APPENDIX 1

Tabulated summary of extant coal-fired power stations with cooling towers in England, illustrated

Station name	Build date	Consultant architects and engineers	Design interest	Cooling towers and chimneys	Landscape	Additional interest/ considerations
Cottam Nottinghamshire	1964-70	Yorke, Rosenberg & Mardell Balfour Beatty & Co. Ltd	· Good functional distinction: turbine-boiler house "Cottam Amber" colour to blend with local/traditional brickwork; control room block, administration building, office etc.; fully open/exposed 400 kV switch station type.	· 8 in one rectangular array (engineering optimisation) · Single concrete chimney 654 ft (200m) high.	· Mitigating landscaping by Kenneth & Patricia Booth who created a 50 ft-high tree-clad ridge to shield Cottam village from visual mass and noise of the station.	· Office block 'over-wrought and made gratuitously rhetorical' (R. Banham). ·Trent Valley (MC/LC20 Power production heartland).
Didcot 'A' Oxfordshire	1965-70	Frederick Gibberd & Partners C.S. Allott & Son	· Unusual degree of architectural consideration/input; chimney employed as fulcrum around which the towers appear to move and change in number and scale (c.f. West Burton). · Local atmospheric conditions permitted fully open/exposed 400 kV switch station type.	· 6 in two groups of three half a mile apart (triangular formation), standard 375ft height 'one of the most attractive features of the station'. Drakelow 'C' had used same formation, although closer together. · 1 concrete 650 ft-high chimney.	· Sir Frederick Gibberd was appointed as both executive architect and landscape architect· landscape design followed the precepts Colvin promoted (and exampled at Drakelow in 1959), and she admired way he 'eased' the huge cooling towers into an 'inappropriate and resentful setting'.	Like West Burton, extensive use of models, landscape analysis etc to see effect of differing heights and combinations of towers from range of viewpoints Like Fiddlers Ferry, away from coalfields/ Trent Valley MC/LC20 Power production heartland.
Drakelow 'C 'Staffordshire *(demolished 2006)*	1961-63	Frankland Dark (Farmer and Dark)		6 in two groups of three half a mile apart (triangular formation). Two coloured a warm red in order to bring them forward visually, two 'twinned' concrete 600 ft-high chimneys.	Brenda Colvin's landscaping included woodland belts around the edge of the site, detailed landscape treatment for the 'non-operational' space within it & a wildfowl nature reserve on lakes created by gravel extraction for construction purposes.	· Received award under the 'Countryside in 1970' scheme, which applauded Colvin's 'innovative and ecologically sound proposals'.
Drax North Yorkshire	1967-711979-86	Jeff King (Clifford, Tee and Gale) W.S. Atkins & Partners	· Last of Britain's ten "large set philosophy" coal-fired power stations of the 1960s, but market next (and final) leap-forward in generator-unit size (660MW), and infrastructure/ building size in C20; a 'double-station'.	· 12 in two sets of six at either end of the station (circular and diamond formation) - visually striking; standard 375ft height. · Single concrete chimney 850 ft (258m) high (dwarfs BT Tower).	Landscape architect Arnold E. Weddle employed strategic planting of clumps of trees to avoid the vast complex dominating nearby villages.	· Generating capacity of 3,960 megawatts was in 1986 highest of any power station in the United Kingdom and Western Europe. · Not threatened & of different category in many respects
Eggborough, North Yorkshire	1962-67	George Hooper (Sir Percy Thomas and Son) Rendel, Palmer and Tritton	· Parent for Ironbridge 'B'· 'ideal' textbook (engineering) diagrammatic layout with clear relationship between station's buildings, coal delivery by rail 'merry-go-round', and the cooling tower field. · 3 distinct components: extensively glazed turbine hall/boiler house, admin block and enclosed 400kV switch house, all stepping down in height.	· 8 in one rectangular array (engineering optimisation); first employment of larger standard (375 ft x 275 ft). · 1 concrete 650 ft-high chimney.	· Site enclosed by low woodland/hedges designed by Brenda Colvin to provide horizontal balance to verticality of megastructures & harmonise with field pattern/boundaries; unsightly coal store and railway sited low & screened behind trees planted on soil banks. · Part of Gale Common Ash Disposal Scheme, a 50m high hill of waste ash piped from Eggborough and Ferrybridge 'C', landscaped/ terraced by Brenda Colvin who drew inspiration from Maiden Castle hill fort.	· Site inspected by John Piper (RFAC) at an early stage. · Gale Common hill now prominent in an otherwise 'flat monotonous landscape'; CEGB created fish-lake and funded excavation of a medieval moated-farm farm house: 'the venture became a model of how industry might assist archaeological studies, well ahead of the need to develop the actual site'. · Post-privatisation, Gale Common Motopark, an off-road training facility.
Ferrybridge 'C' West Yorkshire	1961-67	Building Design Partnership C.S. Allott & Son	· First power station in country to have 500,000 kW single line turbo-alternator connected to the Grid.	· 8 in one lozenge array, standard 375ft height, cone-toroid type; 3 destroyed in gale 1965 (replaced). · 2 'twinned' concrete 650 ft-high chimneys.	No obvious/significant landscape architecture element.	· Ferrybridge A (1927) and Ferrybridge B power station (1957) both demolished. · Best known for tower collapse & subsequent inquiry/CEGB design changes.

Station name	Build date	Consultant architects and engineers	Design interest	Cooling towers and chimneys	Landscape	Additional interest/ considerations
Fiddlers Ferry Cheshire	1967-71	Gordon Graham (Architects' Design Group)	· 'Almost identical to West Burton'· lacks a 400 Kv switch-house, one of the largest and most defining elements of 1960s 'super-grid' era power stations.	· 8 in two mirrored lozenge arrays flanking station; standard 375ft height. · 1 concrete 650 ft-high chimney.	· Landscaping and tree planting possibly by in-house landscape architects	· Design 'the best of those recently submitted' (RFAC)· Ministry of Power: 'the imposing dynamic bulk' power station should provide 'a suitable termination to the squalid industrial area of Widnes' . With Ratcliffe, heralded increasing CEGB mitigation of environmental/pollution concerns that characterised the 70s more than visual amenity.
Ironbridge 'B' Shropshire	1963-68	Alan Clark (Sir Percy Thomas and Son) Rendel, Palmer and Tritton	· Visual sensitivities of the site meant architects were given greater control over the designs than at Eggborough, its immediate predecessor/'parent'.	· 4 reddy-pink (earth) tinted cone-torroid towers on sweeping curve with forested backdrop, designedly invisible from certain viewpoints.	· Landscape Architect Kenneth Booth created series plateaux/ embankments, planted with trees and shrubs to soften visual impact of the station in the superb, verdant landscape.	· Shortlisted for a RICS/Times conservation award in 1973. Cooling towers particularly credited which 'somehow look right and natural, almost as if they had grown there'. · Immense location/technological context; Ironbridge Gorge WHS, coal-iron-electricity etc.
Ratcliffe Nottinghamshire	1963-67	Godfrey Rossant & J.W. Gebarowicz (Building Design Partnership) C.S. Allott & Sons	· 'Daughter' of Ferrybridge 'C', but higher quality design different treatment of components: 'monumental' concrete and white metal-clad turbine hall/boiler house; extensively smoke-glazed enclosed 400kV switch house; courtyard-plan admin block near entrance.	· 8 in one lozenge array, standard 375ft height.	· Flat farmland so bands of trees (including oak, beech, sycamore, ash. larch, poplar and Scots pine) used to screen site at close quarters but otherwise low-key, perhaps in-house landscaping. ·Trent Valley (MC/LC20 Power production heartland).	· RFAC (and CPRE) 'strongly objected to the use of this site, in view of its attractive surroundings' · Rare example of open-air sculpture used in a 1960s coal-fired power station(The Generators' by Richard Fowler). · Alternative 'angel of the north', at the meeting of the M1, River Soar and Midland main line.
Rugeley 'B' Staffordshire	1964-70	L. K. Watson and H. J. Coates Mott, Hay and Anderson (?)	Turbine house towers over boiler house and verticality accentuated by strip glazing - most 60s power houses low-slung fully open/exposed 400 kV switch station type.	· 4 in one lozenge array, standard 375ft height; 2 coloured charcoal ·Single concrete chimney 600 ft (183m) high	· Mitigating landscaping by Colvin and Moggridge both on and off-site (on National Coal Board's land).	· Overall scheme 'well handled and acceptable'.
West Burton Nottinghamshire	1961-67	Rex Savidge & John Gelsthorpe (Architects' Design Group) Metz and McLellan	· First 2000MW station · First 400 kV substation. · First 'merry-go-round' coal delivery system. · Good compromise between engineering & architectural requirements. · Pioneering use of colour (yellow and black) to soften the visual impact of main components including cooling towers (contrast & nodal points). · RFAC 'favourably impressed'.	· 8 in two sets of four at either end of the station (lozenge and line formation) for architectural effect, greatly improving views of the station from the surrounding country (following Heliodon/ model studies). · 2 concrete 600 ft-high chimneys. · 4 steel 250ft-high chimneys.	· Derek Lovejoy (Derek Lovejoy and Associates) extensive water barrier in lieu of a security fence provided imaginative setting for the station and reflected cooling towers. · The method of approach, and the analytical work undertaken, laid the foundations for a more logical criticism and assessment of visual design problems esp. Zones of Visual Influence (ZVI) techniques still used by Landscape Architects (e.g. Wind Farms). ·Trent Valley (MC/LC20 Power production heartland).	· First English power station, in 1968, to receive a Civic Trust Award: 'an immense engineering work of great style, which far from distracting from the visual scene acts as a magnet for the eye from many parts of the Trent valley and from several miles away'; an 'outstanding contribution to the local scene'. · First attempt to predict, in comprehensive and systematic manner, the visual impact of a power station on its surroundings. · Model studies by Gordon Graham.

Cottam, Nottinghamshire

No image available

Didcot 'A', Oxfordshire

© Historic England 29185_001

Drakelow 'C', Staffordshire *(demolished)*

Drakelow C, Staffordshire, training centre in foreground, Eric De Mare, Historic England AA98/06516

Drax, North Yorkshire

Drax Phase 2 under construction in c.1985 (foreground) with Drax Phase 1 in distance

Eggborough, North Yorkshire

The turbine hall and boiler house tower over the administration block

A model of the completed Gale Common scheme

Ferrybridge 'C', West Yorkshire

Above: Ferrybridge in 1995 © Wayne Cocroft.

Below: Ferrybridge in 2010 ©Historic England 28107_069

Fiddlers Ferry, Cheshire

Fiddlers Ferry in 1995 © Wayne Cocroft

Ironbridge 'B', Shropshire

Above: © Historic England 28747_012

Below: The control room at Ironbridge in 1995 © Wayne Cocroft

Ratcliffe, Nottinghamshire

Above: © Historic England 28668_042

Below: © Historic England 28668_050

Rugeley 'B', Staffordshire

Rugeley ‘B’ in 1995 ©Wayne Cocroft

West Burton, Nottinghamshire

No image available

APPENDIX 2

MINUTES OF THE ROYAL FINE ART COMMISSION ON POWER STATIONS INCLUDED IN APPENDIX 1

(TRANSCRIBED FROM TNA BP 1/11 (1955) to BP 1/19 (1971)

Cottam Power Station

8 May 1963 No. 8053 Cottam Power Station, Nottinghamshire

In 1959 the Commission had objected to the use of this site on the Trent (7 miles from Gainsborough and 10 from Lincoln) for a conventional power station, as inappropriate in an attractive rural area.

The C.E.G.B. had now applied to the Minister of Power for consent to use this site for a 2,000 MW station. The Commission should re-affirm to the Minister its objection to the proposal.

11 September 1963 No. 8222 Cottam, Nottinghamshire

In spite of the Commission's objections the Minister of Power had accepted this proposed site for a Power Station.

8 July 1964 No. 8606 Cottam Power Station

The design for this large coal-fired station on a site already accepted by the commission had been discussed with the consulting architects, engineer and landscape architect and the Architect to the C.E.G.B. On the Examination Committee's recommendation the scheme was accepted. Virtually the whole of the main building would be finished in a warm brown colour. The architects should be told that the Commission assumed that a sample of this colour would be looked at on the site before the final decision was taken.

Didcot Power Station

13 November 1963 No. 8296 Didcot: Proposed Power Station. The Commission had been informed confidentially by the C.E.G.B. that formal application was shortly to be made to the Minister of Power for the use of part of the former Army Ordnance Depot site for a 2000 MW station, probably involving a 650 ft. chimney and eight 375 ft. cooling towers.

The Commission recognised that the site had practical advantages from the point of view of, for example, road access and water supply. But structures of the height proposed would seriously damage important views in the Thames Valley and completely change the character of the whole area; everything possible should be done to persuade the authorities to find an alternative site, which would do less damage to amenities.

11 December 1963 No. 8328 Didcot: Proposed Power Station. This proposal has been discussed with the Chairman and representatives of the Central Electricity Generating Board on 5th December by the Chairman, Lord Esher, Mr. Jellicoe and Mr. Piper.

The Chairman of the Board had emphasised the urgent need for increased production on south-east England. The Didcot site had great practical advantages. If an alternative, such as that tentatively suggested by the Commission near Reading was to be considered, he thought that objection would be raised, similar to those made in the case of Holme Pierrepont, that a large new station should be sited in open country rather than near a built up area. Among other alternatives a site at Burghfield would have insufficient water, and sites nearer Oxford would raise similar difficulties and would moreover be within the Oxford Green Belt.

The Commissioners had felt that if this site had to be used for a power station the main objection was to the height of the cooling towers; if they were reduced from 375 ft. to 200 ft. however, the number would have to be increased from eight to thirty-two, and would require a larger site. Any reduction in the height of the chimney would raise greater difficulties, but this seemed to the Commissioners a little less important.

Sir William Holford said that one of the difficulties inherent in the Act was that it encouraged the siting of stations away from centres of population on grounds of air pollution etc; another was the cost and time required to secure wayleaves for high tension transmission lines through built-up areas. He thought however that the Commission would be failing in its duty were it not to protest against the irreparable damage that would be done to the landscape in this case.

The Commission agreed to inform the C.E.G.B. of its view, already expressed by the Chairman in his letter to the Chairman of the Board that a power station of this size on this site would have a disastrous effect over a wide area and that alternatives should be considered. If in spite of the Commission's objections the scheme was to proceed, consideration should be given to alternative provision for cooling which would substantially reduce the height of the towers.
The proposed siting of a large power station at Didcot raised the broader question of the importance of providing valuable open areas in south-east England having regard to the increase in population expected in this part of the country over the next two decades. The matter should be referred to in the next Report of the Commission.

8 July 1964 No. 8636 Didcot Power Station

The Minister of Power had decided that since the siting of this Station had been accepted by the local authorities concerned, subject to certain assurances given by the C.E.G.B., a local public inquiry was unnecessary and the scheme should proceed.

14 April 1965 No. 8948 Didcot Power Station

Mr. Gibberd presented his design for this station, which had been discussed with him, his associate and representatives of the Consulting Engineers and of the G.E.G.B. The aim had been to minimise the impact of the station on the landscape:

(a) by keeping the cooling towers down to a height of 325 ft. and distributing them in two groups of three (it might be necessary later to add one to each group);
(b) by keeping the main buildings as simple and straight-forward as possible;
(c) by keeping the colour of all structures, including the 25 ft. stack, as neutral as possible;
(d) by planting large groups of trees around the site to screen the buildings from near view-points;
(e) by screening the coal-dumps from near views with an embankment.
The water for the cooling towers would be piped from and to the nearest point of the Thames, but the design for the pump house had not yet been submitted.

13 October 1965 No. 9159 Didcot Power Station: Pump House

At the Commission's request Mr. Gibberd submitted his design for the pump house to be erected on the south bank of the Thames.

The Commission agreed that the matter should be left in the hands of the architect.

13 July 1966 No. 9490 Didcot Power Station

The C.E.G.B. had informed the Commission that, following the collapse of the cooling towers at Ferrybridge Power Station, the Board were proposing to revise the design of the towers at Didcot.
Mr. Gibberd explained that this would mean reverting from the reduced height of 325 ft., proposed by him and accepted by the Commission, to the height of 375 ft. originally suggested by the Board.
The Commission decided to press for the agreed height limit of 325 ft. (Mr. Gibberd would be consulted about the letter).

14 September 1966 No. 9534 Didcot Power Station

In reply to the Commission's protest against the suggested reversion from the agreed height of 325 ft. for the cooling towers to the original 375 ft, the C.E.G.B. had emphasised their wish, since the accident at Ferrybridge, to use only established designs for these towers. The only other alternative night involve an increase from six to eight in the number of shorter towers.

As the Commission had only accepted, with reluctance, the use of this sits on the understanding that the height of the cooling towers was to be limited to 325 ft., as recommended by Mr. Gibberd, it was agreed to publish a statement making clear its position.

14 December 1966 No. 9690 Didcot Power Station

In reply to the Commission's letter of 21st September, the CEGB had stated that the Board were proceeding with the scheme for 375 ft. cooling towers. The Commission would therefore publish the fact that it had only accepted the scheme on the understanding that the height of the cooling towers would be limited to 325 ft.

Drax Power Station (Phase 1)

8 April 1964 No. 8488 Power Station: Drax, Yorks, W.R.

No comment would be made on the proposed use of this site on the river Ouse for a 3000 MW coal-fired station, notified by the C.E.G.B.

13 October 1965 No. 9150 Drax Power Station

The design for this Station had been discussed with the consulting engineer and architect, the landscape consultant and representatives of the C.E.G.B. The Station would be the largest so far built anywhere, extending about a mile in each direction and including an 850 ft. chimney and twelve 400 ft. cooling towers.

9 November 1966 No. 9626 Drax Power Station

In accepting the design for this Station in October, 1965, the Commission had asked to see the detailed proposals for landscaping. A report prepared by Sir. Arnold Waddle had now been submitted. This had been considered by Mr. Jellicoe, and at his suggestion it was agreed that the Commission should commend the scheme.

Eggborough Power Station

12 April 1961 No. 6503 Power Stations, West Riding

The C.E.G.B. had informed the Commission confidentially that application to the Minister of Power had been made for the use of sites at Ferrybridge and Eggborough for coal-fired Stations. These sites had been inspected by Mr. Piper and accepted by the Commission.

12 July 1961 No. 7107 Eggborough Power Station

The design for this Station submitted at the request of the C.E.G.B. had been discussed by the Technical Committee with the Architect and Engineer.

It was agreed to accept the scheme.

9 May 1962 No. 7528 Eggborough Power Station

The architects, Sir Percy Thomas & Son, had asked whether the Commission would wish to comment on changes made in the design, including the substitution of one large chimney for two smaller ones, the division of the building into two main units instead of three and the cladding of the coal tower to match the main building. In the light of the photographs supplied, the architects had been informed that a further submission to the Commission was unnecessary.

Ferrybridge 'C' Power Station

12 April 1961 No. 6503 Power Stations, West Riding. The C.E.G.B. had informed the Commission confidentially that application to the Minister of Power had been made for the use of sites at Ferrybridge and Eggborough for coal-fired Stations. These sites had been inspected by Mr. Piper and accepted by the Commission.

12 July 1961 No. 7108 Ferrybridge 'C' Power Station

The design for this extension submitted at the request of the C.E.G.B. had been discussed with the Architects by the Technical Committee.
It was agreed to accept it. The Architects had asked for the Commission's views on the "twinning" of the chimneys, but the Commission felt that this should be left to technical investigation by the Board.

Fiddlers Ferry Power Station

13 November 1963 No. 8280 Fiddlers Ferry Power Station. The design for this station was considered the best of those recently submitted and was accepted. The architect should be informed however that some Members had doubted whether the proposed yellow bands on some of the cooling towers would look satisfactory.

Grain Power Station

8 June No. 9468 Power Stations. The C.E.G.B. had informed the Commission of their intentions to site an oil-fired power station alongside the refinery on the Isle of Grain and a nuclear power station near the south of the Tees at Seaton Carew. No comment would be made on these locations.

Ironbridge 'B' Power Station

12 September 1962 No. 7683 Power Stations. The C.E.G.B. had notified the Commission of the propsed erection of a second power station at Aberthaw, west of Cardiff, a new one at Cuerdley near Widnes and a second one at Ironbridge, over a mile from the bridge. No comment would be made on the sites.

10 July 1963 No. 8142 Ironbridge 'B' Power Station

The views of the Commission had been sought by the C.E.G.B. on a proposed new power station to replace the existing one, and the scheme had been discussed with the architect by the Technical Committee.

The Commission thought that a station of the size now proposed, which included a chimney 650 ft. high and four cooling towers 375 ft. high was quite unacceptable on this site and that the Board should be asked even at this late stage to give further consideration to the whole proposal. If the scheme must proceed, the design of the buildings might be improved by incorporating the gas turbine flue in the main chimney stack.

Note It was stated at the Meeting that the Commission had not previously been notified of the proposed use of the site. This turns out to be incorrect: the circumstances which led to the Commission being misinformed are set out in a separate note.

While this weakens the Commission's position, a letter has been sent by the Chairman's direction on the lines of the second paragraph of the above Minute.

11 September 1963 No. 8176 Ironbridge 'B' Power Station

The C.E.G.B. had stated that the re-siting of this Station would be impracticable; the scheme had been accepted after careful consideration by the County Council and by M.H.L.G., and there had been "virtually no objection from other quarters"; consent had been given by the Ministry of Power in 1962 and preliminary work had started. There were technical difficulties about incorporating the gas turbine flue in the main stack, as recommended by the Commission.

Kingsnorth Power Station

13 June 1962 No. 7569 Kingsnorth Power Station. The C.E.G.B. were proposing to use this site north of the Medway Estuary for a new coal and oil fired station. The Committee recommended that no comment be made on the site; the Commission would be consulted in due course on the design of the Station.

13 November 1963 No. 8279 Kingsnorth Power Station. The design for this station on the Medway Estuary was accepted, subject to the chimney being finished in a less conspicuous colour, and the landscaping being treated on a broader basis.

14 July 1965 No. 9092 Kingsnorth Power Station. The C.E.G.B. has asked whether the Commission would accept the substitution of the dark grey for mid dark blue s the colour for part of the cladding of the Boiler House and Turbine Hall. They should be informed that the change was acceptable to the Commission.

Ratcliffe Power Station

11 July 1962 No. 7628 Ratcliffe on-Soar Power Station. The C.E.G.B. was seeking approval of the Minister of Power to the use of this site, the County Council having withdrawn their earlier objections in view of the technical advantages put forward by the Board. The Commission and the C.P.R.E. strongly objected to the use of this site, in view of its attractive surroundings. In their view a power station here would be even more damaging than at Holme Pierrepoint, where, following a local public inquiry, the Minister had refused consent.

It was understood that there was some local opposition on the County Council and among the smaller authorities and that formal objections might be made. The Ministers of Power and of Housing & Local Government would be informed of the Commission's continued objection to the use of this site.

11 September 1963 No. 8221 Ratcliffe-on-Soar Power Station, Nottinghamshire

In spite of the Commission's objections the Minister of Power had accepted this proposed site for a Power Station.

13 November 1963 No. 8281 Ratcliffe on-Soar Power Station

The design for this station was based on that for Ferrybridge 'C', accepted in 1961, but the Commission felt that it was not so well suited to the character of this rural site. The scheme should be further considered, to bring it into better relation with the site. In this connection the C.E.G.B. should be reminded of the Commission's objections to the use of the site.

11 December 1963 No. 8324 Ratcliffe-on-Soar Power Station

Following receipt of a letter from the Central Electricity Generating Board the Commission's objections to this scheme had been discussed informally by the Chairman and some members of the Commission with the Chairman and representatives of the Board on 5th December. The scheme had been further discussed by Examination Committee B with the Architect to the Board and representatives of the consulting engineers, architects and landscape architects. It was made clear that the design for Ferrybridge 'C' had been modified in layout and in the colour of finishes in order to adapt it to the site, and that the proposed landacape treatment would go far to screen the coal dump from public view.

In the light of these discussions it was agreed to confirm the Commission's regret that this site was to be used, and to make no further comment.

9 November 1966 No. 9631 Ratcliffe on-Soar: Ash Disposal

The C.E.G.B. had now submitted a revised scheme for ash disposal, which included landscape proposals extending over 30 years. The Board should be informed that the Commission had no comment.

Rugeley 'B' Power Station

9 January 1957 No. 4718 Rugeley Power Station. The siting of this Station had been settled before the new procedure for consultation with the Commission had been agreed. If there were local objections the scheme would be further considered at the next Meeting, otherwise the architects should be asked to reconsider the elevations of some of the ancillary buildings.

13 February 1957 No. 4764 Rugeley Power Station. The Commission was doubtful about the siting, but no further action could usefully be taken. The design had been improved in detail.

10 September 1958 No. 5487 Rugeley Power Station: Cooling Towers

The Central Electricity Generating Board was proposing to experiment at Rugeley with a new type of dry cooling tower, which, if successful, would enable some coal-fired Stations to be sited nearer industrial areas. The towers would be wider than the existing type and more widely spaced, but it was not clear whether a smaller number would be needed, and the question should be taken up with the Board.

The Commission agreed to raise no objection to the propsed experiment at Rugeley.

13 November 1963 No. 8282 Rugeley Power Station

Since the Examination Committee had met, the Commission had been informed confidentially of the proposed erection of a second station at Rugeley. It was agreed not to comment on the siting of this station. The Commission would be consulted on the design in due course.

10 March 1965 No. 8909 Rugeley "B" Power Station

The duplication of the existing power station had been discussed with the architects, the landscape architect, the consulting engineer and the Project Engineer and Architect of the C.E.G.B.

The C.E.G.B. had been informed that the Commission considered the scheme to have been well handled and acceptable.

The success of the landscaping would depend to some extent on planting beyond the site, on land by the Coal Board. The Commission would support the efforts of the C.E.G.B. in obtaining the collaboration of the Coal Board at this point.

West Burton Power Station

11 May 1960 No. 6503 East Midlands: Sites for Power Stations. On the recommendation of Mr. Piper who had inspected five sites in Nottinghamshire with the Deputy Secretary (Mr. B.W. Watkin) on 3rd May, it was agreed to inform the C.E.G.B. that, although the Commission had some sympathy with the views of Nottinghamshire County Council it would not oppose the use of the site at Holme Pierrepont, nor at Market Warsop, but that it considered those at Ratcliffe-on-Soar, West Burton and Cottam extremely damaging to public amenity. The Commission would deplore the erection of Power Stations in such completely unspoilt rural areas.

12 April 1961 No. 6503 Power Stations, West Riding

The C.E.G.B. had informed the Commission confidentially that application to the Minister of Power had been made for the use of sites at Ferrybridge and Eggborough for coal-fired Stations. These sites had been inspected by Mr. Piper and accepted by the Commission.

10 May 1961 No. 7020 West Burton Power Station

The design for this station, to be erected on a site already accepted by the Commission, had been discussed with the architects by the Technical Committee.

The Commission was favourably impressed with the way in which the scheme had been tackled and decided to support it in its general lines, including the suggested variation in colour. A more developed design, including the actual colours proposed, should be seen at a later date.

9 May 1962 No. 7020 West Burton Power Station A more developed design for this station had been discussed with the architects and Sir William Holford by the Technical Committee. This showed five of the eight cooling towers finished in natural concrete, two in the southern group in black and one in the northern group in a fairly strong yellow. The same yellow was proposed for the upper part of the north and south walls of the Switch House, these walls being some 400 ft. long and 75 ft. high.

The Commission confirmed its acceptance of some variation in colour for the cooling towers but was not convinced that the emphasis it was proposed to give one of them by the use of yellow, was justified. If however the C.E.G.B. wished to accept this proposal as an experiment the Commission would not object. No comment was made on the proposed treatment of the Switch House.

12 September 1962 No. 7704 West Burton Power Station

The C.E.G.B. had now decided to proceed with the scheme seen by the Commission in May 1962.

APPENDIX 3

Supplementary research on England's surviving post-war oil-fired power stations, 1945-1980

Supplementary research on England's surviving post-war oil-fired power stations, 1945-1980

Jonathan Clarke, M.Soc.Sci
July 2014

1. The history of oil-fired power stations

Large oil-fired power stations are an entirely post-war phenomenon, whose origins lie in the controversial decision to replace London's bomb-damaged Bankside Power Station (*c*1891), opposite St Paul's Cathedral. Because of the desperate need for electricity, Lewis Silkin as Minister of Town and Country Planning ruled against the LCC's plans to relocate industry to peripheral zones in favour of a new central station sited near demand load. That it burned oil rather than coal was key to the ruling, since it would not require unsightly coal and ash-handling facilities, allowing it to be set back from the river. Furthermore, oil-burners could be shorter than those burning coal, thus reducing the height of the buildings and the visual threat to St Paul's Cathedral. The use of cedar-wood flue gas 'scrubbers' - previously used at Battersea - allayed fears that the station's emissions would damage Wren's masterpiece, although the cathedral's leadwork would later show that discharging the gasses unwashed, hotter, and from a taller chimney would have been kinder. When the first half of Bankside B opened in 1953 it was the first large public supply station to be specially designed for oil-firing in Britain,[1] and possibly the world.[2]

On political grounds Bankside had to be 'oil-fired or nothing',[3] in spite of the fact that oil had to be bought from Persia (Iran) and that British coal was a third cheaper. The reliability and competitiveness of oil in relation to coal prices were to govern all subsequent decisions regarding fossil-fuelled power stations. In 1953 as part of its fuel policy to meet a likely coal shortage, the Government introduced an oil burning programme for 17 existing and projected power stations in the UK. A number of stations, including **Barking C** (1952-4); **Belvedere** (1954-60; dem), and **Tilbury A** (1949-57) were converted to burn oil yet still retaining their coal handling and firing plant, with boilers capable of conversion back to coal at short notice. Others were purpose-built as oil-burning stations with space left to install coal firing, were this to become advantageous on economic or supply grounds. Improved supplies of coal and uncertainty about future oil supplies led to a modification of the programme in 1957, reducing the number of stations to 14 and the oil burn to 4½ million tons a year rather than 5⅔ million tons. **Marchwood** station (1957-9), Southampton Water, with 8 x 60 MW units was included in the programme, supplied by the nearby Esso refinery. It was designed also for ready adaptation to coal if necessary, and included a giant coal conveyor for bringing up coal from the wharf area. By the early 1960s when the CEGB's 500MW programme was underway, the economic pendulum had swung firmly to coal, and only three of the 13 'super stations' were oil or dual-fired: Fawley, Kingsnorth and Pembroke. All were sited near developing refineries, which made them economic. Kingsnorth was unique in Britain in having the ability to burn either oil or coal almost simultaneously (requiring specialised split furnaces, with two furnaces for each boiler), and was the largest dual-fuel power-station in Europe, although for the first five years it burned only oil, making increasing use of coal thereafter. Relative fuel prices from about 1965 provided a case for a increased oil burn, yet until c1970, conversions to oil were largely prevented by the Government's support for coal policy. The 1973 oil crisis and its aftermath effectively drew a line under the CEGB's oil-fired programme, changing the relative costs. Hitherto 'oil fired stations were vying with the most efficient coal-fired stations in supplying the electricity to meet the base load, while the less efficient coal-fired stations produced the remainder'; afterwards it was the big coal-fired stations in the north that met base load, with oil-fired stations used largely to help meet the peak demands.[4] Both Grain, the biggest oil-fired power station in Europe, and **Littlebrook B**, were based around 660 MW units but in train before the oil crisis; **Ince B** (c1972-1983; *dem*.) was seemingly the last of the oil-fired stations, and like the larger two 1970s stations, suffered from lengthy construction delays and disputes. Its location was politically influenced as the government wanted a station in the North West of England, leading to the unfounded rumour that the power station was built with the only purpose of creating jobs.

2. The architecture of oil-fired stations

The design of oil-fired and dual-fired power stations was dictated or influenced by most of the forces and factors that shaped their coal-fired siblings. As a sub-type, fossil-fired power stations exhibit considerable affinity, perhaps more so than nuclear power stations. All were reflections of innumerable compromises between engineering and architectural requirements, operational efficiency/integration and site layout, and cost and amenity. **Fawley**, for example, was sited not in the best technical position but in an area which lay completely outside the proposed Hampshire Green Belt, and was afforded special architectural treatment because of its dominant position at the entrance to Southampton Water.[5] Subsequent stations mostly tried to blend in, or at least mitigate their bulky impact on the landscape. As a broad generalisation, oil-fired stations tended to occupy more compact sites since they required less extensive plant for discharging, conveying and preparing the fuel for the boilers. Their coastal or estuarine locations typically precluded the need for cooling towers, since unlimited quantities of water for the boilers could be drawn directly from the sea or river. Only the 1,000 MW **Ince B**, Cheshire seems to have required additional cooling, from a single 116.7 m (383 ft)-tall hyperboloid assisted-draft cooling tower - a unique, experimental design designed to reduce visual impact and further the CEGB's experience of such structures. And their low-lying, littoral locations to a degree limited the scope of meliorating landscape architecture, since contours and woodland were unnatural to most sites. The use of oil as a fuel instead of, or in conjunction with coal, also resulted in other distinctive yet wholly functional components to the complex, namely outfall tunnels, water treatment and chlorination plant, and expansive fuel oil tank farms.

Architectural design

The first generation of oil-fired and dual-fired stations, erected in the era of the British Electricity Authority (1948-58), maintained the monumental 'brick cathedral' tradition of pre-war coal-fired stations such Battersea. Edifices such as **Tilbury A** (1949-58: Sir Alexander Gibb and Partners and Merz and McLellan: dew) and **Bankside** (1947-60: Sir. G. G. Scott and Mott, Hay and Anderson) epitomized this monumental tradition, the latter applauded as 'the most important building of its kind to be erected in this country'.[6] Farmer and Dark's dual-fired **Belvedere** (1954-60, which like Tilbury A was adapted during construction to take oil) and **Marchwood**, Hampshire (1954-59) helped sweep aside this tradition, replacing it with a functionally expressive, machine-aesthetic style that used aluminium and concrete instead of brick to clad the steel structural frames All accommodated 120 MW sets which were standard for the late 1950s, but conservative compared to Continental and American practice (see *High Merit*).

Fawley was the first oil-fired power station to embody the CEGB's 'large set philosophy' of the 1960s, and was the first of three 2000 MW power stations to be completed in the board's South Western Region. Two of these, Fawley and Pembroke, were oil-fired and the third, Didcot was coal-fired. Particular care was called for in the grouping and architectural treatment of the station buildings because of their prominence when viewed from Southampton Water, and accordingly leading specialists Farmer and Dark were drafted in as consulting architects, assisted by Lord Esher, and later Peter Swann of Imery, Porter and Wakefield for the landscaping. The architects gave particular prominence to the boiler house component of the 1050ft-long (308m) turbine/boiler unit, enclosing it with side-wall vertical zigzag glazing that terminated in a distinctive geometric, faintly Egyptian Art Deco cornice.[7] Recalling the early modernism of Merz and McLellan's glass-walled Dunston 'B' at Gateshead (1933-4) and Barking 'B' (1931-9) as well as the firm's own Marchwood, it was seemingly the last extensively glazed turbine/boiler house, marking the end of that line of architectural development. Equally distinctive was the 180 ft diameter combined administration and control building, a circular freestanding structure of reinforced concrete that housed the advanced English Electric LEO KDF-7 computers and gave operatives 360-degree views of the site. Probably inspired by harbour control towers, it was covered by an aluminium dome and was described as resembling 'a large flying saucer'.[8] Its futuristic appearance was also noted by Maldwin Drummond, OBE, owner of the Cadland Estate (a third of which had been appropriated for the oil refinery), who described Fawley as 'that great glass and steel cathedral with what seemed then a control room straight out of 1984'.[9]

Subsequent oil and dual-fired stations were almost all sited in the Thames Estuary, and were generally less architecturally distinguished. Despite being the largest dual-fired power station in Europe and the only example in Great Britain, **Kingsnorth** on the Hoo Peninsula had limited architectural input. The three integral buildings forming the body of the station, housing four 500 MW turbo-generators, four boilers, and four 17.5 MW gas turbines, were severely functional and boxlike, clad in beige-coloured aluminium sheeting with minimal expanses of glazing. The administration and control room block was similarly treated, with little to announce its presence architecturally. Colour was used to break up the horizontal mass of the low-slung complex, preventing it 'blocking' in conditions of haze or mist, which would have increased its visual bulk. Perhaps the most cogent architectural feature of this 2000 MW station was the grouping of the four boilers into two projecting blocks rather than the usual four, signifying its dual-fuel nature. Other components such as the 200m-high chimney, 400 kV switchhouse, coal store and tank farm were dictated almost entirely by engineering and operational requirements, and were consequently wholly utilitarian in character. The overall architectural languidness may have resulted from the decision to engage an architect on the staff of the consulting engineers, L. G. Mouchel & Partners, rather than an independent firm of consulting architects.[10]

The sheer size of the main buildings at **Grain** precluded application of the usual surface colour or texture techniques for minimising visual mass. Here L. G. Mouchel & Partners's input was limited to civil engineering design, whilst Farmer and Dark ('with an unparalleled pedigree in power station design')[11] assisted by Donald Rudd and Partners, were brought in as executive architects. To lessen their 'biscuit tin' appearance the architects introduced curved eaves and slightly pitched roofs, features that were also claimed to improve air flow around the buildings and assist ventilation within them. To unify the main elements of the complex, big and small, 'two-stage' cladding was employed, consisting of a lower band of flint-aggregate concrete panels with troughed stucco-embossed aluminium sheeting above. Windows were almost entirely absent, the designers accepting that it was essentially a continuous process plant, where the disadvantages resulting from attempts to cater for mixed daylight/artificial light conditions outweighed any inherent advantages of natural light. Normal glazing was used in areas of primarily daytime usage, and narrow, 15 metre-long acrylic windows were introduced to one side of the giant turbine house, extending at high level around the curved eaves. The overall result was commended for going 'a bit further than plain functionalism' and for being 'practical and robust' with 'good clean detailing'.[12]

The consulting architects for **Littlebrook D**, Architects Design Group, employed a similar 'two-stage' cladding system to visually unify buildings with diverse functions, which by the mid -1970s was a preferred technique. The lower precast concrete plinth units had splayed bases which ensured immediate stability during construction, and ensured vehicles were kept clear of the exposed aggregate finish of the higher panels. Profiled alkyd amino-coated aluminium sheeting was used above the concrete level, the two elements used in a variety of combinations to 'express a comprehensive design philosophy'.[13]No attempt was made to ameliorate the 'biscuit tin' rectangularity through curved eaves or sloping roofs as at Grain; instead a crispness of form and outline seems to have been the desired effect. Colour was however used more forcibly, to identify the various buildings and to make the power station an explicit focal element in the 'grey and visually confusing industrial landscape' as viewed from the Temple Hill Housing Estate at Dartford. The boiler house and the deaerator were coloured a dark yellow ochre with dark brown detail, the turbine hall and ancillary building complex white, and the auxiliary plant buildings dark brown with bright red and green detail. By varying the scale of such items as the pitch and form of corrugations in cladding, louvres, ventilators and doors, the architects endeavoured to resolve the problems of scale resulting from the juxtaposition of buildings of widely differing sizes.

Building and civil engineering works

Direct Cooling System components

In oil-fired stations and waterside coal-fired stations water was drawn directly from the sea or river via a screened underwater intake, and onshore screen chamber before being pumped to the condensers via concrete culverts or metal pipes. The pumps were housed in a pump-house. An outfall discharged the water heated by use in the heaters back into the river or sea at low velocity. The scale of such engineering works is impressive, and demanded the use of cofferdams during construction. **Fawley** required some 5,000ft of twin 14ft-diameter tunnels that extended from the surge shaft to the outfall structure in Stanswood Bay in the Solent. The pumphouse at **Grain** was constructed using a concrete diaphragm wall 70 m (330ft) in diameter and 30 m (99ft) deep - at the time one of the largest circular diaphragm walls ever constructed.

Wharves, Jetties and Docks

Where fuel was not supplied directly from a refinery, wharves or jetties had to be built in reinforced concrete to accommodate berthing tankers. Fuel handling at the dual-fired **Kingsnorth Power Station** was unusually elaborate, requiring two jetties, Long Reach and the larger Oakham Ness. Long Reach handled oil tankers or colliers of up to 10,000 tons, whilst Oakham Ness was an ocean tanker terminal jointly owned by the CEGB and Berry Wiggins Oil Refineries capable of receiving tankers of up to 45,000 tons. The aptly-named Long Reach was 1,000 ft-long and supported two 54-inch conveyors fed by five 10-ton cranes. Oil was normally received at the Oakham Ness terminal which was equipped with two berthing dolphins and four mooring dolphins; it was piped to the enormous tank farm using the delivery tanker's pumps. At **Ince B** oil was supplied directly to the station by a pipeline from Shell's Stanlow Oil Refinery, but could also be brought to the station by ship, via a berth on the Manchester Ship Canal. **Fawley** was unusual in having a tidal dock to receive ships carrying heavy plant; this was positioned to enable the overhead crane from the turbine house to run over it by means of an outdoor gantry.

Substructure

Both piled (precast-concrete) and raft (solid or cellular concrete, poured *in-situ*) foundations were used in oil-fired stations, the latter usually chosen where the subsoil was adequate to carry the required loading. The proportion of the loads due to the buildings was comparatively small; the largest items of plant, namely the boilers, overhead travelling cranes, turbo-alternators and ancillary parts required deep, dedicated foundations. Traditionally turbo-alternator blocks which supported the machines at operating-floor level were made in reinforced concrete, but in the 1960s they began to be made from structural steelwork. Although more costly, they were quicker to build, reduced foundation loads and facilitated the installation and inspection of plant. **Fawley** was seemingly the first oil-fired station to use steel turbo-alternator blocks; by the time of **Littlebrook D** (where the turbine generators and boiler feed pump turbines were supported on carbon-manganese steelwork designed by MAN of Germany) it was standard.

Superstructure

Steelwork was largely used for the structural frames of most power station buildings. In the 1960s, universal beams and columns and castellated beams had come into common use, as had welding and friction grip bolts as a means of forming rigid connections. At **Fawley**, some 36,500 tons of structural steelwork was required, including 3750 tons for the 400 kV switch-house. It was erected by Dorman Long (Bridge & Engineering) Co. Ltd[14] between early 1965 and late 1967 at an average rate of 300 tons per week. **Littlebrook D** used some 34,000 tons of structural steelwork, some of it highly-specialised (e.g. 0.5Cr0.5Mo0.25V) for service temperatures of up to 541°C. Fawley used reinforced concrete for its distinctive, combined control and administration building, and **Ince B** employed reinforced concrete frames for its separate control and administration buildings, the former clad in brick, glass and aluminium and the latter solely in brick and glass.

3. Technological development of plant and equipment at oil-fired stations

From 1950 it was the CEGB's policy to build completely integrated units of large output, the boiler and turbine being matched. The word unit in a power station sense is 'the association of a single turbo-generator and boiler, together with auxiliary services, to form a complete operating unit of virtually self-contained design'.

Turbo-generators

The pattern of increasing standard size of individual generating sets established in the latter years of the British Electricity Authority (BEA), and the upward trend during the late 1950s under the CEGB - culminating with the decision in 1960 to standardise on single shaft machines at an unprecedented 3000 rev/mm and 500 MW output - has been covered in *High Merit*. The CEGB's 'large set philosophy' of the 1960s and 70s applied equally to its small number of oil-fired and dual-fired stations as it did to coal-fired power stations. Fawley, (Pembroke), Kingsnorth and Ince B each employed four of the new standard 500MW turbo-generators (made by C.A. Parsons) and Grain and Littlebrook D used five and three respectively of the 660 MW units (made by GEC Turbo Generators Ltd). Those at Grain were similar to those supplied for the Advanced Gas-cooled Reactor nuclear power stations at Heysham, Hartlepool and Hinkley Point 'B'. Whilst these larger sets which gave more electricity from the same quantity of fuel, this period marked a plateauing out in thermal efficiency and capacity. In the 1950s steam temperatures and pressures were driven up, reaching a (still current) plateau of 566°C (1050°F), with the best units achieving about 39-40% thermal efficiency. The attainment of this temperature was made possible by the introduction of ferritic stainless steels (11-13 per cent chromium) and the adoption of special design features.[15] Yet even with the specialized (and expensive) metals that were used, the super-hot, super-pressurized steam caused metallurgical fatigue to parts of the turbine, decreasing reliability and increasing maintenance. As a result, the CEGB realized that lower-efficiency plants might be more economical to operate. Although turbo-generators might not eke out the last kWh out of a barrel of oil, they would be cheaper to build and less costly to maintain. The decision to stop pushing thermal efficiencies ever higher in the 1970s made economic sense, but with it came the CEGB's (and all electricity providers, internationally) realisation that it could no longer expect to see cost declines from this source of technological advance.[16]

Innovations and developments in the large output turbo-generators of this period were thus modest, incremental and highly-specific. One feature of the design of the turbines at **Fawley** was the application of water extraction condensers to the exhaust system of the low-pressure cylinders. These removed water particles from the steam and so protect the last row of turbine blades from erosion. **Kingsnorth** included some experimental sets that employed either solid-forged or welded low pressure rotors to enable experience to be gained in the manufacture and operation of subsequent rotors. The last-stage low pressure blading was shrouded with a new arch-braced cover banding, designed to obviate the usual lacing wires, and Stellite shields were fitted to the inlet edges of the moving blades to protect them against water erosion. At **Littlebrook** the turbines were of the latest 660 MW, 4-cylinder tandem-compounded (in line) type with water cooled stator windings and hydrogen cooled rotors, designed to be flexible in operation with fast responses to changes in required output.

Boilers
By the 1960s the boiler was the largest single item of plant in a fossil-fuelled power station, often requiring 10,000 tons of steel and some 500 workmen to assemble it over a period of two years. Normally top-slung from an independent steel structure it typically consisted of a forced draught fan, a regenerator type pre-heater, the furnace, a superheater, a reheater, an economiser and an induced draught fan. The configuration and form of any boiler unit was unique to every power station, reflecting the requirements and constraints peculiar to the project, and accumulated experience of the integrated components, which saw improvement and refinement or even complete introduction in the 20th century (reheaters for example date from the 1920s). Oil-fired boilers differed markedly from coal-fired boilers in three main respects. Firstly, the rate of combustion of fuel oil is greater than coal, which allowed a smaller furnace volume. Secondly, the low ash content meant more closely pitched superheater and reheater surfaces could be employed and the restrictions of ash softening temperature did not apply. Thirdly, the absence of alkaline ash (which absorbed the acidity of the products of combustion) demanded low excess air combustion to inhibit the oxidation of sulphur dioxide to sulphur trioxide. Because of the susceptibility of austenitic (i.e. 'stainless' steels) to oil ash corrosion, superheater and reheater outlet temperatures had to be restricted to 541 C to allow the superheaters and reheaters to be designed using ferritic steels only. The 500 MW-unit programme included only one oil-fired boiler design, the **'Fawley design'**, which was used at **Fawley**, **Pembroke** and (with modifications) **Ince B**. These boilers were designed when the largest oil-fired boiler in the CEGB estate was the 120MW Bankside B unit, which used a completely different firing system. Therefore the Fawley design boilers were based on the 500 MW coal-fired boilers, with radiant superheaters installed in the furnace and parallel primary superheater and reheater in the rear pass, with gas biasing dampers to provide reheater temperature control. However circulation margins were only just adequate, and there were problems of corrosion in the furnace floor tubes. In spite of this they were approximately two thirds the size of the coal-fired units of equivalent output and combustion efficiency proved to be better than specified. The 660 MW boilers used at **Grain** marked a radical departure from coal-fired practice with all the superheater and reheater surfaces protected from direct furnace radiation by a water-cooled screen. This arrangement avoided many of the metal temperature problems encountered on the Fawley design. Experience of, and extrapolation from, the Fawley and Grain designs informed the design of those used at **I.ittlebrook D**, which had no radiant superheater in the furnace: the whole superheater and reheater was protected from direct radiation from the furnace by a water-cooled screen.

Another important innovation of the 1950s and 1960s related to the construction of furnace walls. These decades saw the introduction of furnaces using either tangent wall or membrane (or mono) wall construction. The inherent advantages of prefabricated membrane wall construction saw its near-universal adoption for industrial furnaces in the late 20th and early 21st century.[17] The four 500 MW reheat boiler units at **Ferrybridge C** were the first boilers in this country to have membrane type furnace walls. **Kingsnorth** seems to have been the first oil/dual-fired station to use fully welded membrane wall construction for its furnaces.

Manufactured by International Combustion, they were of the assisted-circulation, divided-furnace type. Assisted-circulation permitted the use of smaller diameter and thinner furnace tubes, so reducing the weight of the pressure parts.

In large power stations (using 500 MW and larger units) where coal was the main fuel, either the front or back wall of the rectangular furnace formed the firing face, typically remote from the turbine. Remote firing faces were also employed in oil-fired stations, for example at **Fawley** where 32 front wall burners were used to fire the 30m [100 ft]-high furnace. There was however more inherent flexibility in the positioning of the burners in oil or dual-fired stations. The firing techniques employed at **Kingsnorth** used specialist burners developed by International Combustion Limited which operated at low excess air, injecting the fuel from each corner of the boilers and providing a controlled flame in the centre of the furnace area. This provided maximum heat from the fuel delivered to each of the furnace walls carrying the water tubes. The boilers had split furnaces, that is there are two furnaces for each boiler. Each boiler (that is two furnaces) had 48 oil-burners and 40 pulverised fuel (powdered coal) burners. The majority of the oil burners were towards the top of the furnace and the majority of the coal burners towards the bottom to allow for the different burning characteristics of the two fuels. The three 660MW oil fired boilers at **Littlebrook D,** designed, supplied and erected by NEI Clarke Chapman Power Engineering Ltd, were of more conventional design, each having a single, front-wall-fired furnace. The great size of the boiler components was however extraordinary. The 250ton, 35m-long steam drums were the largest ever supplied to the CEGB, and had to be transported entirely by water from Wolverhampton via the Pomona Docks on the Manchester Ship Canal and Kingsnorth on the Isle of Grain. All other components were to ensure that sections fabricated north of the Thames would pass with sufficient clearance through the Dartford tunnel.

Steam Conditions

Steam pressure and temperature remained the same for coal-fired stations throughout the post-war period irrespective of the unit size, with a superheat and reheat steam temperature of 565 C at the turbine stop valve adopted. However, because of the different corrosion properties of oil, the lower temperature of 538 C instead of 565 C was adopted for all oil-fired stations, a temperature that was seen as being more economic for all advanced gas-cooled reactor (AGR)-type nuclear power stations.

Alternators

One of the principal advances in turbo-alternators in the post-war period was cooling by means of distilled water or hydrogen. The first machine in the world with water flowing through the stator bars was the prototype 30 MW set at the **Bold A** station, commissioned in 1956. In 1958 **Tilbury A** power station (set No. 6, 60MW) employed a stator cooled by distilled water and the experience gained with this cooling system was then applied to the 200 MW sets of the late 1950s/early 1960s. In the same year the No. 2 generator at **Willington A** was the first machine to employ internal hydrogen cooling of both stator and rotor conductors. The 500 MW unit stations of the 1960s were all beneficiaries of these developments; **Fawley** employed alternator rotors that ran in a hydrogen atmosphere to increase cooling and reduce drag, and the stator windings were hollow, permitting the passage of cooling water through them. Such improvements and experience naturally benefited the 660 MW units that began producing power in the 1970s: the 32 per cent increase in output of the hydrogen-cooled generators at **Grain** over the earlier 500 MW machines was achieved with only a 15 per cent increase in the weight and core of the water-cooled windings.[18]

Switchgear

In common with large coal-fired power stations, oil and dual-fired stations used main and auxiliary switchgear of the air blast types; as a switch opens the arc is blown out by compressed air. Although an advance over the older oil-circuit breakers (which posed fire risks), and mandatory for 400 kV switching stations,[19] there was nothing particularly innovative about their use in this period, the air-blast circuit-breaker having been invented in 1926 by W. B. Whitney and E. B. Wedmore.[20] Vacuum circuit breakers, which in the early 1960s were in full scale production by the U.S. General Electric Co., and which were installed by the CEGB in 1968 at the 132 kV West Ham sub-station,[21] were not seemingly used on fossil-fuelled power stations. Whilst the outdoor type of substation was the more economic form of construction, the corrosive effects of salt from coastal locations meant that most oil-fired stations, including **Fawley** and **Kingsnorth**, required the switchgear to be enclosed within a building. In 1967, when the first set at Kingsnorth was commissioned, it was installed with an isolated phase busbar system, thought 'to be the first to be commissioned in this country'.[22]

For the larger-set stations at Grain and Littlebrook, outdoor switch stations were economically inescapable. The 400 kV outdoor switching station at **Grain** occupied a vast area of 1,200ft by 600ft to the east of the power station and fed a double-circuit overhead line that connected to the 400 kV grid system at Kingsnorth and Rayleigh. The 400 kV insulators on the transformers and switchgear are provided with the on-load water washing system developed by the CEGB to prevent build-up of salt deposits. The works power system was slightly unusual in that the station transformers, instead of having their own expensive 400 kV circuits in the main switching station, were connected between generator transformers Nos. 2 and 3 and the corresponding 400 kV switches with load-breaking isolators inserted in both the generator and station transformer connections. In the event of a failure the faulty arm could be isolated and the supply restored to the other transformer.[23]

Oil Fuel Tank Farm

Fuel oil was stored in two or more large oil tanks - often 55m x 18m high - arranged as a tank farm. Because of the high viscosity of the heavy residual oil normally used, it was heated to about 80°C to facilitate pumping and flow and reduce the pumping power required. Wherever possible, oil was taken directly from the oil refinery (e.g. at Fawley, Pembroke, Isle of Grain) by pipeline. At **Fawley**, fuel was received direct from the refinery into two storage tanks of 12,000 tons capacity, a smaller tank of 2,100 tons being provided for test purposes only. To keep the fuel fluid, heating was employed both in the tanks and pipework which contained steam heating elements designed to maintain a temperature of 60°C when the air temperature was freezing (0°C).[24] At **Grain** the oil tank farm, comprising two 120ft diameter by 70ft high oil tanks of 19,000 tonne capacity, provided a buffer against fluctuations in flow from the British Petroleum (BP) Grain refinery and served as metering vessels.[25] The dual-fuelled **Kingsnorth** power station received oil and coal by tanker or collier at two jetties (Long Reach and Oakham Ness), and thus required larger oil reserves. Oil was normally received at the Oakham Ness tanker terminal whence it was piped, with the use of the delivery tanker's pumps, to a tank farm of six 25,000-ton and three 50,000-ton storage tanks, all steam-heated.[26] In size and capacity, the most impressive tanks were the five 110,000-ton oil storage tanks at **Littlebrook**, which have an internal diameter of 84m and a height of the top curb of 22m.[27] They were manufactured by Motherwell Bridge Engineering Ltd in accordance with BS 2654:1984,[28] and with column supported roofs. Because experience with other tanks had shown that corrosion could occur at the base of the shell through condensation running down behind the lagging, the bottom metre of the shells were coated with a bitumastic type sealant. This was contoured to give a fall from the base and thus to ensure that water ran away from the foundation, to obviate corrosion problems should any moisture settle between the base plates and the underlying bituminous layer.[29] The whole Tank Farm area was bunded to suit the requirement for Class A petroleum storage so that crude oil could be stored if required. The gravel bunding also protected the adjacent Dartford Tunnel from effects of any disaster occurring with one tank.

Chlorination Plant

Experience showed that estuarine or coastal water drawn for cooling purposes fouled the coolers and condensers on the Circulating Water System because of the growth of organic slimes, accretions and shellfish. **Fawley** was one of the first in which chlorine was injected into the cooling water automatically in accordance with a predetermined cycle supply.[30]Subsequent stations incorporated treatment plant for the introduction of a sodium hypochlorite solution into the water at a number of points; at **Kingsnorth** provision was also made for the injection of Zimmite for mud flocculation at the condenser inlets, and of ferrous sulphate for the protection of cast iron surfaces from corrosion.[31]

Automatic Control

Automatic control was pioneered in oil-fired power stations. In 1957 the 240 MW (4 x 60 MW) oil-fired station at **South Denes, Great Yarmouth** (demolished 1980s) with steam turbines was commissioned and was notable at the time for the completeness of its automatic control. The first fully-automatic remote-controlled station in England was the 3 MW gas-turbine station at **Princetown, Devon**, which started generating electricity for the South Western Electricity Board in 1959. In the same year Agecroft C in Greater Manchester started up, with a capacity two 120 MW coal-fired sets equipped with automatic control of *turbine output*. 1959 also saw **Little Barford B** station commissioned in Bedfordshire. This (demolished) coal-fired station had completely remote operation of its two 60 MW units, and its automatic electronic boiler-control system used single-analogue on-line computers and three-term process controllers—the first comprehensive installation of its kind in the country. The 1960s saw the introduction of more powerful computers, applied to larger and more plant. In 1964 the 200 MW unit at **West Thurrock** began operation under computer control—the world's first application to a large coal-fired unit.[32] When **Fawley** oil-fired station started up in 1969, its control system was among the most advanced in the world: 'Each of the four 500 MW units had computer control capable of taking the set from hot conditions to a selected load target, without intervention of the operator, taking corrective action if a fault occurred, and shutting down if necessary. Temperatures, pressures, flows and actions taken were displayed on a cathode ray tube'.[33] The station was capable of normal operation in the event of a computer failure as all the basic safeguards involving the normal electrical interlocks and operating sequences were retained at all times independently of the computers, although the latter (English Electric LEO KDF-7's) would 'frequently employ more sophisticated logic when in control'.[34] At **Kingsnorth**, each of the four 500 MW units was computer-controlled with automatic start-up of individual auxiliaries and pulverised fuel mill, and automatic loading of the turbo-alternator from half load, with automatic control of fuel supply etc.[35] **Grain**'s turbo-generators also had their own dedicated on-line computers dealing with alarm annunciation, data presentation and aspects of operational control; the main innovation in the employment of computers there was in helping construct the station, including routing the 1,100 miles of cabling that was installed.[36]

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[1] Northern Ireland's first oil-fired power station was Coolkeeragh which began operating in 1960; the Republic of Ireland's was at Great Island, County Wexford, opening in 1968; and Scotland's was to have been Inverkip (1970-76), but was never utilised commercially.
[2] 'Britain, although it still relies more heavily on coal for power than other nations, has some of the world's oldest oil-burning power stations, rapidly approaching the end of their working lives'. *New Scientist*, 7 May 1981, 342.
[3] Silkin, as quoted in Sheail, J 1991, 40
[4] An engineer in the CEGB's National Control, as quoted in Cochrane, R 1985, 61
[5] Lenihan, J MA and Fletcher, WW 1979 *Economics of the environment*, 160
[6] Edwards, A T 1952, 6
[7] Or possibly evincing the influence of the 'New Formalism' on Farmer and Dark, particularly the work of Minoru Yamasaki (1912-1986) who drew inspiration from Gothic architecture and employed narrow vertical windows. This has some credence if the architects' intention was a 'glass cathedral' of power. Thanks to Geraint Franklin for alerting me to Yamasaki.
[8] 'Self-supporting dome covers 1/4 acre of uninterrupted floor area', *Design News* **24** (1969), 80
[9] *Gardeners Chronicle & Horticultural Trade Journal* **198** (1985), 20
[10] The architect was R. Maggs, who previously (with S. Simmons, also on the staff of L. G. Mouchel & Partners, Ltd) had worked on the architecturally similar Northfleet Power Station, Kent. Maggs seemingly abandoned power station design in the 1970s, designing among other structures Leazes Bowl multi storey car park in Durham.
[11] *BD*, 16 September 1977, 21
[12] *BD*, 16 September 1977, 21
[13] CEGB 1986, 150
[14] A short-lived consortium comprising the former firm, together with Tees Side Bridge, United Steel and South Durham
[15] McNeil, I, ed 1990 *An Encyclopedia of the History of Technology*. London and New York: Routledge, 300-1
[16] http://americanhistory.si.edu/powering/past/history3.htm
[17] Kumar Rayaprolu *Boilers: A Practical Reference* (2012), 210
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[19] CEGB 1971b, 394
[20] Electricity Council 1982b, 46
[21] Electricity Council 1982b, 85, 98
[22] *Electrical Times*, 18 May 1967, 795
[23] *ER*, 28 September 1973, 419
[24] 'Fawley Power Station', *S&HE*, June 1971, 7-8
[25] Braun, J 'Steel Structures Go to Plan at New Grain Power Station', *Steel Times*, November 1973, 757; 'Spotlight on the Isle of Grain', *Construction Worker*, June 1979
[26] Kingsnorth Power Station *CEGB* (opening booklet, nd. c1970s)

[27] 'Construction of Littlebrook 'D' power station. Part 1 The Overall Concept, *Metal Construction*, March 1981; 'Construction of Littlebrook 'D' power station. Part 3 Tank Farm and Structural Steelwork, *Metal Construction*, March 1981, 18

[28] BS 2654:1984 *Specification for manufacture of vertical steel welded storage tanks with butt-welded shells for the petroleum industry*.

[29] 'Construction of Littlebrook 'D' power station. Part 3 Tank Farm and Structural Steelwork, *Metal Construction*, March 1981, 20-21

[30] 'Fawley Power Station', *S&HE*, June 1971, 11

[31] Kingsnorth Power Station *CEGB* (opening booklet, nd. c1970s), 21

[32] Electricity Council 1982b, 74, 77-8, 87

[33] *ibid*, 101. In 1965 this was the biggest contract for automation equipment ever awarded in Britain - a £1m tender for 4 computer-controlled assemblies; used four English Electric-Leo-Marconi (EELM) KDF-7 units specially designed for the robot control of both boilers and generators. *FT* 1965

[34] 'Fawley Power Station', *S&HE*, June 1971, 13

[35] *ibid*, 103

[36] 'The spectacular transformation of a Dickens' landscape', *Achievement*, December 1979, 30

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A&BN The Architect and Building News
AR Architectural Review
Br The Builder
BD Building Design
BN The Building News
BSE Building Services Engineer
C&CE Concrete and Constructional Engineering
CE The Consulting Engineer
CPWR Civil Engineering and Public Works Review
EEJ English Electric Journal
E&P Electronics and Power
ER The Electrical Review
ET The Electrical Times
FT The Financial Times
H&VE Heating & Ventilating Engineer
ICE Institution of Civil Engineers
IEE Institution of Electrical Engineers
IJER International Journal of Energy Research
JRIBA Journal of the Royal Institute of British Architects
JIEE Journal of the Institution of Electrical Engineers
JILA Journal of the Institute of Landscape Architects
NRJ Natural Resources Journal
OA&P Official Architecture and Planning
PICE Proceedings of the Institution of Civil Engineers
PIEE Proceedings of the Institution of Electrical Engineers
PIME Proceedings of the Institution of Mechanical Engineers
RIBAJ Royal Institute of British Architects Journal
RSAJ Royal Society of Arts Journal
S&HE Steam and Heating Engineer
TIBG Transactions of the Institute of British Geographers
TSE The Structural Engineer

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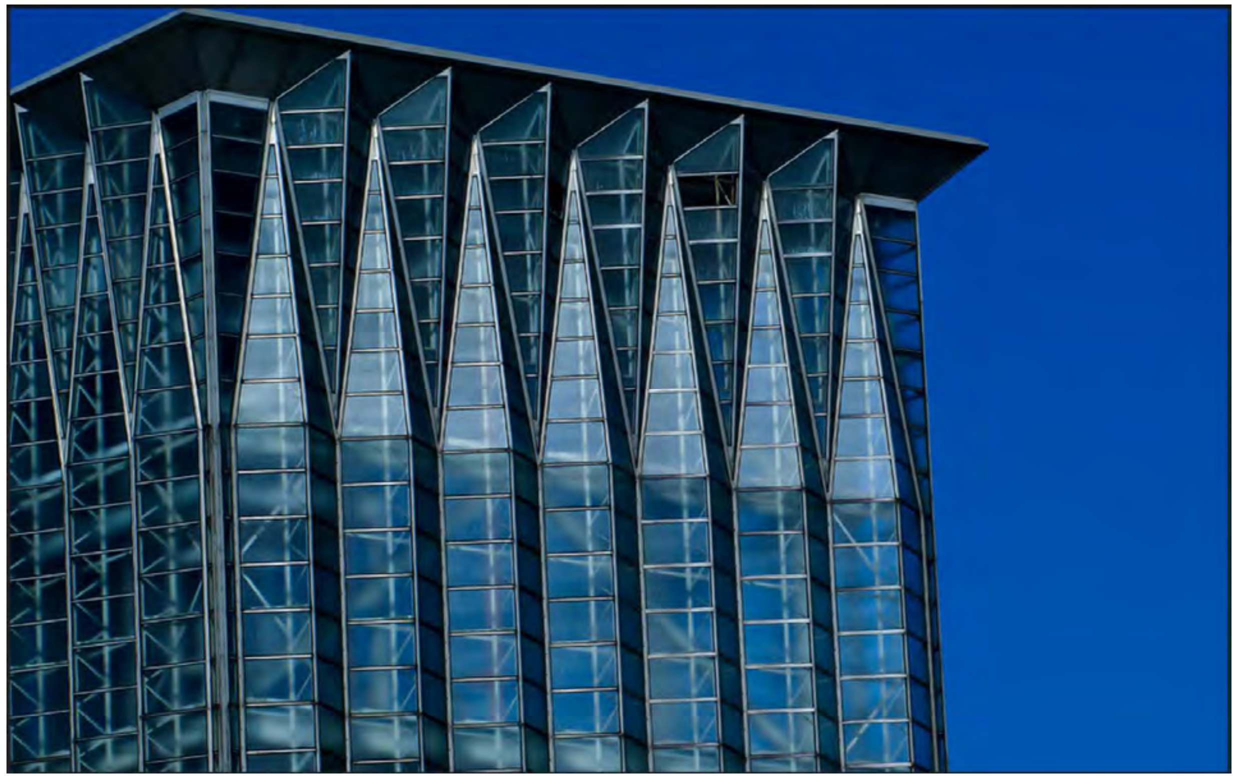
APPENDIX 4

Tabulated summary of extant oil-fired power stations in England, illustrated

Station name	Build date	Consultant architects and engineers; Landscape architects	Design interest	Technological interest	Additional interest/ considerations
Fawley Hampshire	1962-69	Farmer and Dark Rendel, Palmer and Tritton civil engineering consultants Farmer and Dark in consultation with Lord Esher, and subsequently with Peter Swann of Imery, Porter and Wakefield	• First oil-fired 2000MW station to generate power • First 400 kV switch-house (enclosed) at oil-fired station. • Particular care taken in grouping and architectural treatment of the station buildings because of their prominence when viewed from Southampton Water. • Extensively glazed turbine/boiler house – possibly the last of the 'glass cathedrals'. • Unique (?) combined circular administration and control building.	• Automatic control system was among the most advanced in the world in 1969, based around English Electric LEO KDF-7 computers; in 1965 was biggest contract for automation equipment ever awarded in Britain. • 'Fawley design' prototype 500MW boiler used at Fawley, Pembroke and (with modifications) Ince B. • Alternator rotors ran in hydrogen atmosphere to inc. cooling & reduce drag; hollow stator windings were hollow for passage of cooling water. • First oil-fired station to use steel turbo-alternator blocks. • Application of water extraction condensers to exhaust system of l.p. cylinders to remove water particles from the steam and turbine blades from erosion. • First super-conducting d.c. motor (substantially lighter and smaller than conventional types). • water-cooled 400 kV cables.	• Scale of civil engineering works impressive, inc. 5,000ft of twin 14ft-diamter tunnels extending from the surge shaft to the outfall structure in Stanswood Bay in the Solent; also demanded underwater 2-mile, 10ft dia. cable tunnel (Fawley-Chilling). • Unusual tidal dock to receive ships carrying heavy plant, positioned beneath turbine house's overhead crane. • Early use of chlorination plant on Circulating Water System. • RFAC's suggestion of an 'open quatrefoil'-plan for 75-ft-high chimney rejected by designers on engineering (wind) grounds; a circular with the projecting flues was adopted. RFAC's suggestion of irregular grouping/layout to waterline acceded.
Grain, Hoo Peninsular Kent	1971-c1980	Farmer and Dark (architects E Butcher & E Hutchinson), assisted by Donald Rudd and Partners CEGB Architects RC Dent & HN Mason Gothard Landscape & Land Reclamation Ltd Kenneth Booth	• Largest oil-fired station in Western Europe when built; first oil-fired station to use 660MW sets (x5). • Some architectural distinction, particularly the novel approach to minimising usual giant 'biscuit tin' aesthetic of concrete/metal cladding through curved eaves and slightly pitched roofs - streamlined features that were also claimed to improve air flow around the buildings and assist ventilation within them. Commended for going 'a bit further than plain functionalism'; the near-total absence of fenestration perhaps an 'honest' (but severe) acceptance that it was essentially a continuous process plant.	• The 660 MW boilers marked a radical departure from coal-fired practice with all the superheater and reheater surfaces protected from direct furnace radiation by a water-cooled screen. This arrangement avoided many of the metal temperature problems encountered on the 'Fawley design'. Experience of, and extrapolation from, the Fawley and Grain designs informed the design of those used at Littlebrook D. • Turbo-generators had own dedicated on-line computers dealing with alarm annunciation, data presentation and aspects of operational control, although this natural evolution from Fawley etc.	• Engineered under contracting arrangements that were novel when job started (designed to reduce number of main contractors, improve construction performance/labour relations and meet project timelines). Unfortunately a series of strikes delayed completion by years. • Scale of civil engineering works impressive, e.g. pumphouse constructed using a concrete diaphragm wall 70 m (330ft) in diameter and 30 m (99ft) deep - a the time one of the largest circular diaphragm walls ever constructed. • Vast size of the 400 kV switching station (1,200ft by 600ft) at Grain precluded outdoor-type housing (i.e. more unsightly/cluttered). • Computer design techniques aided construction of the station, including routing the 1,100 miles of installed cabling. • West Kent Divisional Planning Officer (G. Smith) disliked the aluminium cladding, open nature of switching station and high floodlighting towers on site's perimeter. RFAC preferred CEGB's scheme to his suggestions.
Kingsnorth Hoo Peninsular, Kent	1963-73	R. Maggs of L. G. Mouchel & Partners L. G. Mouchel & Partners, consulting engineers	• Uniquely designed (in Britain) from outset to burn either oil or coal almost simultaneously (requiring specialised split furnaces, with two furnaces for each boiler), and was the largest dual-fuel power-station in Europe. • Limited architectural input; severely functional and boxlike although the grouping of the four boilers into two projecting blocks rather than the usual four - signifying its dual-fuel nature - was cogently expressive.	• First oil/dual-fired station to use fully welded membrane wall construction for its furnaces; specialist burners developed by International Combustion Limited operated at low excess air, injecting the fuel from each corner of the boilers provided maximum heat from the fuel delivered to each of the furnace walls carrying the water tubes. Boilers had split furnaces; two furnaces for each boiler. Each boiler (that is two furnaces) had 48 oil-burners and 40 pulverised fuel (powdered coal) burners. • Experimental turbo-alternator sets that employed either solid-forged or welded low pressure rotors to enable experience to be gained in the manufacture and operation of subsequent rotors. The last-stage l.p. blading housed under a new arch-braced cover banding, designed to obviate the usual lacing wires; Stellite shields fitted to the edges of moving blades to protect them against water erosion. • Early computerised automation: each of the four 500 MW units was computer-controlled with automatic start-up of individual auxiliaries and pulverised fuel mill, and automatic loading of the turbo-alternator from half load, with automatic control of fuel supply etc.	• First set to be commissioned installed with isolated phase busbar system, thought to be the first to be commissioned in the country. • Additional to usual chlorination plant, provision also made for injection of Zimmite for mud flocculation at the condenser inlets, and of ferrous sulphate for the protection of cast iron surfaces from corrosion. • Fuel handling facilities unusually elaborate, requiring *inter alia* two long jetties.

Littlebrook D Dartford, Kent	1974-82	Building Design Partnership C.S. Allott & Son Derek Lovejoy and Partners	• Architects wanted to 'express a comprehensive design philosophy' with usual 'two-stage' cladding system used to visually unify buildings with diverse functions but strong colours used to identify the various buildings and to make the power station an explicit focal element in the 'grey and visually confusing industrial landscape' as viewed from the Temple Hill Housing Estate at Dartford. Thoughtful, crisp detailing inc. the pitch and form of corrugations in cladding, louvres, ventilators and doors which sought to resolve the problems of scale resulting from the juxtaposition of buildings of widely differing sizes.	• Oil tanks impressive in size and capacity inc. a 'farm' of five 110,000-ton oil storage with an internal diameter of 84m and a height of the top curb of 22m - the oil-fired equivalent of a cooling tower field. Manufactured by Motherwell Bridge Engineering Ltd in accordance with BS 2654:1984, and with column supported roofs. • Employed latest (but did not pioneer) 660 MW, 4-cylinder tandem-compounded (in line) turbo-alternators type with water cooled stator windings and hydrogen cooled rotors, designed to be flexible in operation with fast responses to changes in required output.	• Outdoor 400 kV switch station, which was the most economically attractive, but aesthetically unattractive form. • The flooded gravel extraction works, along with a pre-existing lake formed the centrepieces of a landscaped nature reserve that preserved existing habitats and wildlife. The scheme - unique among coal/dual-fired stations - was designed to conceal or camouflage the visually unattractive elements of the site & provide an attractive foreground to the station when viewed from higher ground to south.
Tilbury B	*c*1962-69	????	• Housed four 350 MW units but designedly prototypical of forthcoming generation of 2000 MW power stations built around 500 MW units. • Prefigures extreme functional/utilitarian 'aesthetic' of metal-clad super stations such as Kingsnorth, with no fenestration to main buildings and no attempt to reproduce the dignified facades of its neighbour, Tilbury A.	• Boilers designed to be coal-fired, but modified to use combination of coal and heavy fuel oil. Gas-fired turbine station contained four 17. MW units - the standard size/number adopted in the 1960s/70s.	• Designed specifically to supply the 275,000 volt national grid and was connected to dedicated 275 kV substation; there is also a 400,000 volt connection with Kingsnorth via a tunnel beneath the Thames. • Possible damage to parts of site as result of a major fire originating in fuel storage area on 27 February 2012.

Fawley, Hampshire



Above: Glazing at Fawley, Hampshire ©Historic England

Below: ©Historic England P172060

Grain, Kent

©Historic England DP165048

Kingsnorth, Kent

Above: Kingsnorth Power Station ©Historic England Detail of 26477011 8-Sep-2009

Below: ©Historic England DP172026

Littlebrook D, Kent

No image available

Tilbury B, Essex

Tilbury B in 1995 ©Wayne Cocroft