



Chicago skyline with early skyscrapers in the 1920s.

# **SKYSCRAPERS THE FIRST CENTURY**

**AND THE INTRODUCTION OF AIR CONDITIONING**

**BRIAN ROBERTS**

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# NEW YORK



Postcard view of Lower Manhattan, looking north from Fulton Street, c.1919.

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New York skyline with early skyscrapers in the 1920s.

**A wealth of information and illustrations on skyscrapers and air conditioning over the century from 1885 is available on the Heritage Group website and in the References and Further Reading listed on page 44.**

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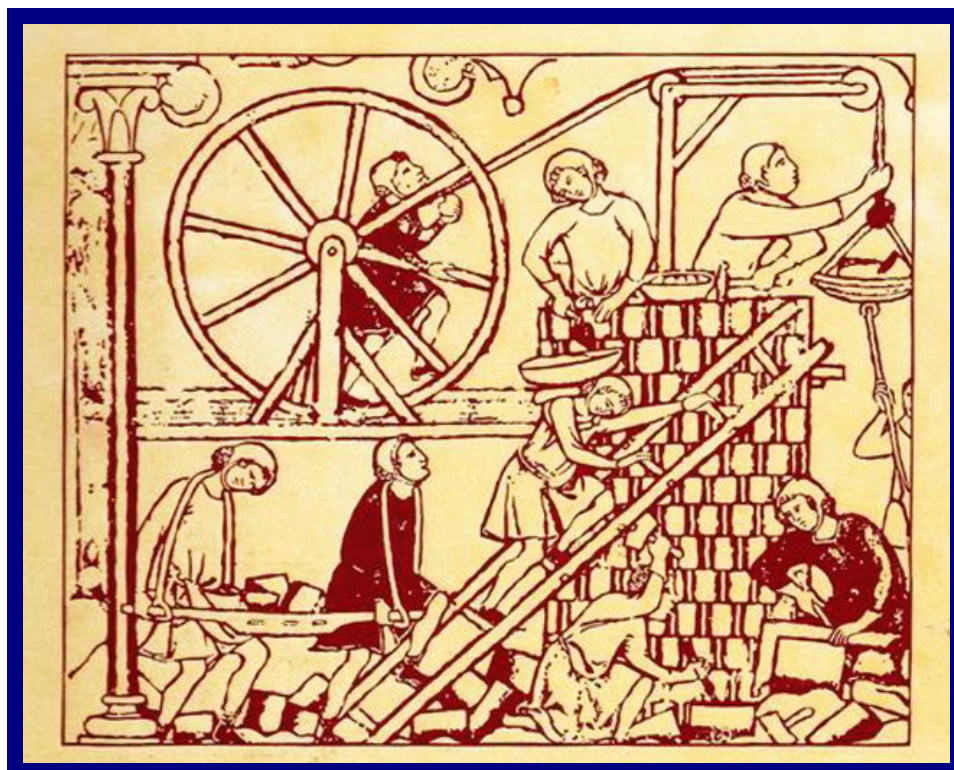
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Buildings with names in bold have been visited by me.  
**BMR, Budleigh Salterton, 2021.**

# SKYSCRAPER CATHEDRALS & CHURCHES



Before the first skyscrapers, the tallest buildings were the Cathedrals, with Lincoln the world's tallest (1311-1548) at 525 feet until it collapsed in a storm, leaving two smaller spires, as shown in this 17th century print, now removed.



The Medieval Cathedral Builders.

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## ST BOTOLPHS, BOSTON, LINCOLNSHIRE



1520: 272 ft, Highest tower (exclusive of spire) of any English Parish Church.  
Popularly known as the "Boston Stump".

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## **SALISBURY CATHEDRAL, WILTSHIRE**



1733: 404 ft, tallest cathedral in England.

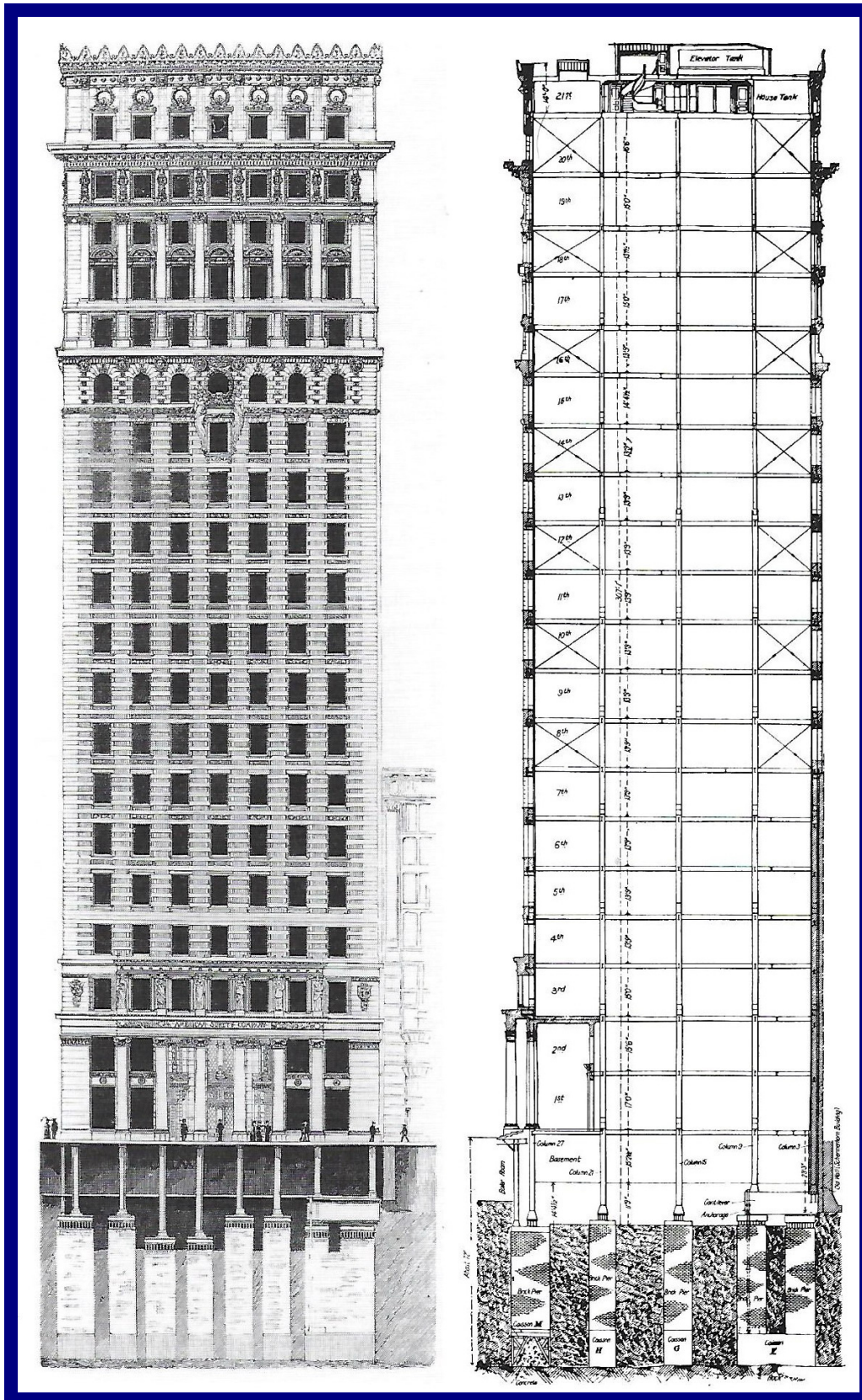
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## ULM CATHEDRAL, GERMANY



1890: 520 ft, The tallest church building in the world,  
The Basilica de la Sagrada Familia in Barcelona, commenced in 1882 is  
scheduled when finished to reach a height of 566 ft.

# SKYSCRAPER BUILDINGS



American Surety Building, New York, Elevation (Scientific American, 1894).  
Section (Engineering Record, 1896).  
1896: 112 ft, 23 floors. Architect: Bruce Price.



# ENGINEERING USA STYLE

**Brian Roberts' personal view of  
American services engineering.**

This article looks at American building services engineering, particularly air conditioning, as seen through the eyes of the author in more than a dozen trips to the USA over the past ten years. The impressions, opinions and conclusions (and any factual errors) are his alone. They are based on visits to many buildings and installations. They also reflect tours of exhibitions and factories, participation in ASHRAE Committees, and discussions with owners, consultants, contractors, manufacturers and maintenance engineers — ranging from the Eastern Seaboard to the deep South, Texas and the West Coast.

It is perhaps first appropriate to briefly recap on some of the contributions made to building services by the USA. The work of Edison in lighting and later electrical generation and distribution, the invention by Otis of the lift, and the developments due largely to Willis Carrier, air conditioning, psychrometrics, the centrifugal refrigerating machine and the induction system, are generally well known.

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## HOME INSURANCE BUILDING, CHICAGO



1885: 180 ft, 12 floors. Regarded as the First Skyscraper. Demolished 1931.  
Architect: William Le Baron Jenney.

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## WAINWRIGHT BUILDING, ST LOUIS



1891: 147 ft, 10 floors. Architect: Adler and Sullivan.

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## RELIANCE BUILDING, CHICAGO



1894: 202 ft, 15 floors. Architect: Burnham and Company.

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## FLATIRON BUILDING, NEW YORK



1902: 285 ft, 21 floors: Architect: Daniel H. Burnham.

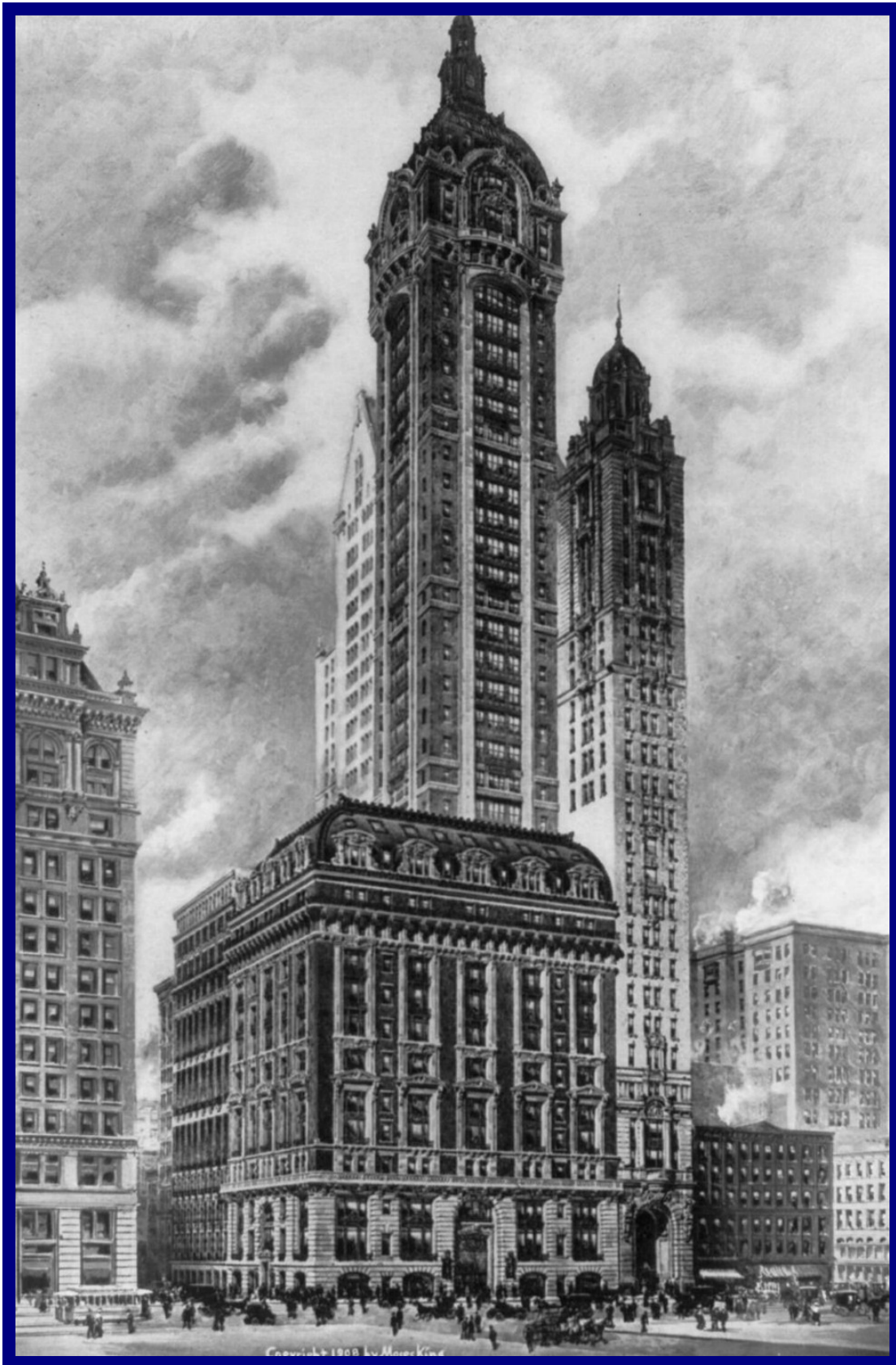
## METROPOLITAN LIFE, NEW YORK



1909: 700 ft, 50 floors. Architect: Napoleon Le Brun & Sons. Not air conditioned. By the late 1920s, the clock tower and its annexes were too small. The Company approved the design for a 100-storey tower, but the Great Depression in 1929 led to only the 28-story base being built. Said to have been fully air conditioned, but no confirmation or details of refrigeration (?) discovered.

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## SINGER TOWER, NEW YORK



Tower completed 1908: 612 ft, 47 floors. Architect: Ernest Flagg. Demolished 1968.  
Tallest building in the world 1908-1909.

## WOOLWORTH BUILDING, NEW YORK



1913: 792 ft, 57 floors. Architect: Cass Gilbert.

H&V Consultant: Nygren, Tenny & Ohmes. Dunham vacuum steam heating.  
Mechanical ventilation with plant rooms up to 46th floor. Some specialist rooms at lower levels served by Kinealy air washer cooling systems. Tallest building in the world 1909-1913.



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## PITTSFIELD BUILDING, CHICAGO



1923: 551 ft, 38 floors. Architect: Graham, Anderson, Probst & White.  
When built the tallest building in Chicago. Once offices, now partly student accommodation

## WRIGLEY BUILDING, CHICAGO



1924: 438 ft (spire), 30 floors (North Tower), 21 floors (South Tower).  
Architect: Graham, Anderson, Probst & White. Air conditioning in a few areas,  
Wittenmeier Machine Company (1927 advert). Possibly CO<sub>2</sub> refrigeration.

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## TRIBUNE TOWER, CHICAGO



1925: 462 ft, 34 floors. Architect: John M. Howells & Raymond Hood.  
Air conditioning in a few areas. Wittenmeier Machine (1927 advert). Possibly CO<sub>2</sub> refrigeration.

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## CHICAGO SKYSCRAPERS



View north on South LaSalle Street, early 1920s (from Willis).  
Left: Federal Reserve Bank, Illinois Continental and Commercial Bank.  
Right: Illinois Merchants Bank, Rookery Building.

## NEW YORK SKYSCRAPERS



View north on Broadway, c.1915 (from Willis)- narrow facades and tall towers.  
Left to right: Trinity, U.S. Realty, Singer, City Investing and Woolworth Buildings.

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## MILAM BUILDING, SAN ANTONIO



1928: 280 ft, 21 floors. Architect: George Willis.  
Regarded as first air conditioned office block in the USA, installation by Carrier.  
Refrigeration 300 TR with overnight chilled water storage, condenser cooling water  
from adjacent river. (ASME Book No. HH9106).

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## PSFS BUILDING, PHILADELPHIA



1932: 491 ft (roof), 46 floors. Architect: William Lescafe & George Howe. Now Loews Hotel.

## EMPIRE STATE BUILDING, NEW YORK

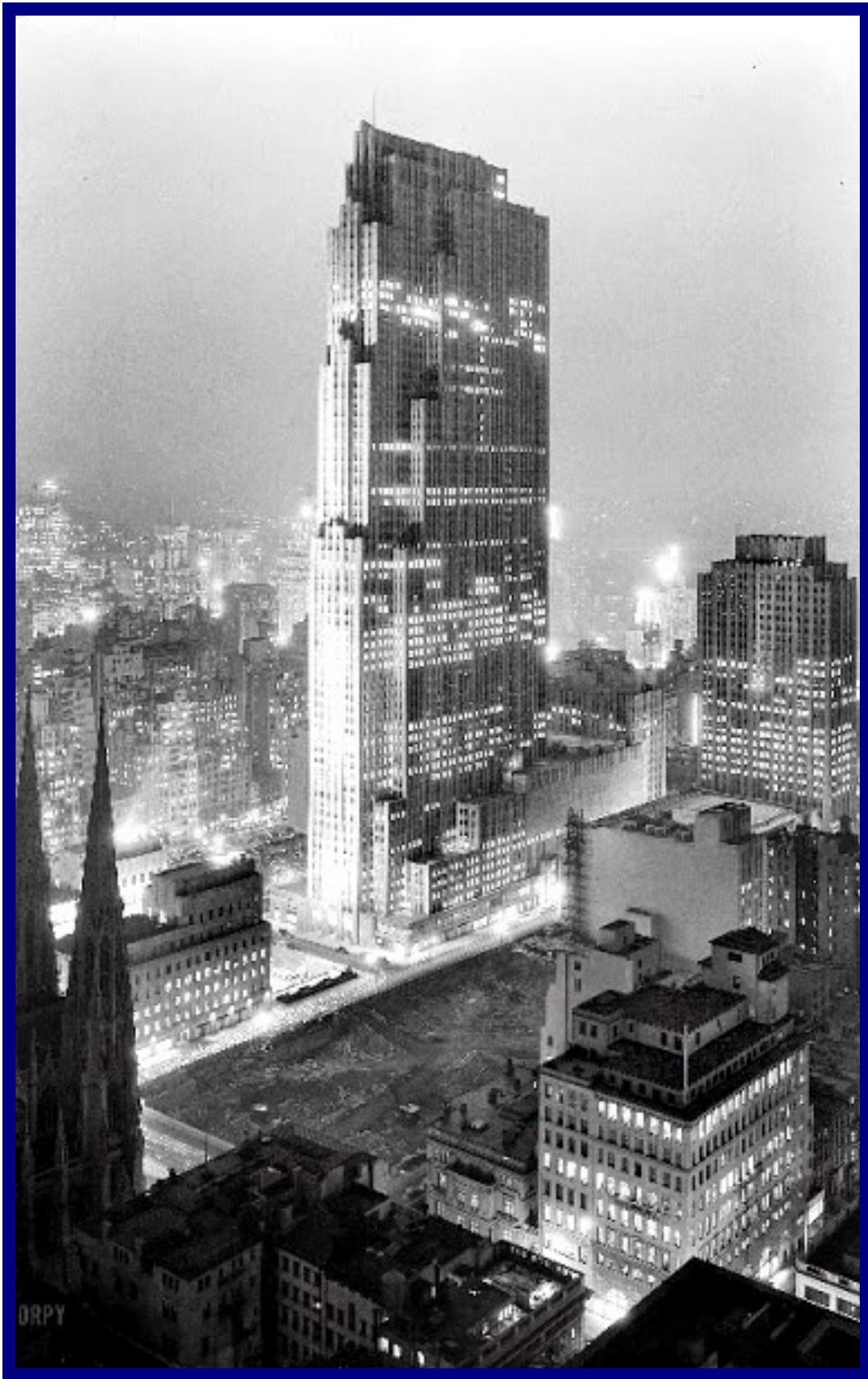


1930: 1250 ft, 102 floors. Architect: Shreve, Lamb & Harmon.  
Tallest building in the world 1931-1972. Not originally air conditioned.  
Air conditioning progressively added from 1950s.



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## RCA BUILDING, NEW YORK



Completed in 1940, 850 ft, 70 floors. Architect: Raymond Hood.

Not originally air conditioned except for a number of radio broadcasting studios  
**Radio City Music Hall** movie theatre (6000 seats) air conditioned 1933 (600 TR, 240,000 cfm).

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## UNITED NATIONS, NEW YORK



1951: 510 ft, 39 floors. Architect: Oscar Niemeyer, Le Corbusier, Wallace Harrison.  
Air conditioned by Carrier Weathermaster induction unit system (Ingels, p.95).

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## LEVER HOUSE, NEW YORK



1952: 307 ft, 23 floors. Architect: Skidmore, Owens & Merrill.  
Air conditioned by perimeter induction units and interior high velocity all-air systems.  
HVAC Consultant: Jaros, Baum & Bolles.

## GATEWAY CENTRE, PITTSBURGH



1952: 344 ft, 24 floors: Architect: Eggers & Higgins. Part of complex of five buildings.  
Air conditioned by Carrier Weathermaster induction unit system. (Ingels, p.95).  
Possibly the world's largest comfort system at the time, over 6000 units, 4500 TR.

## ALCOA BUILDING, PITTSBURGH



1953: 410 ft, 30 floors. Architect: Harrison and Abramovitz.  
External wall cladding is thin lightweight aluminium.  
Offices provided with radiant ceiling panel heating and cooling systems.

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## SEAGRAM BUILDING, NEW YORK



1958: 516 ft, 38 floors. Architect: Mies Van Der Rohe.

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## MARINA CITY, CHICAGO



1964: 588 ft, 61 floors. Architect: Bertrand Goldberg. Lower levels-18 floors of car parking. Apartments had own heating and cooling units (no central plant).

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## LAKE POINT, CHICAGO

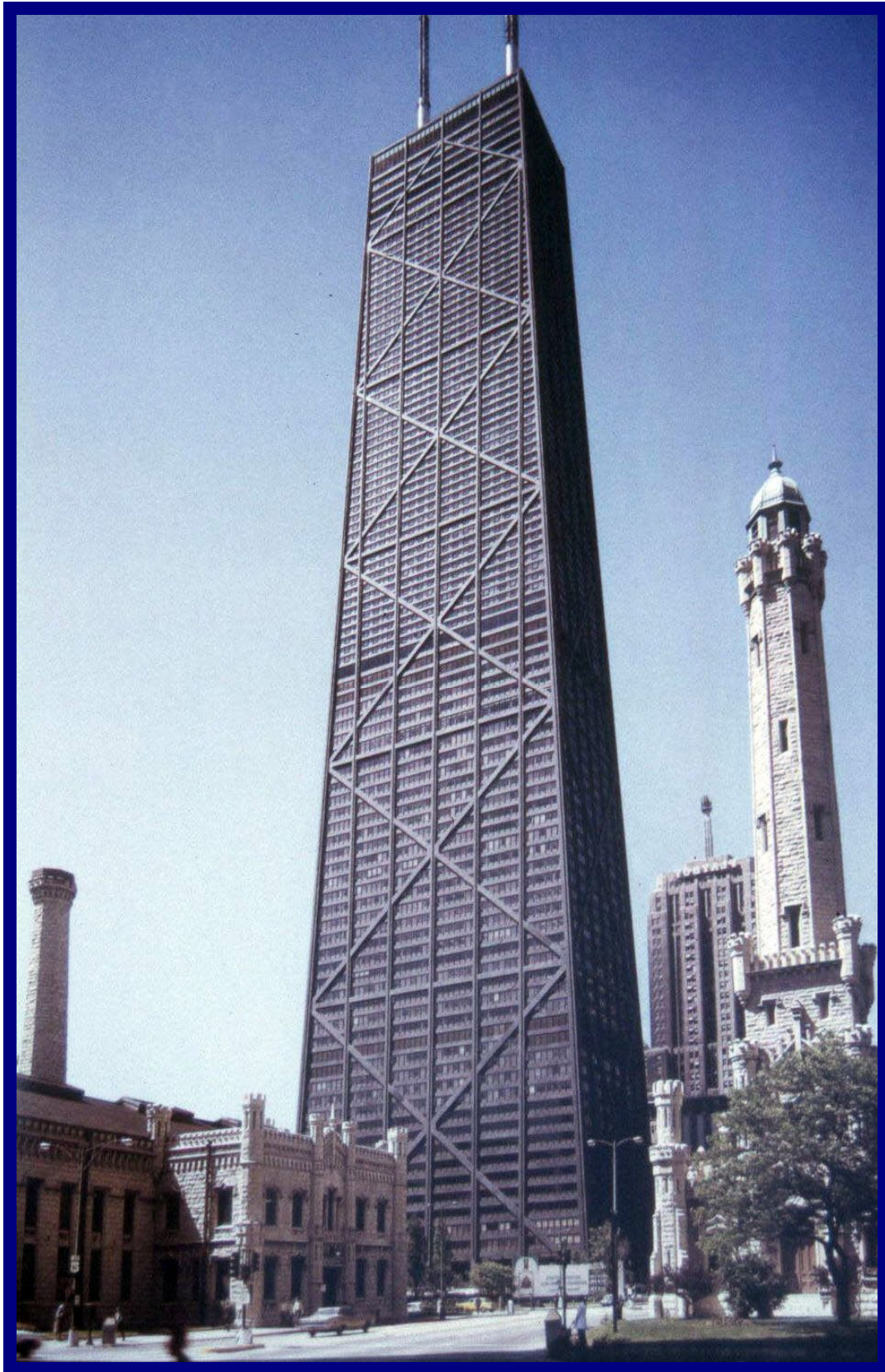


1968: 645 ft, 70 floors. Architect: Schipporeit-Heinrich Associates.  
When completed it was then the tallest Apartment Block in the world.  
"Air conditioning provided by wall units".



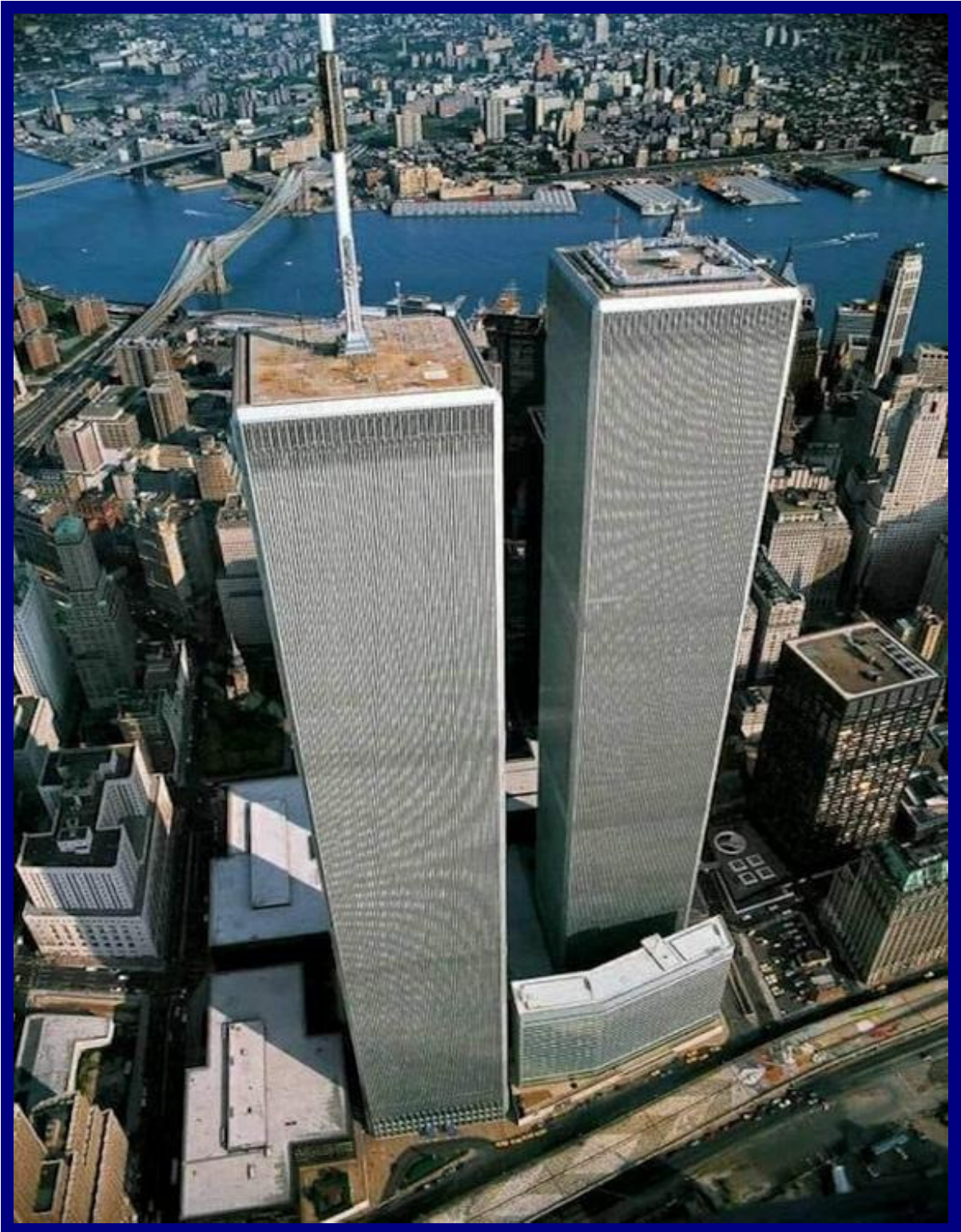
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## JOHN HANCOCK BUILDING, CHICAGO



1969: 1127 ft, 100 floors. Architect: Skidmore, Owings & Merrill.

## WORLD TRADE CENTRE, NEW YORK



1972-73: 1368 ft, 110 floors. Architect: Minoru Yamasaki and Emery Roth & Sons.

Both towers destroyed in the terrorist attack of 2001 (referred to as 9/11).

Tallest building in the world 1972-1974.

Fully heated and air conditioned with 2-pipe under-window induction units and an all-air constant volume system throughout, having seven York 1000 TR chillers (49,000 TR total) and a condenser system employing water from the nearby River Hudson.

## **WORLD TRADE CENTRE, NEW YORK (1973)**

The World Trade Centre is a six-building complex totalling nearly 1 000 000 m<sup>2</sup> of floor area, next to the Hudson River. The twin towers, each of 110 storeys and 412 m high (475 m if you count the TV masts), contain some 43 600 windows employing around 60 000 m<sup>2</sup> of glass. Below ground are six levels that house the Port Authority Trans Hudson rail rapid transit system, parking space for 2000 cars, and the central air conditioning and refrigeration plant. The working population of the Centre is some 50 000; business and other visitors can amount to a further 80 000 daily.

Each tower has mechanical equipment rooms on floors 7, 41, 75 and 108. There are over 100 000 supply and return air grilles and diffusers, 1000 fans circulating over 5000 m<sup>3</sup>/s of air, 250 steam humidifiers, 300 pumps, 100 heat exchangers, 30 000 under-the-window induction units and a central refrigerating plant with over 170 000 kW of cooling capacity.

There are seven centrifugal chillers, each of 24 400 kW cooling capacity, driven by 13.8 kV water-cooled synchronous motors rated at 5200 kW. Each machine uses 10 000 kg of R22. The evaporators take the full static head of the tower's chilled water systems. Water for condenser cooling is taken at the rate of 5600 litre/s from the Hudson River. The chilled water pumps include "low pressure" zone pumps of 930 kW, delivering 630 litre/s at a head of 107 m and a working pressure of 3.2 MPa, while the "high pressure" pumps are 450 kW and handle 300 litre/s with a head of 100 m; however, in the latter case the working pressure is 5.6 MPa.

## TRANSAMERICA, SAN FRANCISCO



1972: 853 ft, 48 floors. Architect: William L. Pereira.

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## SEARS TOWER, CHICAGO



1974: 1451 ft, 108 floors, now Willis Tower. Architect: Skidmore, Owings & Merrill.

Tallest building in the world 1974-1997.

Originally had induction unit air conditioning now replaced with fan-coil units.

The refrigeration capacity was 17,000 TR with four 300 TR cooling towers.

Automatic control system has been upgraded.

## UNITED CALIFORNIA BANK, LA



1974: 875 ft, 62 floors (now Bank of America). Architect: Charles Luckman Associates. HVAC Consultant: Syska & Hennessey. All-air air conditioning, dual duct for exterior zones, VAV for interior. Refrigeration four 912 TR chillers (3650 TR total).

## UNITED CALIFORNIA BANK, LOS ANGELES (1974)

What was claimed at the time to be a "unique all air system" which conserved energy provides the air conditioning for the bank and office building for United California Bank. This 62 storey 261m high block has a floor area of 116 000 m<sup>2</sup> in the USA's tallest building west of Chicago. The 56 × 38 m tower has a steel frame with bronze curtain walling of solar control glass.

The hvac system, which at 1971 prices cost \$38/m<sup>2</sup> of floor area, consists of an all electric and all air system, dual duct for exterior zones, vav for the centre of the building. There are fan room at floors 4, 5, 22, 42 and 61. The supply air volume is 8.3 m<sup>3</sup>/s per floor, each floor being 1670 m<sup>2</sup>. Refrigeration plant consists of four 3.2 MW centrifugal chillers. These are located on the roof and mounted on an airbag system maintained at 560 kPa through a pneumatic system and air compressor.

The electricity supply enters at 34.5 kV and is transformed in the basement to 12.7 kV for distribution to floors 22, 42 and 61. 3 MVA lighting and 1 MVA power transformers at these levels feed 480/270 V and 208/120 V systems.

The fire protection system begins with a 375 000 litre basement reservoir. There are two 224 kW fire pumps, each 47 litre/s capacity at 370 m head.

The maintenance staff is 12. The Delta 2000 building automation system alone costs \$30 000 per year for its maintenance contract, and one complete change of the filter bags costs \$12 000 for the bags and the same again for labour (1977 prices).

Architects were Charles Luckman Associates, services consultants Syska & Hennessy.

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## PENNZOIL PLACE, HOUSTON



1975: 394 ft, 36 floors, Architect: Philip Johnson and John Burgee.  
M&E Consultant: I.A. Manning & Associates. Dual duct air conditioning.  
Refrigeration four chillers each 1600 TR (6400 TR total).



## **PENZOIL PLACE, HOUSTON, TEXAS (1975)**

Penzoil Place is a 36 storey office block, 120 m high. The floor area is 167 000 m<sup>2</sup> in twin towers which have curtain walls with solar glass. The towers are linked by an atrium lobby. Parking for 600 cars is provided on three levels.

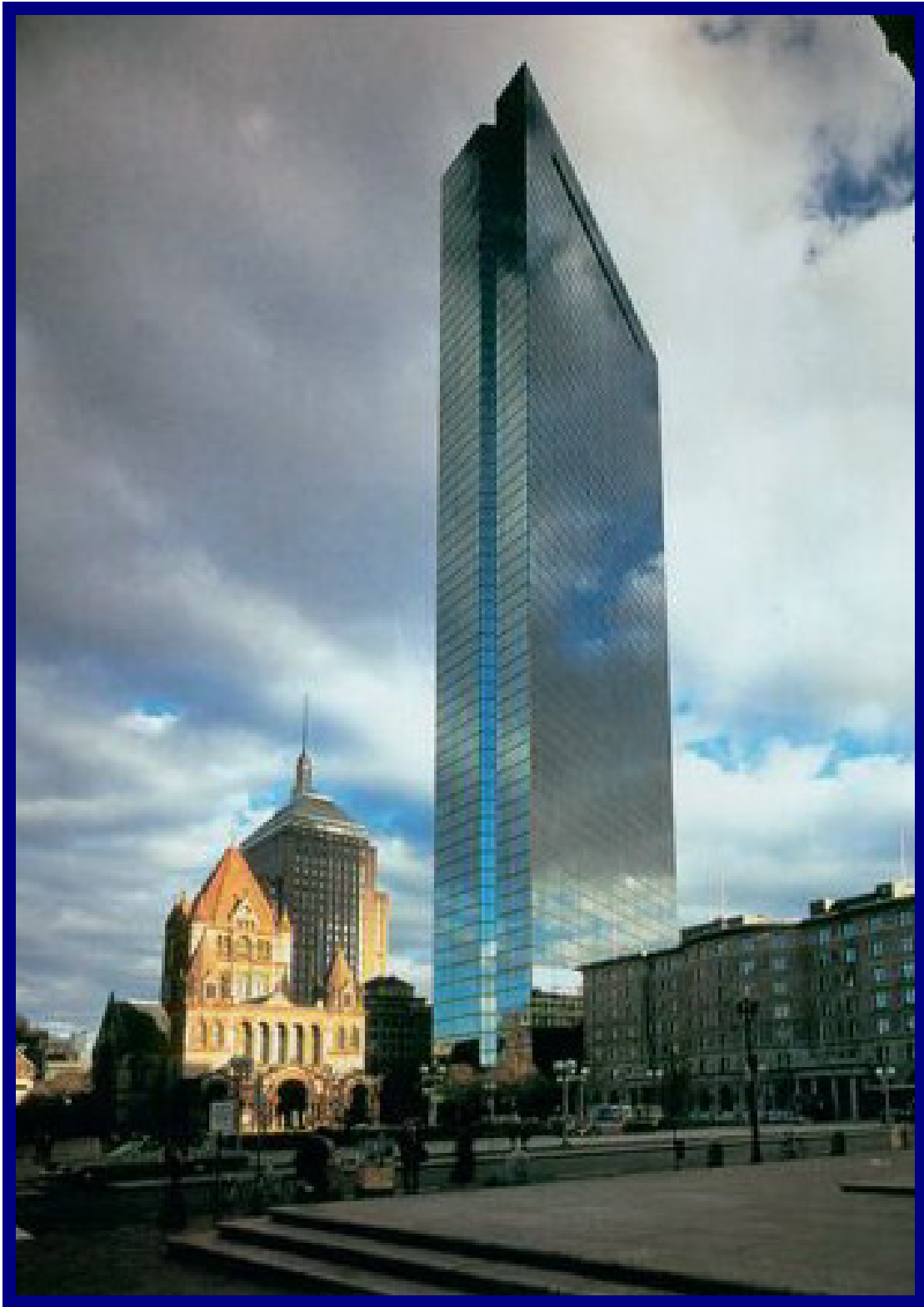
The air conditioning is a dual duct type with two air plants per floor. The atrium is served by 16 air handlers. The central fresh air plant is on the roof. The main pipes runs are four 250 mm diameters pipes for chilled water and four 150 mm pipes for heating hot water. Refrigeration is supplied by four 5600 kW chillers linked to a single five-cell roof top cooling tower of 25 MW heat rejection capacity. The fans of the cooling towers have 5 m diameter blades. The boiler plant consists of two 5 MW mthw boilers, with nitrogen pressurisation, generating hot water at 120°C primary, with heat exchangers having 82°C secondary. The two boiler flues are 800 mm diameter, discharging through a 10 m high stack at the pavement edge.

The electrical system has two 4 kW aluminium bus-duct risers in each tower. There are 23 000 lamps in each tower and the total power is 12.5 MVA. In 1977 electricity bills were \$110 000 per month. Also in 1977, the bill for water treatment for the cooling tower was \$25 000 per year. There is a maintenance staff of five.

Fire protection includes sprinklers in the lobby and at lower levels, fire detectors in the towers, and pressurised staircase ventilation for smoke control. The architects were Philip Johnson and John Burgee, services consultant I A Manan & Associates.

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## JOHN HANCOCK, BOSTON



1976: 790 ft, 62 floors. Architect: Henry N. Cobb, I.M. Pei & Partners.

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## PEACHTREE PLAZA, ATLANTA



1976: 723 ft, 73 floors, 1068 rooms. Architect: John Portman and Associates.  
When built the tallest hotel in the world, complete with a rooftop revolving restaurant  
and an immense atrium lobby. Fully air conditioned.

## REFERENCES AND FURTHER READING

- 1913 Master Builders of the World's Greatest Structure, Hugh McAtamney & Co., New York.
- 1952 Father of Air Conditioning, Margaret Ingels, Country Life Press, Garden City, USA.
- 1981 Engineering USA Style, Brian Roberts, Building Services (CIBSE Journal) May, London.
- 1987 Frank Lloyd Wright's Larkin Building, Jack Quinan, The University of Chicago Press,  
(see detail and drawings of air conditioning, pp.66-72).
- 1991 The Milam Building, ASME National Engineering Heritage Site, Book No. HH9106.
- 1992 Mechanical & Electrical Systems for Historic Buildings, Gersil Newmark Kay,  
McGraw-Hill, New York.
- 1995 Form Follows Finance, Carol Willis, Princeton Architectural Press, New York,
- 1996 Rise of the New York Skyscraper 1865-1913, Sarah Bradford Landau & Carl W Condit,  
Yale University Press, New Haven.
- 1997 The Quest for Comfort (CIBSE Centenary), Brian Roberts & CIBSE Heritage Group.
- 1998 Air Conditioning America 1900-1960, Gail Cooper, John Hopkins University Press,  
Baltimore.
- 1999 The Evolution of Modern Office Buildings and Air Conditioning, David Arnold, ASHRAE  
Journal, June, Atlanta.
- 1999 Air Conditioning in Office Buildings after World War II, David Arnold, ASHRAE Journal  
July, Atlanta.
- 2001 The Empire State Building, Lewis W. Hine, Prestel, Munich.
- 2001 Churches, Judith Dupre, Harper Collins, New York (Cathedrals throughout the World).
- 2002 World Trade Centre, Property Risk Report, Alternative Insurance Works, New York.  
(Copy of original, being Deposition Exhibit 4/9/02: With full details MEP Engineering).
- 2013 Skyscrapers, Judith Dupre, Black Dog & Leventhal Publishing, New York.
- 2016 NY Skyscrapers, Dirk Stichwel, Prestel, Munich.
- 2020 Heritage Revisited-3, Brian Roberts, CIBSE Heritage Group, Privately printed.
- 2020 Heritage Revisited-4, Brian Roberts, CIBSE Heritage Group, Privately printed.
- 2021 20th Century Air Conditioning, David Arnold, ASHRAE, Atlanta.
- 2021 Comfort Air Conditioning, Brian Roberts, CIBSE Heritage Group, Privately Printed.

**The Skyscraper Museum** is an architecture museum located in Battery Park City, Manhattan, New York City and founded in 1996. The museum focuses on high-rise buildings as "products of technology, objects of design, sites of construction, investments in real estate, and places of work and residence." The Skyscraper Museum also celebrates the architectural heritage of New York and the forces and people who created New York's skyline. The Skyscraper Museum was founded and is directed by Carol Willis, a professor of architectural history and author of "Form Follows Finance" in 1995.