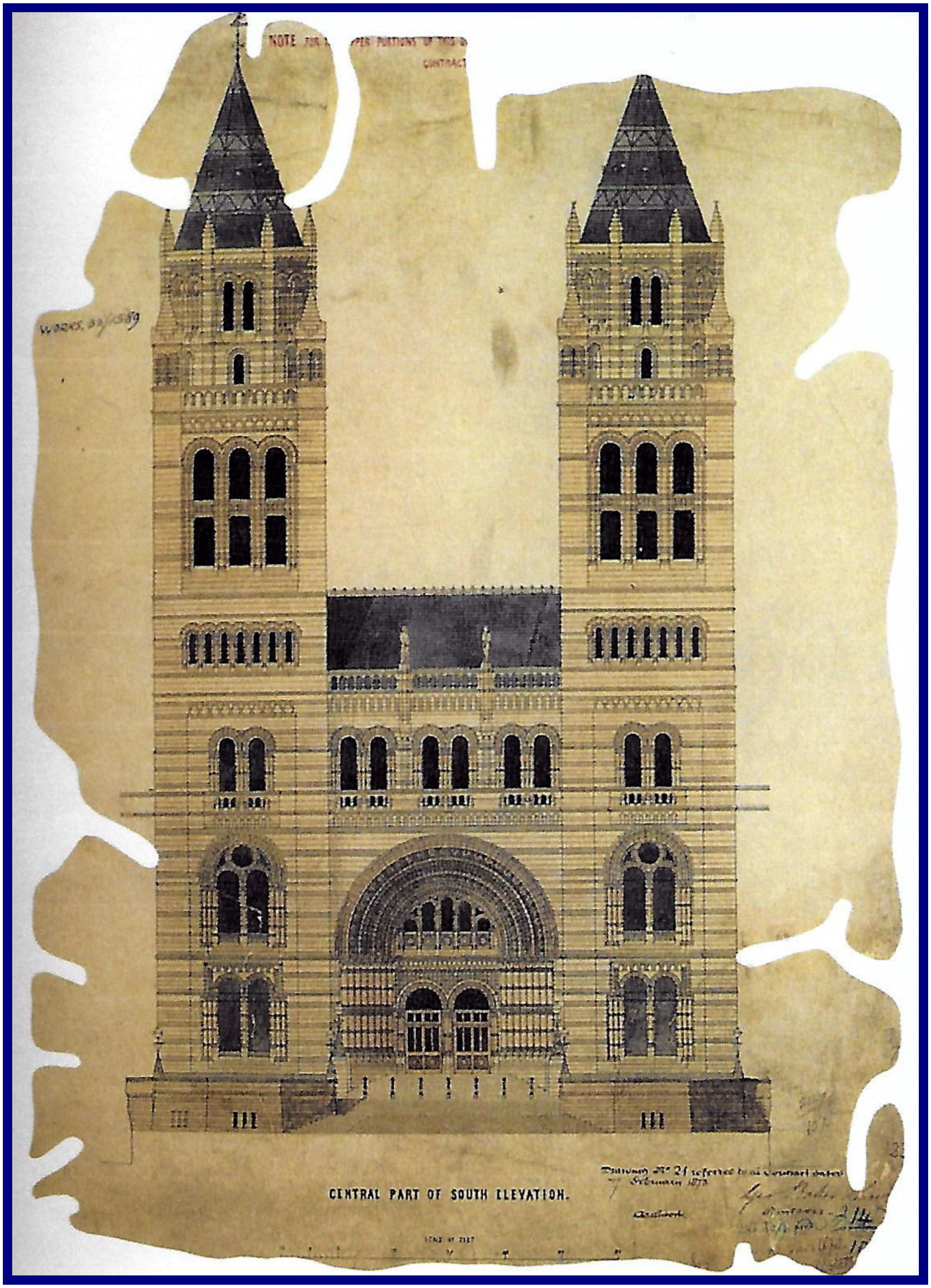
Building Engineering Services
HERITAGE REVISITED
PART THREE

Brian Roberts
and the CIBSE Heritage Group

The Royal Albert Hall in London, built 1871, with Heating and Ventilation by W.W.Phipson

NATURAL HISTORY MUSEUM, LONDON



Built 1880 with Heating and Ventilation by W.W. Phipson

DULWICH PICTURE GALLERY, LONDON

Built 1817 with Heating by James Watt Jr. & Matthew Boulton Jr.

INTRODUCTION

This is a continuation of the first *Building Services Heritage* and later *Revisited Parts-1 & 2.* It features engineering services in a variety of buildings and structures, some outside the UK, which have been researched and visited by Heritage Group members, individually or as a group.

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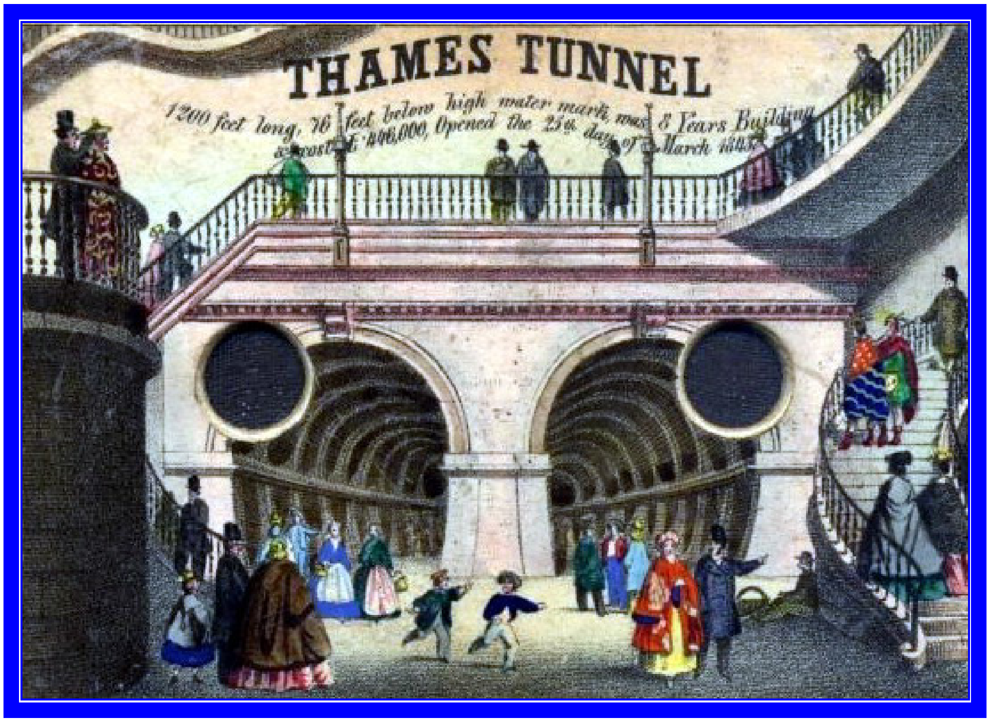
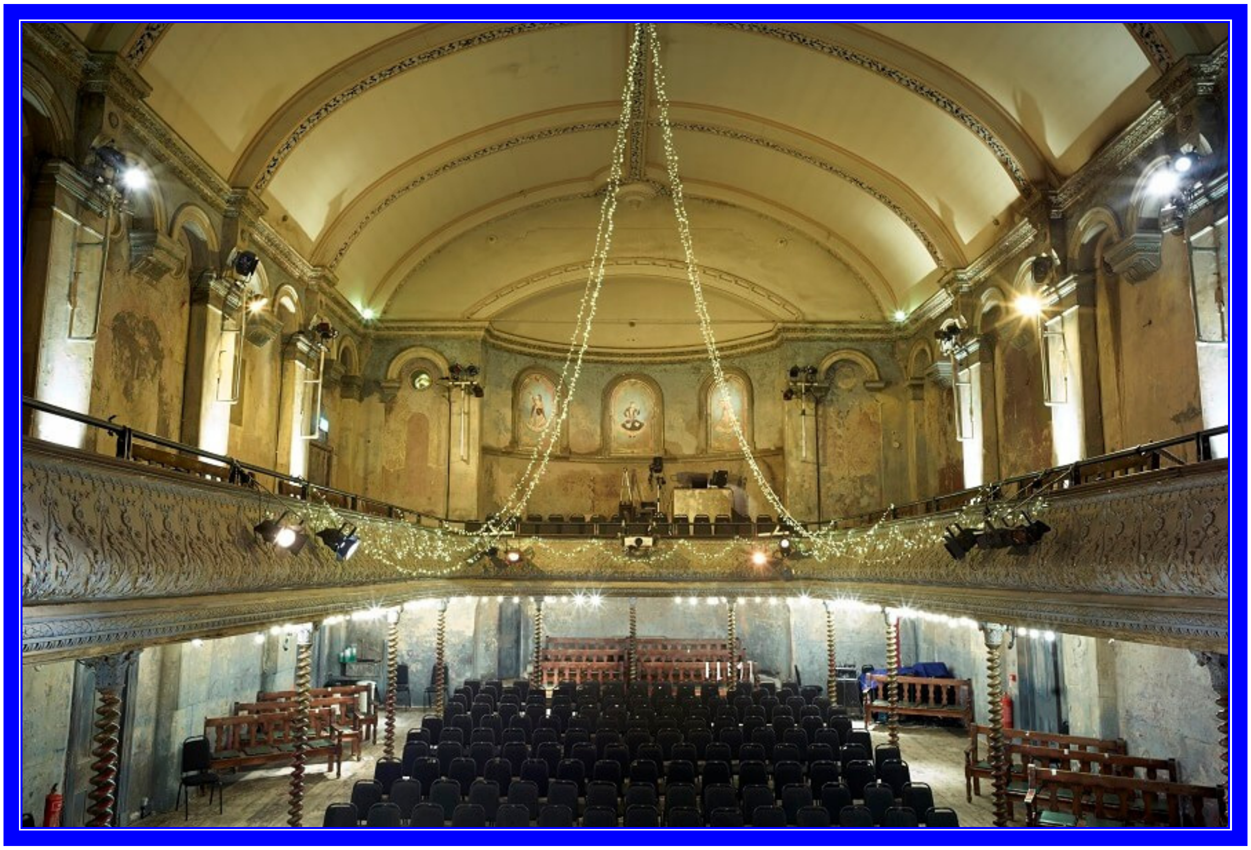
THAMES TUNNEL, LONDON



After many difficulties, including collapse and flooding, the 1300 ft long underwater tunnel between Rotherhithe and Wapping (engineered by Marc Brunel and son Isambard Kingdom Brunel) was finally opened in 1843. It was intended to transfer cargo unloaded from ships on the south bank to the north bank using horse-drawn vehicles. This proved impossible and the tunnel was used by pedestrians until taken over in 1869 by the East London railway. Brunel Museum is now housed in the old engine house that was used to drain water from the tunnel.

WILTON'S MUSIC HALL, LONDON



Wilton's began life as five houses in Graces Alley, now in Tower Hamlets, as far back as the 1690s and in turn became the Prince of Denmark Public House (1828), then the Mahogany Bar (1839) before John Wilton turned it into a Victorian Music Hall in 1858-9. "He furnished the hall with mirrors, chandeliers and decorative paintwork and installed the finest heating, lighting and ventilation systems of the day." It was rebuilt after a disastrous fire in 1877. The Hall reopened with a capacity for 400 persons as Fredrick's Royal Palace of Varieties. Public performances ceased when it proved impossible to fit a safety curtain and the building fell into decay. The gallery is still supported by distinctive "barley sugar" cast iron pillars. The Hall was once lit by a gas "sun-burner" chandelier with 300 jets and heated by a Grundy coal-fired warm air furnace which still survives in the basement.

Saved from demolition through the efforts of Sir John Betjeman and others, it is now being restored. Owned by the Wilton's Music Hall Trust it is used for opera and theatrical productions and other events.

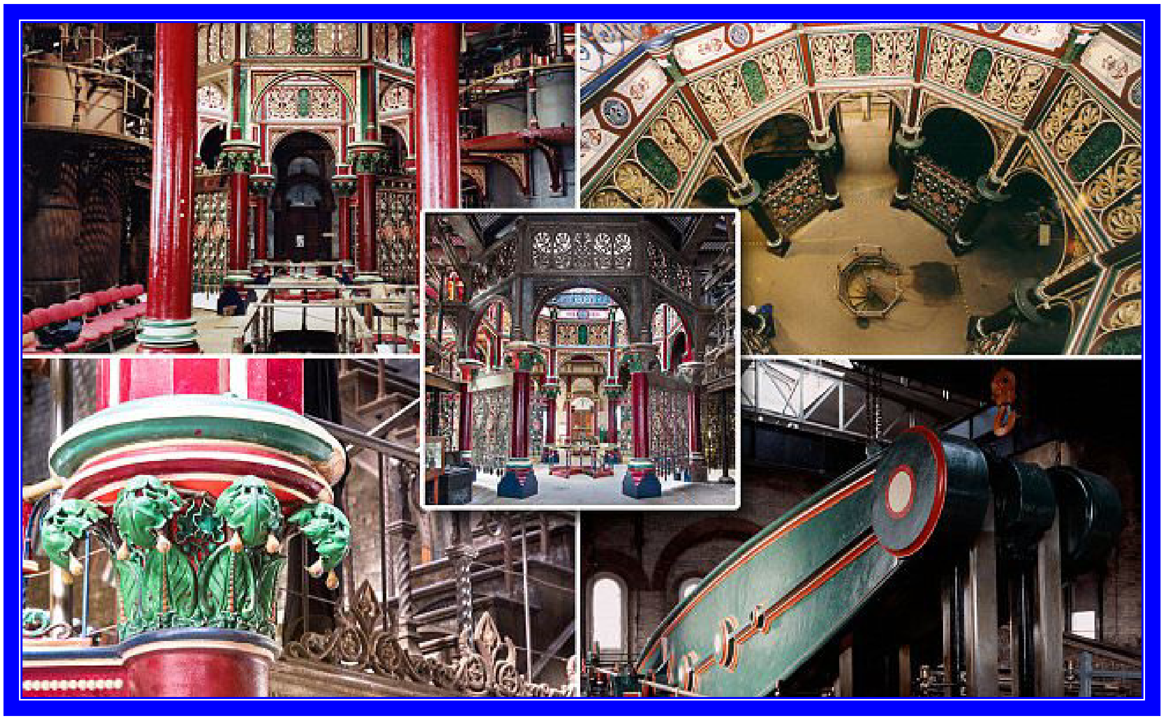
CROSSNESS PUMPING STATION

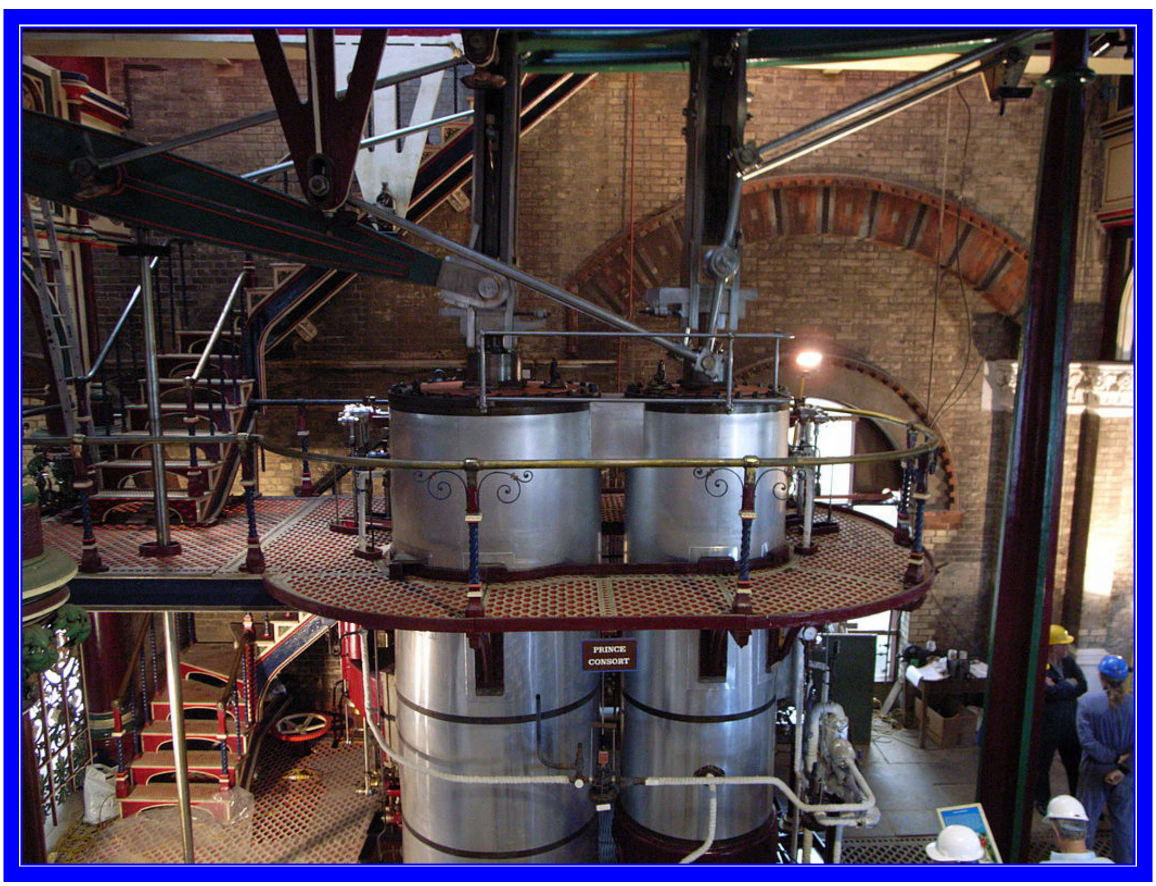
The Crossness Works is a former sewage pumping station at the eastern end of the London's Southern Outfall Sewer. Designed by Sir Joseph Bazalgette it opened in 1865, lifting the liquid some 30 to 40 ft by four enormous steam-driven pumps built by James Watt & Company and originally disposing of the raw sewage into the river seawards. At 11 rpm, some 6 tons (about 1500 gallons) of sewage per stroke per engine were pumped into a 27 million gallon reservoir and released into the Thames during the ebbing tide.

The station contains the four original pumping engines (named *Victoria*, *Prince Consort*, *Albert Edward* and *Alexandra*) thought to be the largest rotative beam engines in the world with 52-ton flywheels and 47-ton beams. The steam required to drive these engines was raised by 12 Cornish boilers which consumed 5000 tons of Welsh coal annually.

In 1891, sedimentation tanks were added and the sludge was carried out to sea by steam boats and dumped. Around the turn of the century, the engines were converted from single to compound operation and the single cylinders augmented by high and intermediate pressure cylinders. The additional steam required was obtained by replacing the original boilers with the more efficient Lancashire type. *Prince Consort* was returned to steam in 2003 and runs on open days of the Crossness Engines Trust.

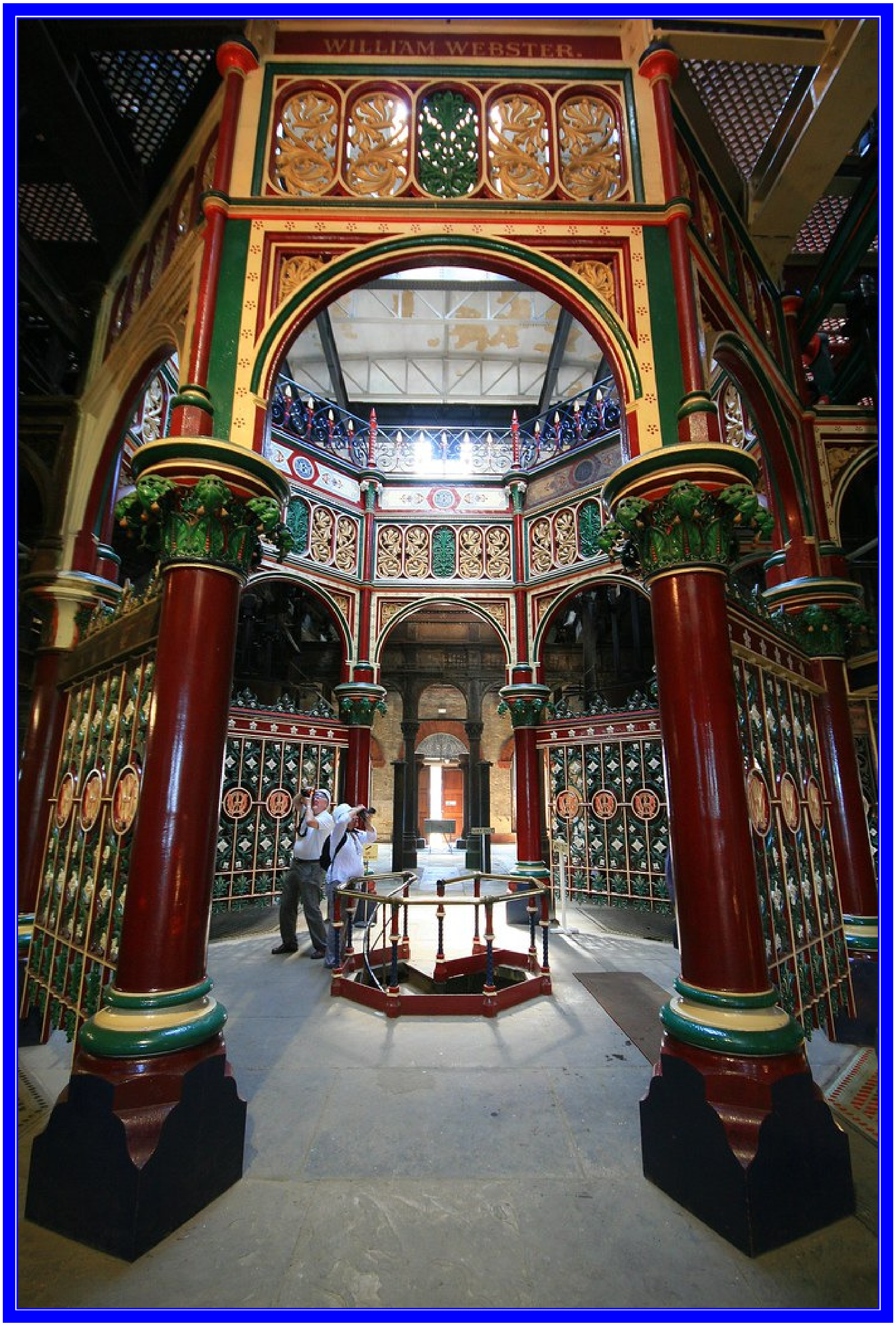
CROSSNESS PUMPING STATION





The *Prince Consort* Engine

CROSSNESS PUMPING STATION



CROSSNESS PUMPING STATION

One of the 47-ton beams

PAPPLEWICK PUMPING STATION

The Station was opened in 1884, the ornate pump house having two huge beam engines by James Watt & Company, powered by steam from a bank of six Galloway (modified Lancashire) boilers. Decommissioned in 1969, it was restored from 1975 onwards and opened as a working museum in 2005.

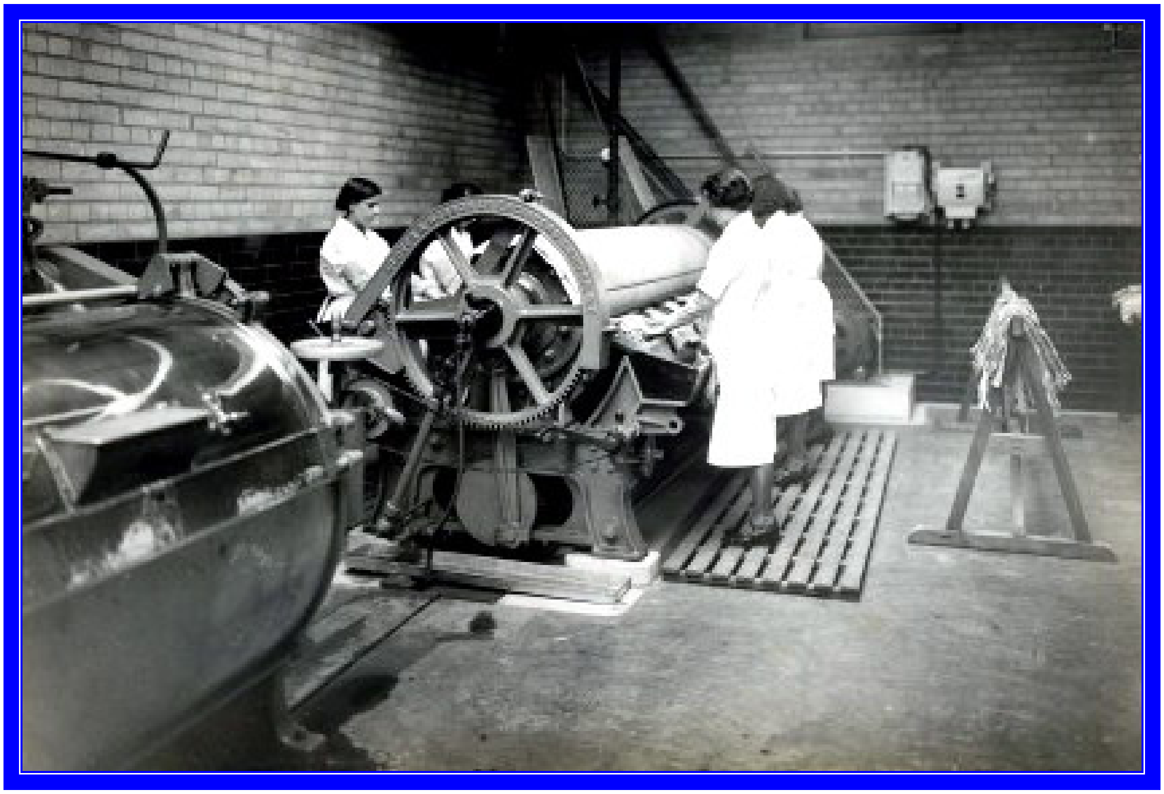
PAPPLEWICK PUMPING STATION

Three of the Galloway coal-fired steam boilers, original output 97 kW each, later uprated.

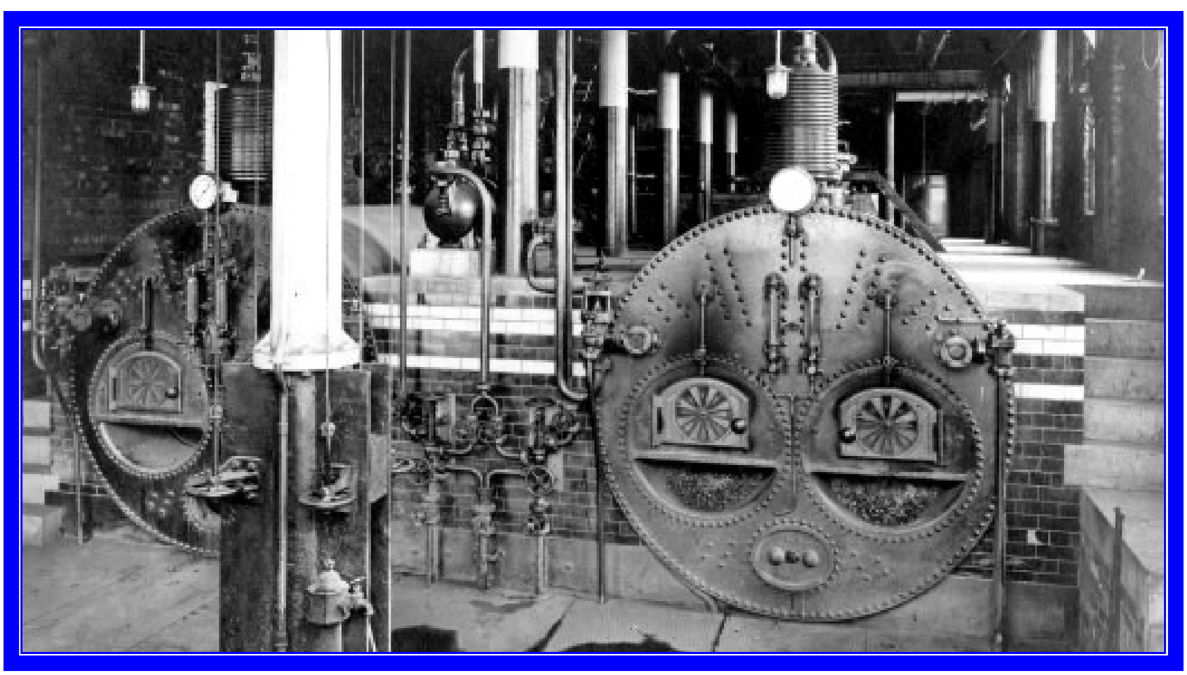
VICTORIA BATHS, MANCHESTER

When Victoria Baths (Manchester's Water Palace) opened in 1906, after six years in the planning and construction it contained three swimming baths (one Female and 1st and 2nd Class for Males), 64 wash baths, Turkish and Russian baths, plus the addition of a Laundry. Then there was ornamental ironwork, decorative tiling and expensive stained-glass windows. Engineering works included coal-fired steam boilers, calorifiers, lighting and the pool equipment. The total cost of building and services was £59,144. After many years in use the Baths closed to the public in 1993. A Gala Pool was re-opened in 2017 and restoration continues.

VICTORIA BATHS, MANCHESTER

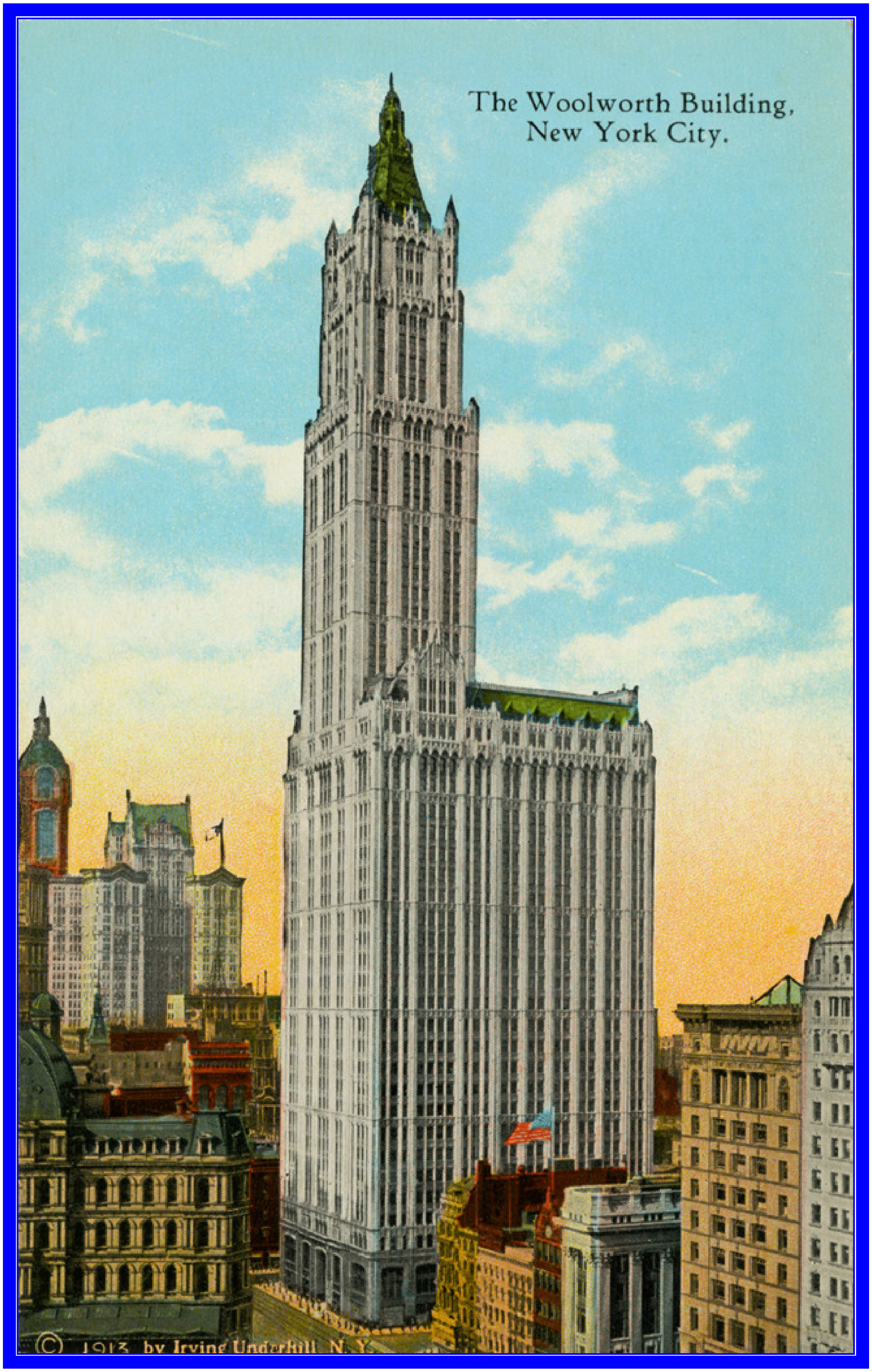


The original Laundry



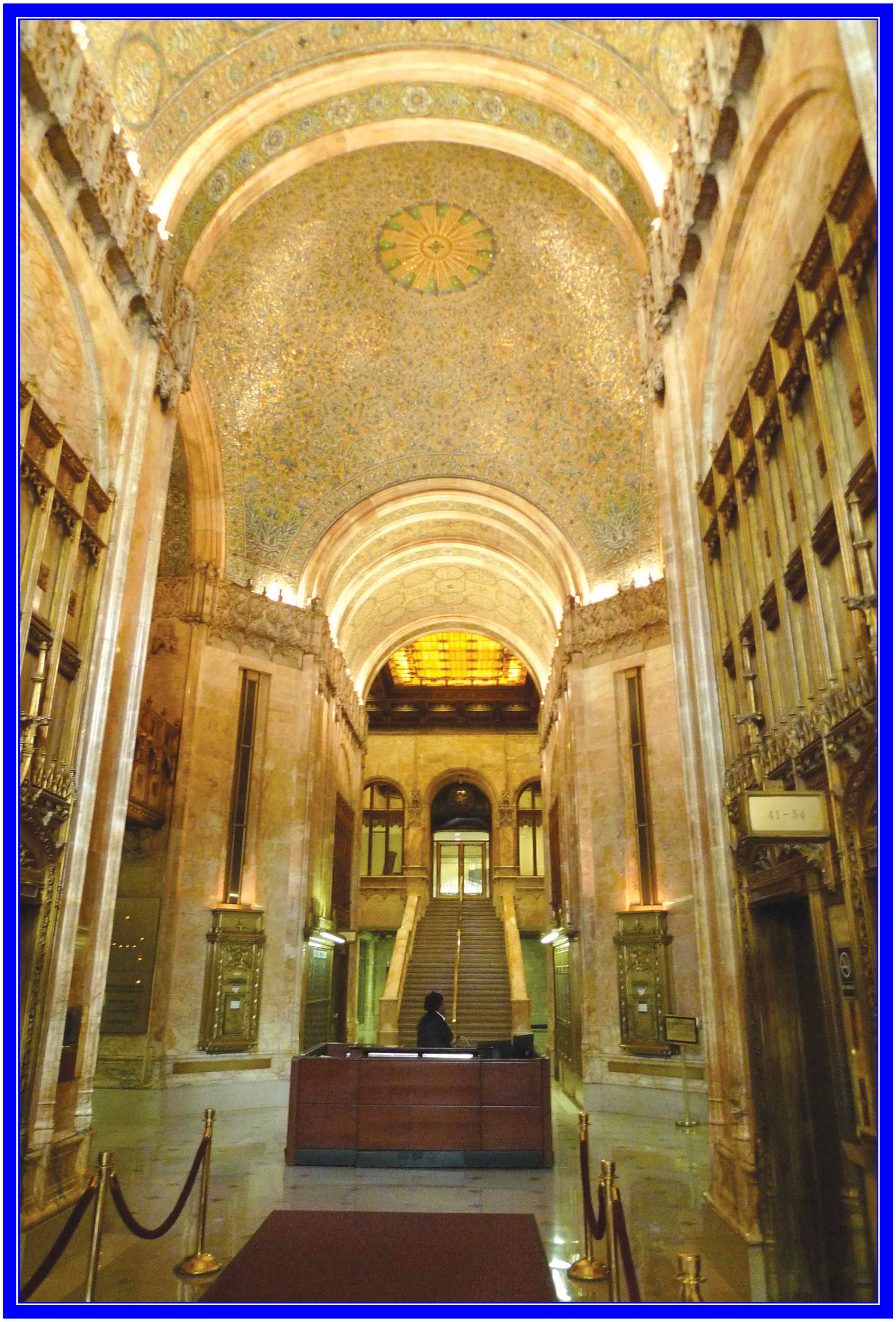
The Galloway, Lancashire type, coal-fired steam boilers

WOOLWORTH BUILDING, NEW YORK



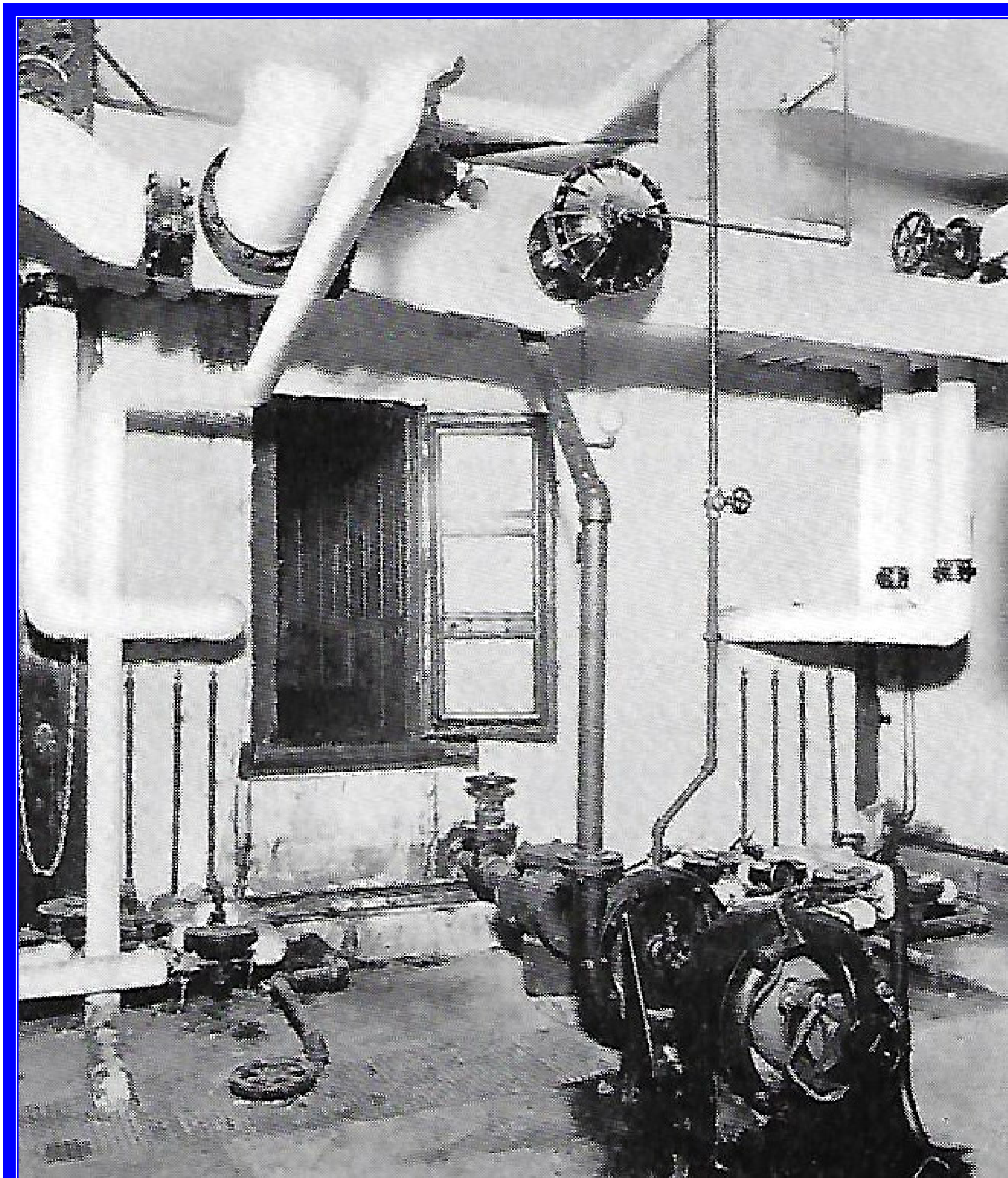
Opened in 1913, the Woolworth Building at 792 ft was the World's tallest until 1930.

WOOLWORTH BUILDING, NEW YORK



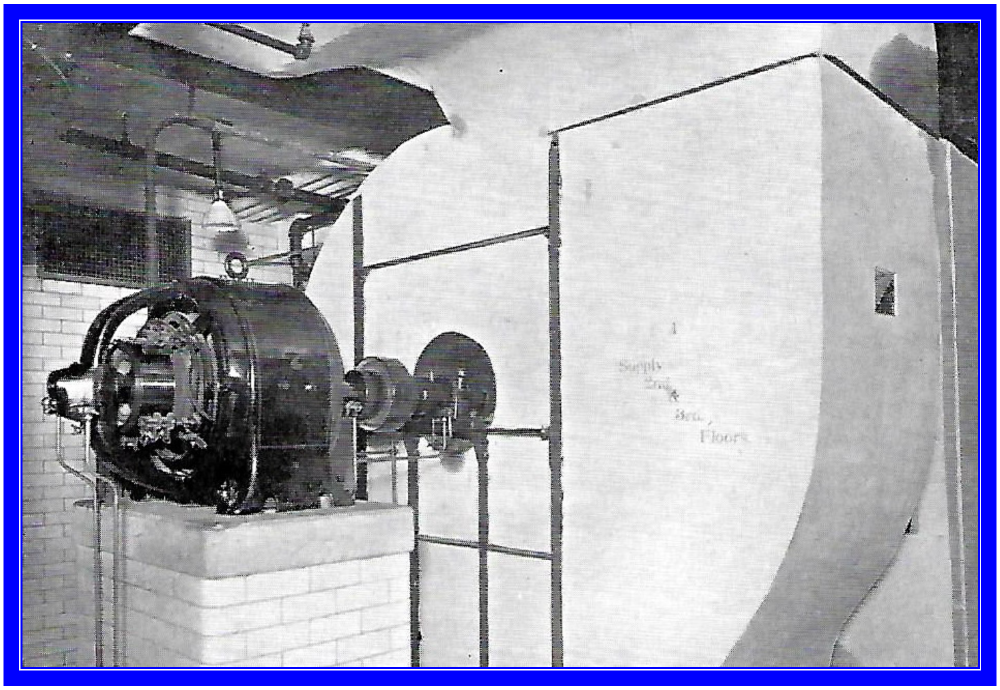
The building was provided with mechanical fresh air ventilation and heating by steam radiators (Dunham system of vacuum steam heating). There were 29 Otis electric elevators.

WOOLWORTH BUILDING, NEW YORK

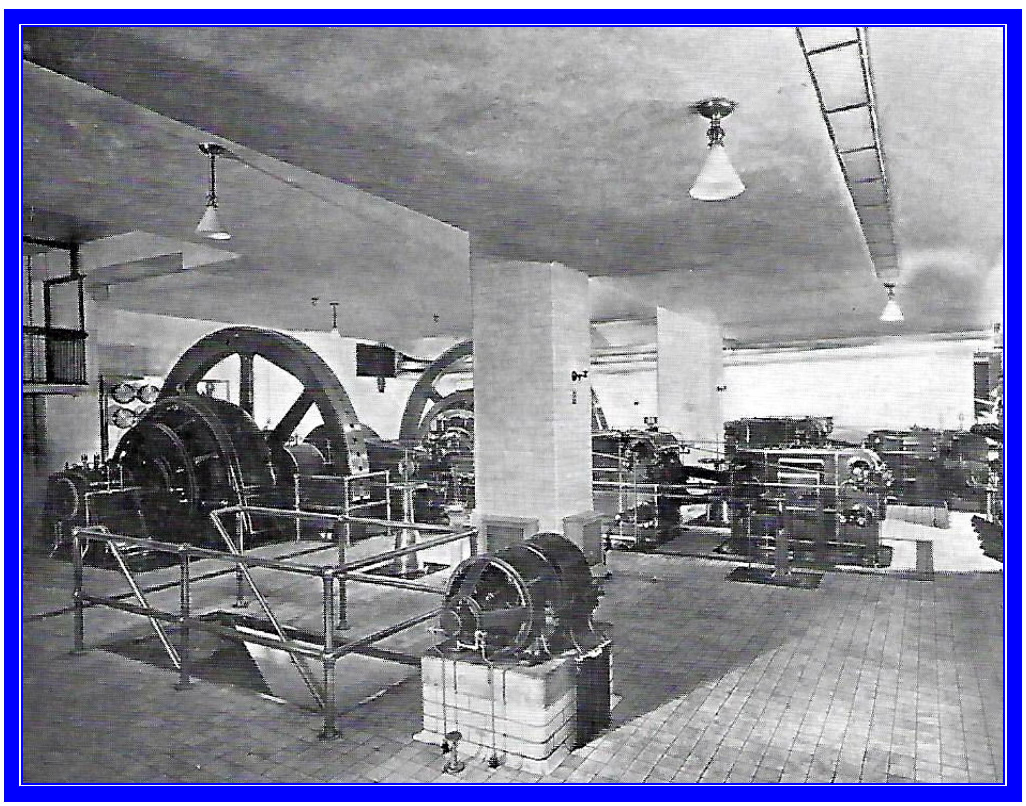


Certain non-office rooms were supplied with an evaporative cooling air-washer system of mechanical ventilation. (Kinealy air washers by Kauffman Heating)

WOOLWORTH BUILDING, NEW YORK

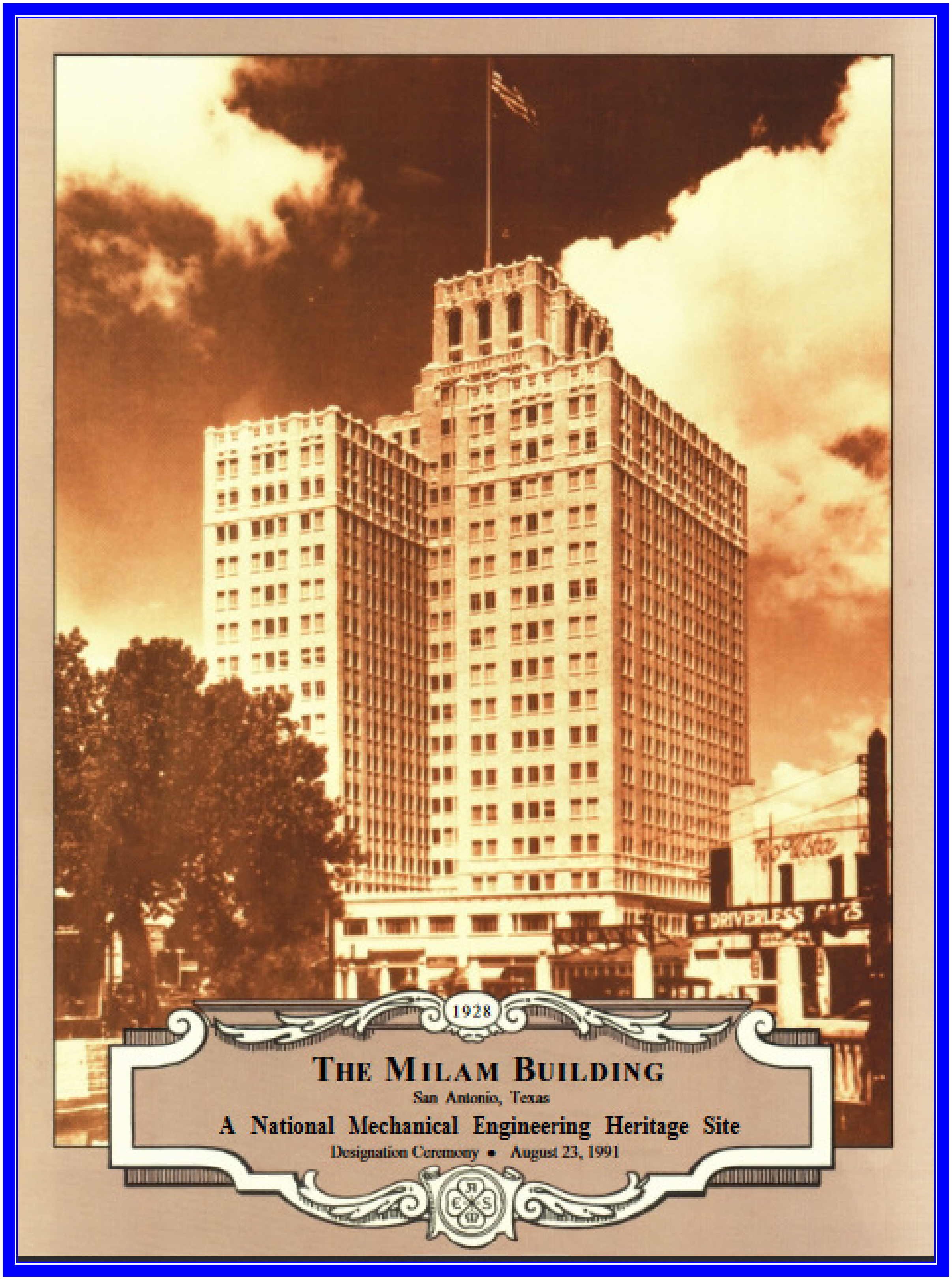


Typical centrifugal/motor set (C&C electric motor)



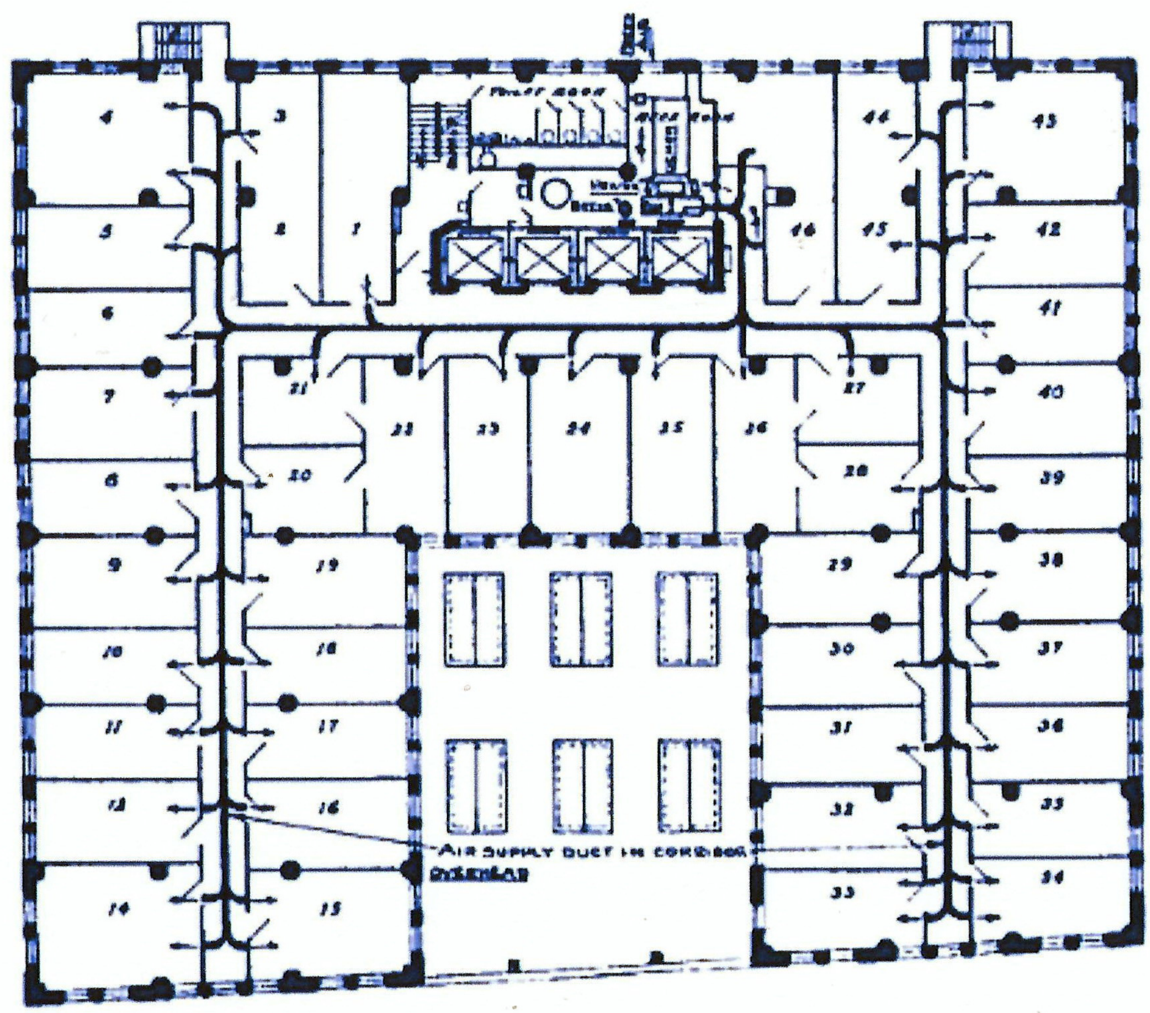
Electrical supply provided by four direct-current generators (1500 kW total) driven by Corliss type non-condensing steam engines.

MILAM BUILDING, SAN ANTONIO



Cover of ASME Book No. HH9106

MILAM BUILDING, SAN ANTONIO



Opened in 1928, the 20-storey Milam Building was 280 ft high and is generally regarded as the first air-conditioned office block in the USA. A number of features were unusual. The refrigeration water-chilling machine had a capacity of 300 TR, obtaining condenser cooling water from the adjacent river, charging a chilled-water storage tank overnight then using chilled sprays to cool and dehumidify the air during the following day. Generally, one air handling unit served two floors except the basement, cafeteria, ground and 17th floors each having their own unit. The four tower floors also had their own unit. On the main office floors, supply air ducts were housed in a false ceiling bulkhead with side-wall outlets. Return air was taken back to the fan room via transfer grilles and along corridors. The installation was by Carrier. Modern analysis would suggest that, bearing in mind the San Antonio summer climate, the system only provided partial air conditioning which may explain the provision of opening windows.

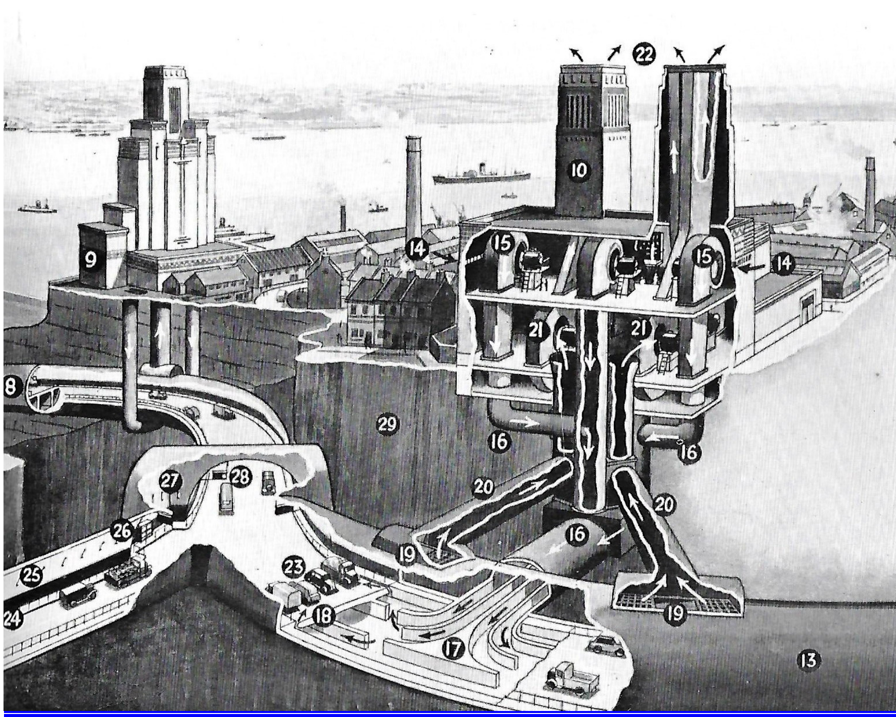
LOUISIANA STATE CAPITOL

The 34-storey Louisiana State Capitol building constructed in Baton Rouge in 1931 and at 450 ft tall, is its highest building. Bearing in mind the climate, it is surprising that it was not air conditioned but relied on natural ventilation by outside air. It was considered that the best use for mechanical refrigeration would be to provide the building's occupants with copious supplies of chilled drinking water, achieved by installing an extensive ice-water drinking fountain system. However, three internal areas were belatedly air conditioned using chilled water taken from the drinking water system. Hence water that had circulated through air-cooling coils was apparently used for drinking.

MERSEY QUEENSWAY TUNNEL

KEY

1. Main entrance at Old Haymarket, Liverpool.
2. Subsidiary entrance at New Quay, Liverpool.
3. New Quay ventilating station, Liverpool.
4. North John Street ventilating station, Liverpool.
5. George's Dock ventilating station, Liverpool. This station is the main control centre.
6. River Mersey.
7. Section of Rock river bed. (Sandstone).
8. Section of circular under-river main tunnel, 44 feet in diameter.
9. Woodside ventilating station, Birkenhead.
10. Sidney Street ventilating station, Birkenhead.
11. Taylor Street ventilating station, Birkenhead.
12. Birkenhead—Dock Branch to Rendel Street, 26 feet diameter.

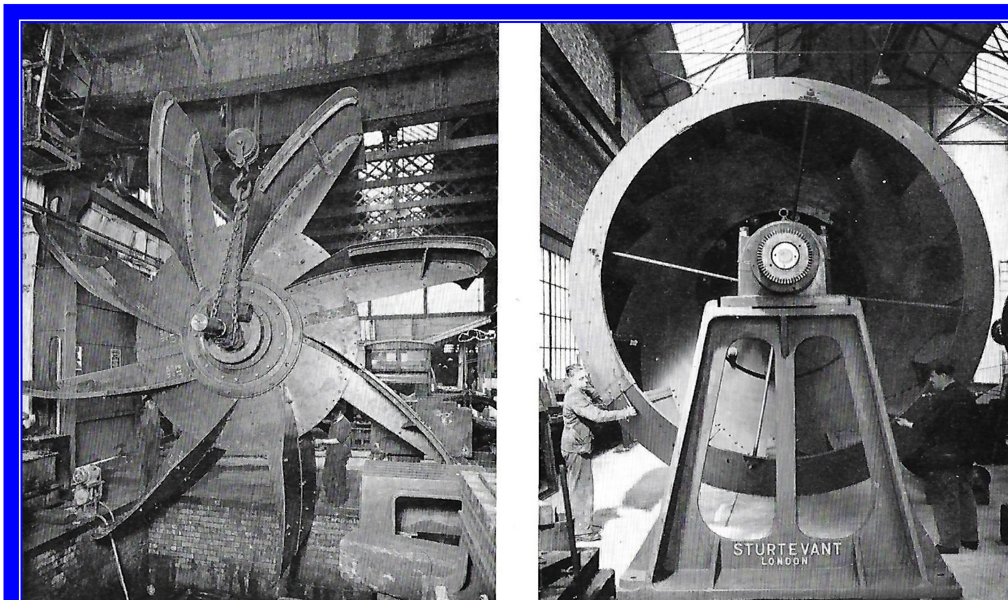


KEY

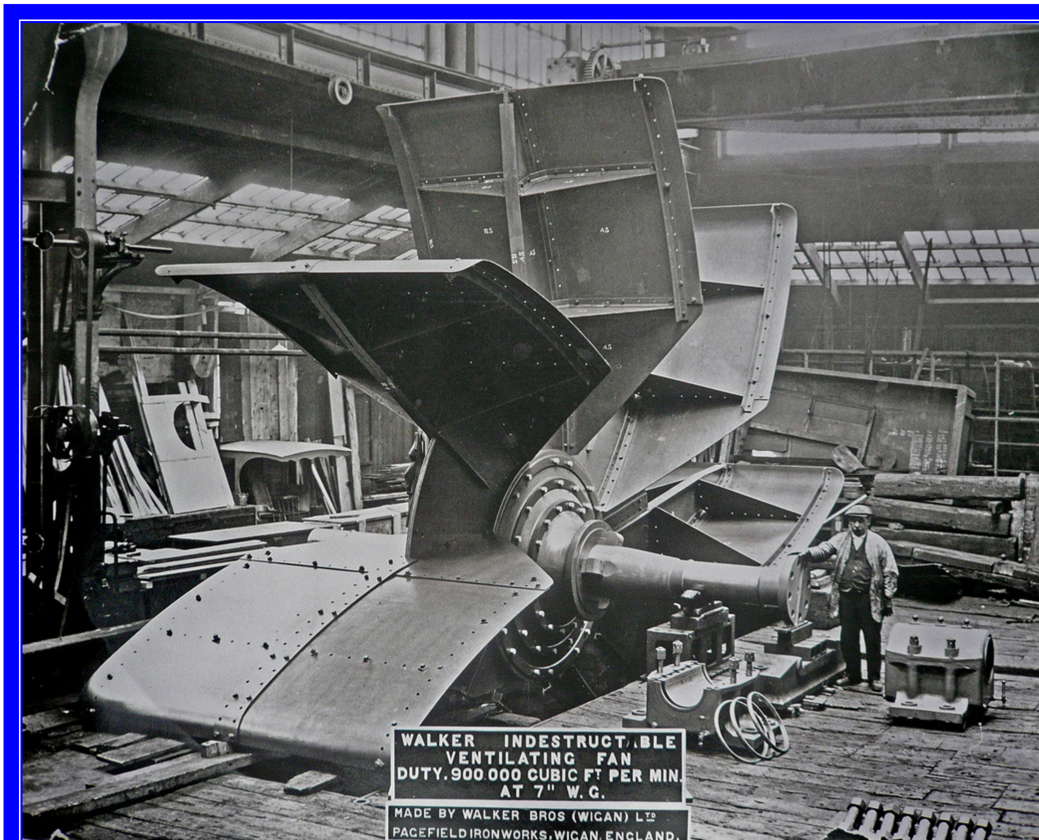
13. Main tunnel to King's Square, Birkenhead.
14. Fresh air intake vents in ventilating station.
15. Fresh air Fans.
16. Fresh air Ducts.
17. Fresh air ducts under roadway.
18. Fresh air entry grills to tunnel.
19. Exhaust air grills in roof.
20. Exhaust air ducts.
21. Exhaust air fans.
22. Exhaust air outlets.
23. Four lines of traffic in 36 feet road.
24. Side walk for maintenance staff only.
25. Electric wall lights.
26. Telephone and Fire Alarm.
27. Birkenhead Junction chamber.
28. Traffic lights.
29. Clay subsoil.

The Tunnel was opened in 1934 with a large system of mechanical ventilation

MERSEY QUEENSWAY TUNNEL

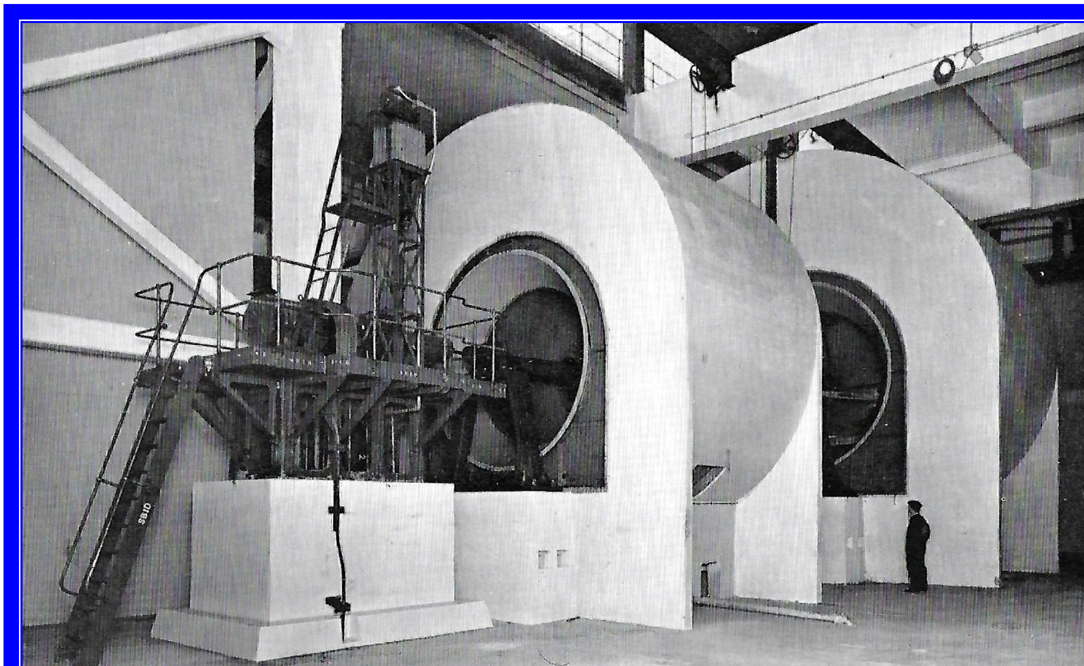


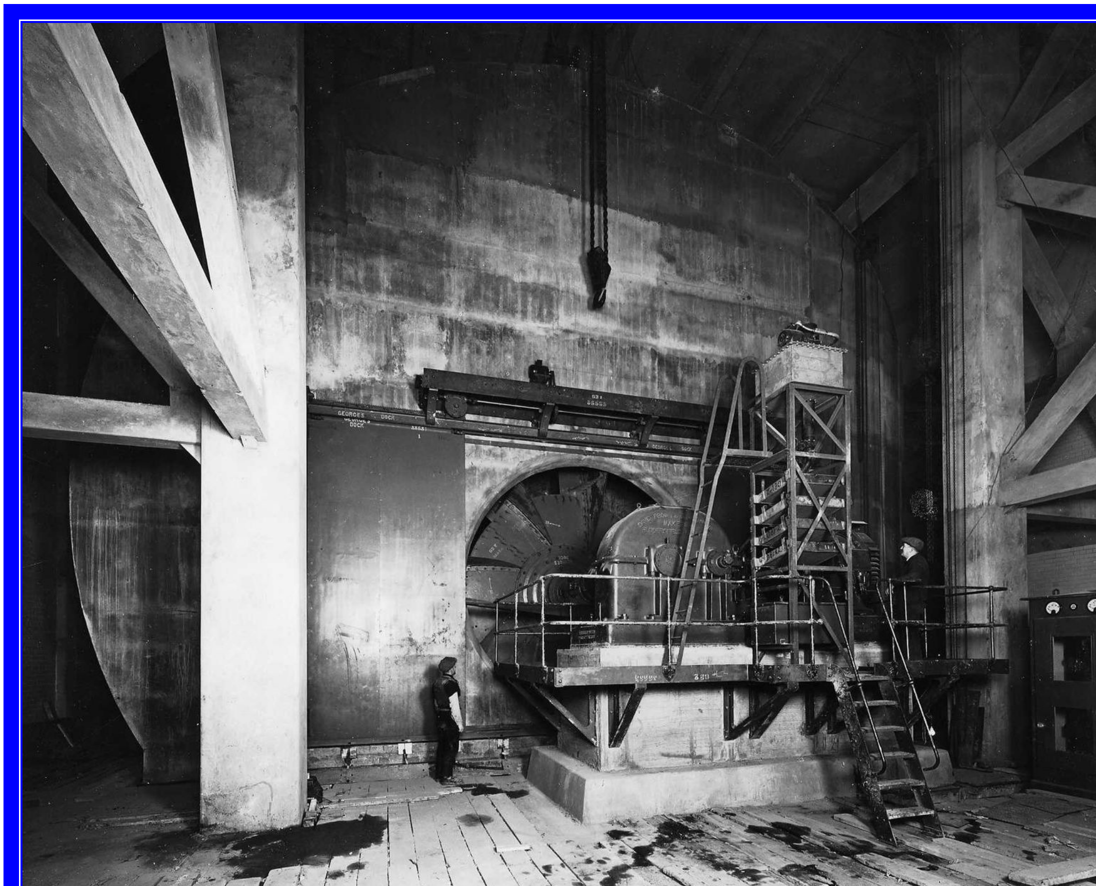
Examples of the Walker and Sturtevant ventilating fans



One of the Walker "Indestructible" fan impellers

MERSEY QUEENSWAY TUNNEL





Some of the giant ventilating fan and motor-drive sets

BRABAZON HANGAR, FILTON

Construction of the huge assembly building at Bristol's Filton Aerodrome began in 1946. The heating system for the three bays required 80 steam unit heaters.

Steam was generated by 4 Economic type boilers in an adjacent boilerhouse.

BRABAZON HANGAR, FILTON

The successful maiden flight of the Brabazon airliner took place in 1949. It was designed to fly up to 180 passengers, with a maximum range of 5500 miles, at a cruising speed of 250 mph and at a cruising height of 25,000 ft. It was fitted with 8 Bristol Centaurus engines developing a total of 2650 hp.

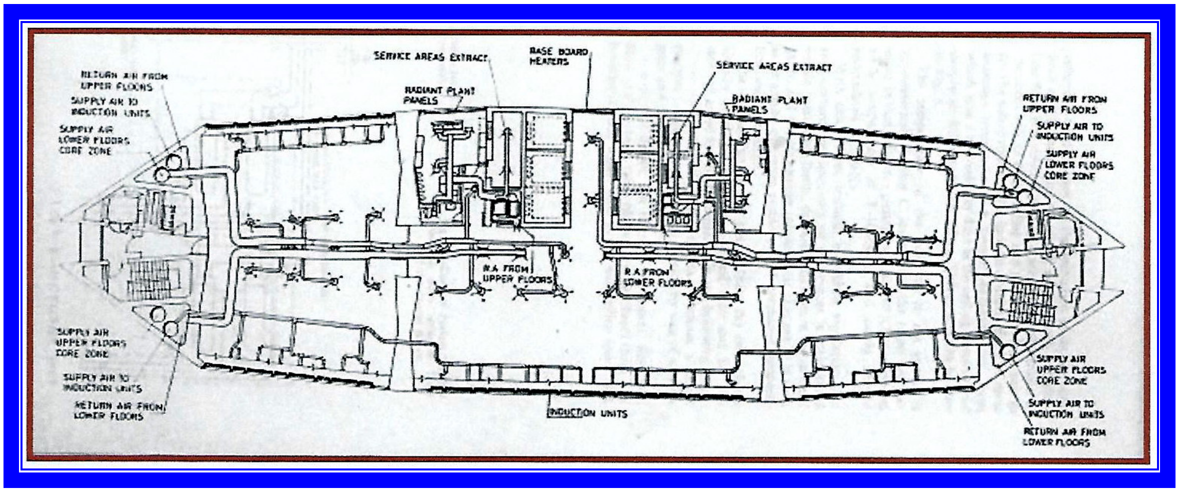
Its other statistics are as follows:
wingspan 230 ft
length 177 ft
height 50 ft
take off weight 130 tons

It was overtaken by the development of more suitable airliners, notably the Lockheed Constellation (which first flew in 1943) and the Boeing Stratocruiser (in 1947), followed by the promising jet-engined De Haviland Comet (1951). The two major British airlines, BOAC and BEA, never expressed any serious interest and the prototype Brabazon was broken up in October 1953. However, the huge structure, the Brabazon Hangar where the supersonic Concorde was also built (and is no more) still exists, though there is talk of it being converted into an "entertainment complex."

CENTRO PIRELLI, MILAN

The Pirelli Tower

CENTRO PIRELLI, MILAN



When opened in 1959 the Pirelli Skyscraper was one of the earliest and largest air conditioning office buildings in Europe at 445 feet high. The air conditioning employed some 1500 induction units for external areas of office accommodation with a single duct all-air system for core areas. The basement and lower three floors, housing conference rooms and a computer room, were air conditioned by a high velocity dual-duct system. The basement cooling plant was equipped with two centrifugal water chillers (893 TR total) operating in conjunction with a well-water system having both intake and discharge wells. The well, yielding water at 15 degC, being used for precooling the conditioned air, providing about 18% of the peak cooling load and then serving as condenser cooling water.

Modern view of the Pirelli Tower (2nd from right) with the Alps as a background

SHELL CENTRE, LONDON

Built between 1957 and 1962 Shell Centre, situated on the south bank of the River Thames, comprised a number of office buildings: Upstream a 26-storey tower (351 ft high) with an adjoining U-shaped 10-storey block; Downstream a 10-storey building with a 3-storey wing. The air conditioning systems considered included double-duct, induction and fan-coil types, but the choice was a chilled water radiant-panel ceiling system combined with ducted fresh air ventilation. This used both outer and inner ceiling panel grids with some 3000 sets of local controls and a central mimic control board to operate and monitor some 200 mechanical plants. Refrigeration was provided by three centrifugal water chillers (2700 TR total). Due to problems in siting cooling towers, river water was used for condenser cooling. Redevelopment has seen the disappearance of the Downstream offices with eventual plans to leave only an altered Upstream tower in place as part of a major mixed-use development.

BOSTON CITY HALL

Opened in 1968, the Boston City Hall had an early Variable Air Volume air conditioning system

WORLD TRADE CENTRE, NEW YORK

The Twin Towers

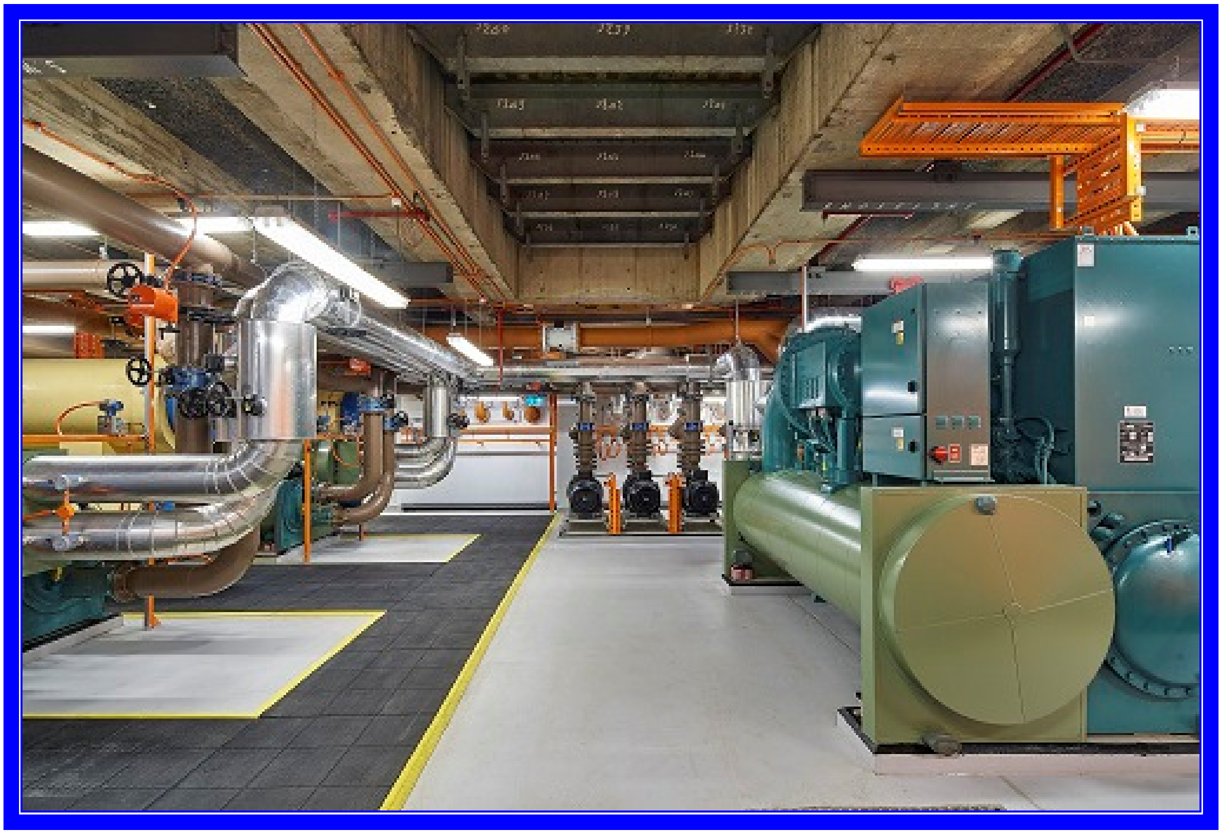
WORLD TRADE CENTRE, NEW YORK

The sub-basement plant room housing the refrigeration plant

When opened in 1973, the World Trade Centre was a six-building complex with the famous Twin Towers standing 1350 feet high, then the tallest in the world (until surpassed by the Sears Tower in Chicago). But both Twin Towers no longer exist, having been destroyed in the infamous 9/11 terrorist attack.

The central air conditioning plant had mechanical equipment rooms on floors 7, 41, 75 and 108. The system had some 30,000 under the windows induction units with 1000 fans circulating over 10 million cfm and employing 250 steam humidifiers, 300 pumps and 100 heat exchangers. The central refrigerating plant employed seven centrifugal chillers with a total cooling capacity of 49,000 TR. Each 7,000 TR chiller was driven by a 13.8 kV water-cooled synchronous motor rated at 5,200 kW, and used 10,000 kg of refrigerant R22. Water for condensing was taken at the rate of 80,000 US gpm from the Hudson River. Steam was supplied from a plant on New York's East River.

SYDNEY OPERA HOUSE



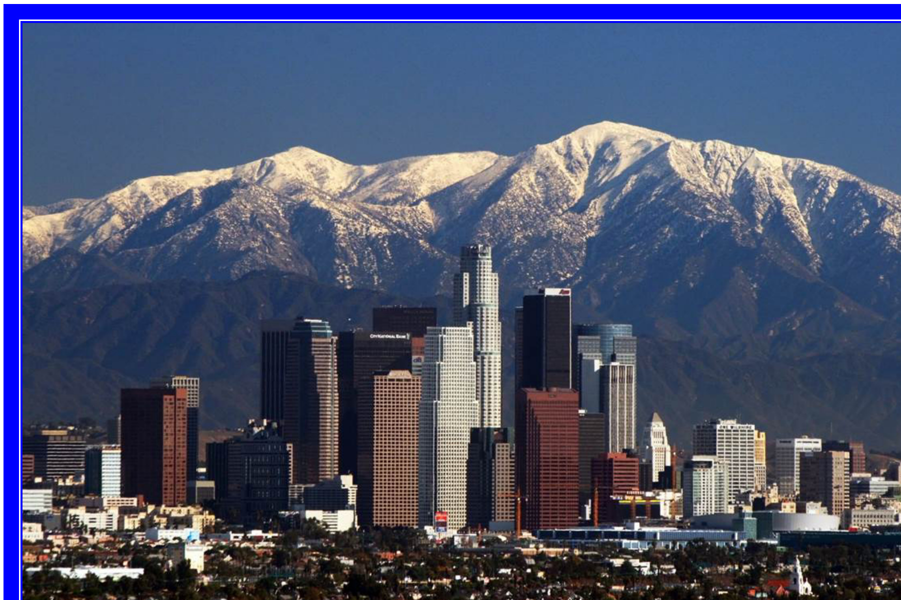
To avoid cooling towers and chimney stacks, the Opera House, opened in 1973, has three centrifugal chillers operating in heat pump mode using the water in the harbour as the heat source/sink. Conditioned air is supplied by 120 fans, to 3000 outlets through 22 miles of ducting.

SEARS TOWER, CHICAGO

When opened in 1974, the 110-storey Sears Tower (now the Willis Tower) reached a height of 1450 feet, then the tallest in the world. It was air conditioned with an all-electric system having a refrigeration capacity of 17,000 TR. It was equipped with 103 lifts including double deck express cars.

UNITED CALIFORNIA BANK, LA

At the time of construction in 1974, the 62-storey Los Angeles United California Bank (later the Bank of America) at 850 feet high, was the USA's tallest building west of Chicago. The air conditioning consisted of an all-electric, all-air system employing dual duct for exterior zones and variable air volume for the centre of the building. Fan rooms were situated at floors 4, 5, 22, 42 and 61, providing 17,600 cfm per floor. The refrigeration consisted of four 910 TR water chillers (3640 TR total) located on the roof. The incoming electrical supply at 34.5 kV was transformed in the basement to 12.7 kV for distribution to floors 22, 42 & 61 to feed 480/270 V and 208/120 V systems.



Now just one of many Los Angeles skyscrapers, some taller

WASHINGTON RAPID TRANSIT SYSTEM

When opened in 1970, the Washington Metro was designed to have 100 miles of track with 87 stations, 53 of them underground. All the underground stations require air conditioning in summer. In winter, the piston-action airflow of the trains and the heat which they generate was considered generally sufficient for heating and ventilation.

Inside a typical underground station, heat is generated by train traction power, train air conditioning (heat rejection), passengers and by station lighting and equipment. A supply of tunnel air is also introduced into the station by train piston action, which either adds to or reduces the heat load on the station. Air is exhausted from the station by gravity flow through roof vents and by an underplatform exhaust system of some 60,000 cfm at track level which removes some of the dynamic braking heat produced by the trains.

A typical station has four mechanical equipment rooms, each with a 100% recirculation air handling unit having cooling coil and return air bypass served by a 340 TR centrifugal chiller/cooling tower combination (1360 TR for the four equipment room typical station).

Tunnel sections have powered ventilation fans located about mid-way between two stations with each fan shaft equipped with two or more axial fans of about 60,000 cfm, designed to operate automatically if the tunnel temperature rises above a predetermined level. These fans may also be used to draw smoke and fumes away from tunnels or stations in case of fire or other emergency.

PENNZOIL PLACE, HOUSTON

Twin towers with a connecting podium

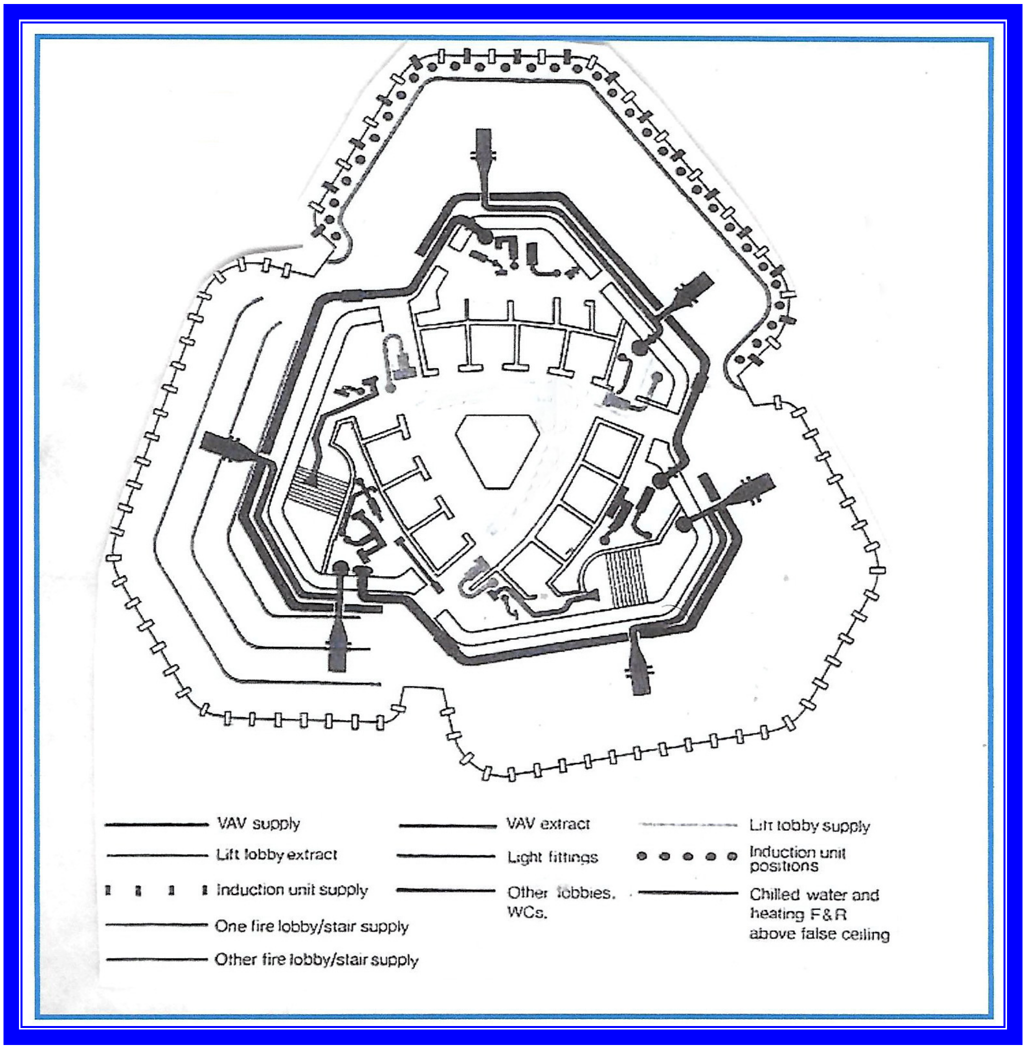
PENNZOIL PLACE, HOUSTON

Unusually, the boiler flue stacks discharged at street level next to the atrium

Pennzoil Place is a 36-storey office block, nearly 400 ft high, comprising twin towers linked at ground level by an atrium lobby. The tower's air conditioning system is dual-duct type with two air plants per floor while the atrium is served by 16 air handling units. There is a central fresh air plant on the roof. Refrigeration is provided by four 1600 TR chillers (6400 TR total) linked to a single five-cell roof top cooling tower having a 25 MW heat rejection capacity. The boiler plant consists of two 5 MW, MTHW boilers, with nitrogen pressurisation, generating heating hot water at 120 degC primary flow for heat exchangers producing secondary water at 82 degC. The electrical system had aluminium bus-duct risers (not the then usual copper type) in each tower serving 23,000 lights in each.

NATWEST TOWER, LONDON

NATWEST TOWER, LONDON



The original air conditioning scheme

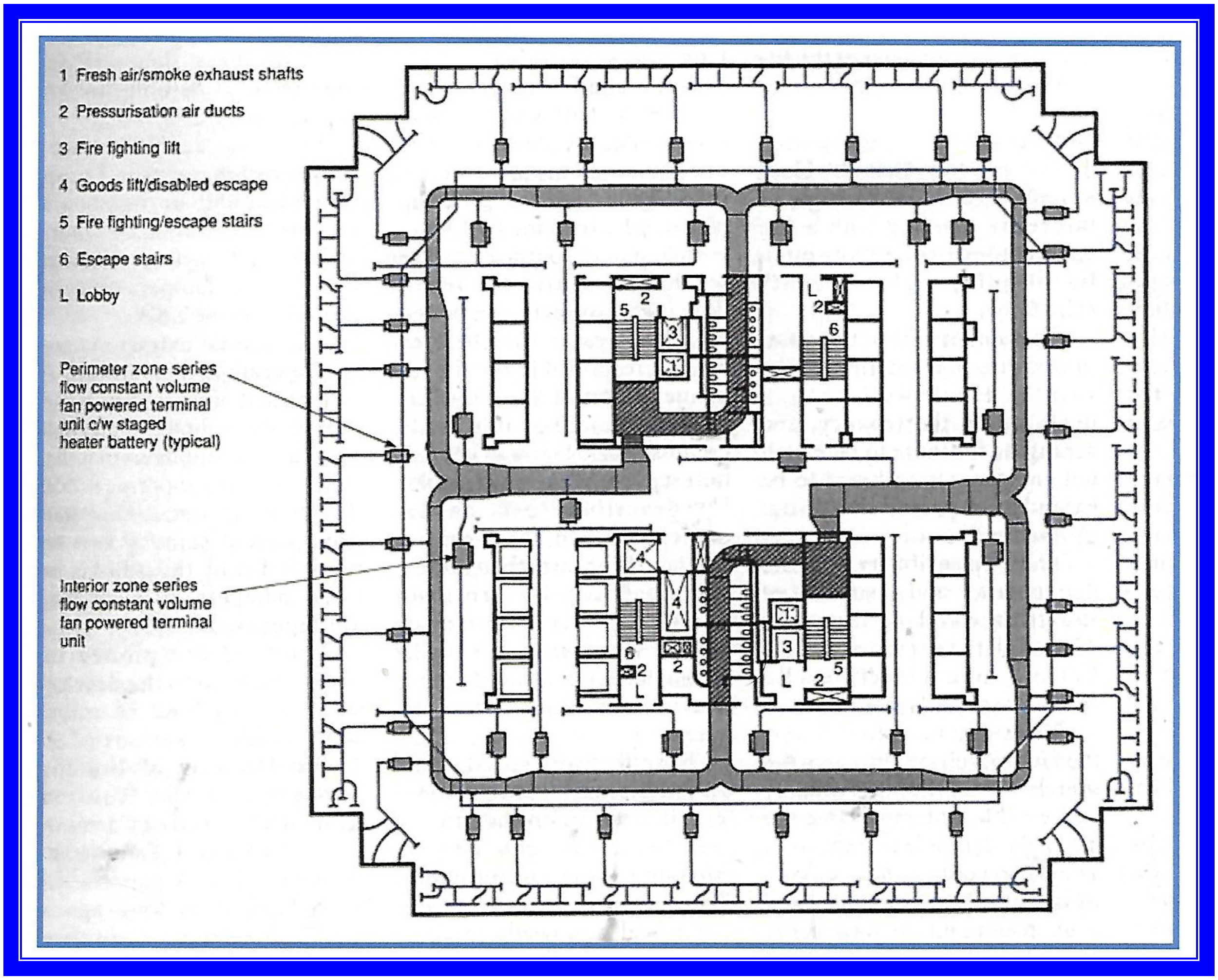
When the 52-storey, 600 ft high, office tower for the National Westminster Bank was completed in 1981 it took the title of the tallest building in the UK. The air conditioning was of the perimeter 4-pipe induction type with secondary induced air bypass control, the water flow running "wild" while a VAV system served the office core. The 3000 induction units were served from three intermediate floor plant rooms. The refrigeration plant was four 1000 TR chillers (one standby) catering for a 3000 TR maximum load and working with roof-mounted cooling towers and with boilers located in the basement.

After the cladding of the building was badly damaged in April 1993 by the blast from a nearby terrorist bomb, it was decided to embark upon a major refurbishment of the tower. This new system was designed to cope with a major increase in heat gains from office equipment and employed 2300 ceiling mounted fan-coil units, refurbished air handling plant rooms, and three replacement centrifugal chillers (now running on R134a refrigerant) and replacement cooling towers.

CANARY WHARF TOWER, LONDON

Also known as One Canada Square

CANARY WHARF TOWER, LONDON



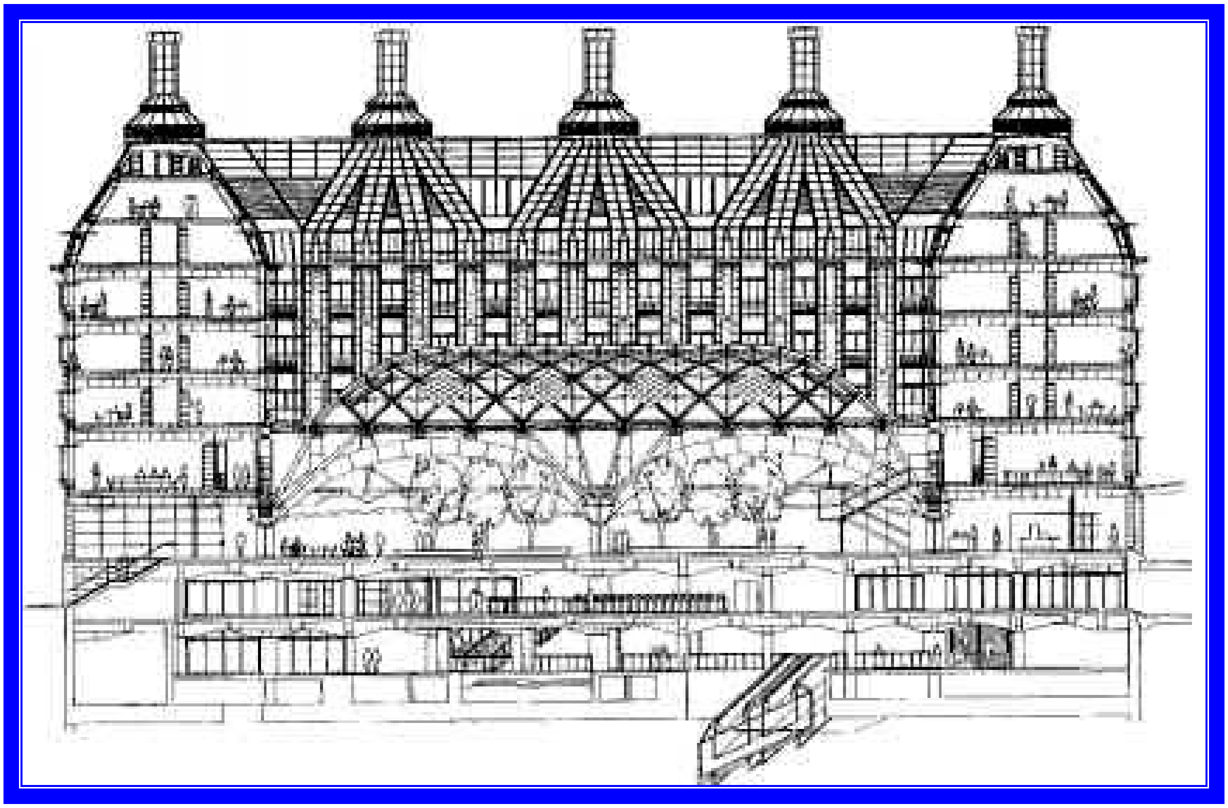
Canary Wharf Tower (One Canada Square) in a rejuvenated area of London's Docklands opened in 1992, a 50-storey tower, 800 ft high, at that time the tallest building in the UK. A conventional approach to the air conditioning uses two air handling units at each office floor level supplied with primary preconditioned air from two central risers. These are fed with fresh air from two plants, one at lobby level serving upwards to the 28th floor, the other 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 units for perimeter and exterior zones, the former being augmented with staged electric heaters. Six 1000 TR chillers (6000 TR total, using refrigerant R11) operate in conjunction with cooling towers on the 50th floor.

PORTCULLIS HOUSE, LONDON

The Members of Parliament Offices, opposite Big Ben

The atrium lobby

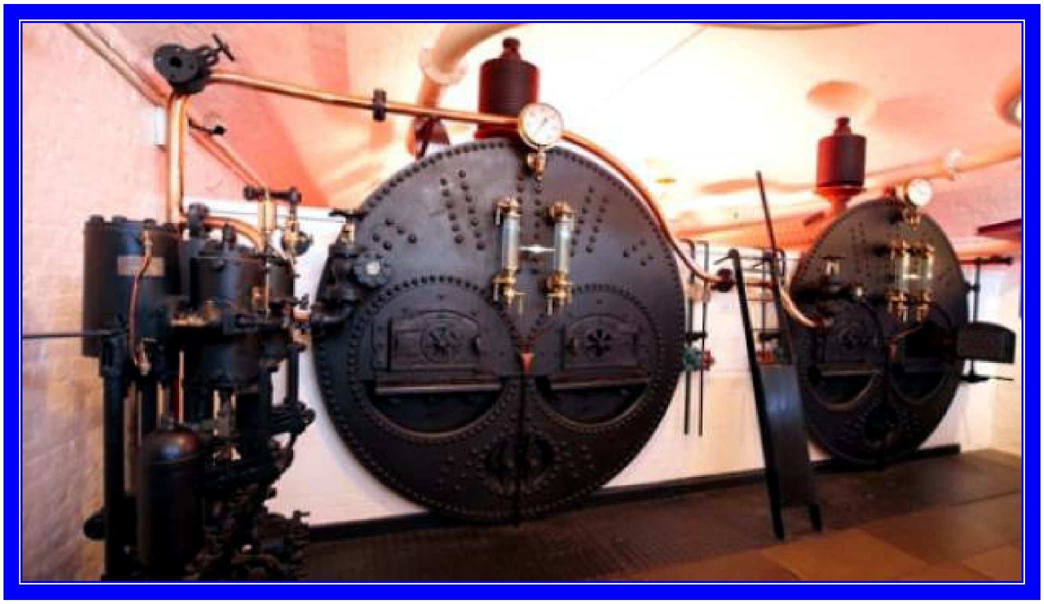
PORTCULLIS HOUSE, LONDON



Portcullis House opened in 2001 providing office accommodation and amenities for MPs, being connected below street level to the Houses of Parliament opposite. It was required that the building should set an example in energy saving and this is reflected in the method of providing heating and cooling. Although often quoted as only having natural ventilation systems, these are assisted by mechanical ventilation where a series of air handling units with water cooling coils are located in plant rooms above the offices. The tall, bronze "chimneys" or turrets which crown the roof ridge line are the terminals of the vertical duct systems through which conditioned fresh air is supplied down the side of the building into the floor void of each office where the occupant has manual control. Return air, taken through the office "light shelves," is passed upwards and through rotary heat wheels in the turrets, which reclaim energy from this air and transmit it to the incoming fresh air. Summer cooling is provided by cold groundwater extracted from two boreholes sunk 450 ft into a chalk aquifer.

TOWER BRIDGE, LONDON

An early photograph showing the Wm. Sugg gas street lamps



Opened in 1895, London's famous Tower Bridge is a combined suspension and bascule bridge arrangement. The original raising mechanism was powered by pressurised water (at 700 psi) in hydraulic accumulators pumped into them by two stationary steam engines, steam being supplied by four Lancashire boilers. In 1974, the operating mechanism was replaced by an electro-hydraulic drive system.