was Butyl, developed in the same period by the Standard Oil Company of New Jersey.[98] This was another synthetic rubber, manufactured from gaseous hydrocarbons and containing a small proportion of Isoprene[99] [CH_2:C(CH_3).CH:CH_2] a

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93 *Cross-Section,* 61 (November 1957), p 1.
94 *Architecture in Australia,* September 1959, p 35.
95 Interview with Mr Rai Rahni of Melbourne University, an architect who practised at the time and subsequently lectured on curtain walling, 31 January 1992.
96 McGrath & Frost (2nd ed), op cit, p 165.
97 William Kinniburgh, *Dictionary of Building Materials* (London 1966), p 173.
98 M A Tomlan, 'Building Modern America', in T C Jester [ed], *Twentieth-Century Building Materials* (Washington [DC] 1995), p 41.
99 M J Scheffler & J D Connolly, 'Building Sealants', in Jester, *Twentieth-Century Building Materials,* p 274.

methyl derivative of the simple unsaturated hydrocarbon Butadeine.[100] It was not used in the building industry until the 1950s,[101] and though both neoprene and butyl were known to Australian chemists before that time[102] they were not commercially produced in this country, and the technology for sealing glass with them was entirely imported. Other sealants included Thiokol, the first widely used elastomeric sealant based upon a synthetic polysulphide polymer or rubber, developed by the Thiokol Chemical Corporation in 1929 and monopolised by them until the 1950s. Silicone polymers had their origins in the nineteenth century, but the first building sealant based upon them was introduced by Dow Corning only in 1960. Acrylic sealants appeared at about the same time, and urethanes and latex at later dates.[103]

In Adelaide and Melbourne the first substantial failures were the cracking of coloured glass cladding on the MLC Building in Adelaide, by Bates, Smart & McCutcheon, and the General Motors Holden works, Dandenong, by Stephenson & Turner. The MLC Building suffered cracking in 29% of the coloured glass panes.[104] By December 1957 it was reported that the whole of the cracked glass had been replaced.[105]

The General Motors works was clad during June and July 1956 with glass of four colours, ivory, beige, terra cotta and blue. Some cracking appeared soon after installation, and one particular day, which was sunny and windless after a frosty night, eleven of the ivory panes cracked. After all the broken sheets had been replaced in July and August, further cracking ensued, and by the end of the year 9.4% of the coloured glass had failed. Sir Arthur Stephenson approached E R Ballantyne of the CSIRO Division of Building Research to investigate the matter, and the interested parties sponsored him on a trip to the United States to study American practices.

Ballantyne concluded that the causes of stress in installed coloured glass were:

- temperature gradients within the glass

- insufficient clearance between the surface of the glass and the front and back stops

- insufficient clearance between the edge of the glass and the frame

- wind pressure or suction on the glass

- faulty framing

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100 Kinniburgh, *Dictionary of Building Material,* pp 142, 251.
101 Scheffler & Connolly, 'Building Sealants', p 274.
102 A J Hambly, 'Thermoplastic Synthetic Resins', Society of Chemical Industry in Victoria, *Proceedings,* XLII, (1942), pp 406-417
103 Scheffler & Connolly, 'Building Sealants', pp 272-4.
104 E R Ballantyne, 'Cracking of Coloured Glass Used as a Wall Cladding', *Architecture in Australia,* XLVI, 3 (April-June 1957), pp 72-4.
105 *Cross-Section,* no 62 (December 1957), p 1

- hard setting glazing compounds

- unequal coefficients of thermal expansion of the glass and the ceramic enamel

Some amelioration could be achieved by using light and reflective glass colours, ensuring that the panes were free of imperfections and the edges cut clean, and limiting the sizes of the panes and the retaining beads. The sounder answer, however, was to use toughened glass, which was two or three times stronger than ordinary annealed glass (though this was not necessary on the south side or other areas not exposed to the sun).[106] Ballantyne's recommendations were followed in the case of the MLC Building at Perth, where toughened glass was imported from England at about 50% greater cost, or £3,335.[107]

Ballantyne's analysis has proved to be valid, though most individual problems can be reduced to a some combination of three causes. First, minor damage to the sheet: since spandrel glass is heat strengthened when the frit is fired, it cannot be cut or drilled, and even alterations to the edges of the sheet can weaken it sufficiently to fail under some relatively slight imposed stress. Secondly, the absorption and release of heat can cause temperature differences between the glass and the interface with other materials of more than 35 MPa, sufficient to fracture it. Thirdly, the presence of small pellets of nickel sulphide, for although small stones of various sorts are acceptable in glass manufacture, nickel sulphide cooks only partially during the tempering process and thermal changes may complete the cooking and set up stresses which disintegrate the panel.[108]

The most notorious Australian curtain wall failure was that of the ICI Building in Melbourne, which suffered from the same more or less unpredictable shattering of glass sheets, and the added problem that they then sliced down to footpath level, threatening to sectorise unwary pedestrians. The base of the building was for a long time shrouded in protective hoardings while the problem was dealt with, and what it proved to be the presence of nickel salt impurities in the Belgian-made glass. The crystallisation of these salts created points of stress within the pane. This problem was compounded in those panes which were unduly firmly restrained at the edges, where the aluminium framing expanded and contracted differentially, or which were subjected to extremes of temperature, like the sheets which covered the blind concrete wall on the west face of the building.

The problems of curtain walling had now become notorious in professional circles. For the Shell Building at 147-157 William Street, of 1958-60, careful testing was done. The building was designed by John Rogers of Skidmore,

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[106] Ballantyne, 'Cracking of Coloured Glass', pp 72-4.

[107] *Cross-Section,* 58 (August 1957), p 1.

[108] R W McKinley, 'Spandrel Glass', in Jester, *Twentieth-Century Building Materials,* pp 209-210.

Owings & Merrill, and supervised locally by Buchan Laird & Buchan.[109] The curtain walling was tested at Essendon Aerodrome by placing a sample, measuring 12.7 x 5.5 metres, behind a Convair airliner to gain the effect of rain-loaded wind at speeds of up to 160 kilometres per hour.[110] In 1959 C P Sorensen's *Curtain Walls* (technical study no 41 of the Commonwealth Experimental Building Station) was published in Sydney, and it set out the basic principles applicable to curtain walling, and in doing so closed the era of risks and disasters. 'Many of these principles are new,' it was said, 'as is to be expected where the system of construction is novel.'[111]

It does not seem that E Graeme Lumsden, the architect of the Nicholas Building, was particularly familiar with earlier curtain walls in Melbourne other than that of the ICI Building, and his design was too soon for him to have known of its defects. Nor does he recall any specific overseas source for his curtain wall detailing, though he believes that he would have drawn largely on overseas examples. After all, curtain walling was quite widely used in industrial, as opposed to office work, and Lumsden had just travelled overseas to inspect such buildings. He refers also to his dependence upon a local aluminium company and the two or three local glass suppliers, including Oliver Davey Glass. The aluminium company in question was presumably the Bronze Window Frame Co, who with Silverwood & Beck fabricated the curtain wall of the Nicholas Building (and had previously done the curtain wall of the Atlas Building together). The glazing units consisted of two panes 1/4 inch [6.4 mm] thick, held apart by an aluminium spacer, the outer pane of 'Anthelios' glass, the inner one clear, and they were installed with neoprene spacers and oil-based mastic.

The glazing was completed in January 1957, and by February 1959 the seal had failed in 69% of the units, and 39% of them had cracked. The failure of the seal meant that vapour entered the cavity and gave the unit a cloudy appearance. The whole of the glazing was now replaced using units with two clear panes and galvanised iron spacers, installed with full-length neoprene strips inside and outside, and a polysulphide external top seal. This was completed in July 1960, and one year later the polysulphide strips had failed as much as 90% at the sills, 50% at the sides, and 5% at the heads. It appears that the CSIRO was first consulted at this stage, and examined a number of available polysulphides, but found none satisfactory. Despite this, in June 1962 the old polysulphide was completely removed and replaced with another polysulphide, and by October 1963 it was apparent that this too was failing. In October 1964 weepholes were drilled in the rebates of all units to allow condensation to flow out. By May 1965 fourteen units had scummed and thirteen others were showing evidence of moisture within them, but it does not appear that there had been any further scumming after the weepholes were provided. By October 1965 a section was being tested with

[109] 'Office Building', *Architecture and Arts,* 52 (December 1957) , p 22; *Cross-Section,* 61 (1 November 1957), p 3.
[110] *Cross-Section,* 82 (1 August 1959), p 2.
[111] C P Sorensen, *Curtain Walls* (Sydney 1959), p iii.

a silicone sealant, with which it was proposed to completely re-seal the whole.[112]

In the meantime, not surprisingly, problems were experienced with the heat absorbed by the huge west-facing glass wall. The building was occupied in June 1957, when the problem would not have been apparent. In February 1958 vertical venetian blinds were installed behind a number of the window units. In November 1958 the forced ventilation, which had been provided through ducts at sill level, was replaced with air conditioning, still something of a local novelty at this time. The replacement of the anthelios glass with plain sheets in 1959-60 probably exacerbated the heat problem, and the present mesh sun screens in front of the windows were added subsequently, but probably not before 1965 when the glazing problems had been resolved.

[112] Extract from CSIRO Nicholas file, 1965, in National Trust files; Rahni, op cit.