'High Merit': existing English post-war coal and oil-fired power stations in context

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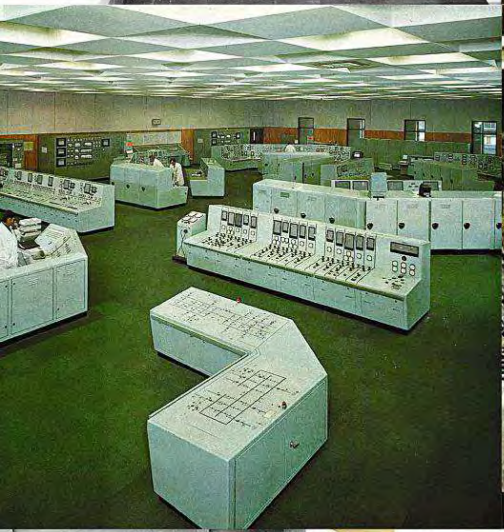

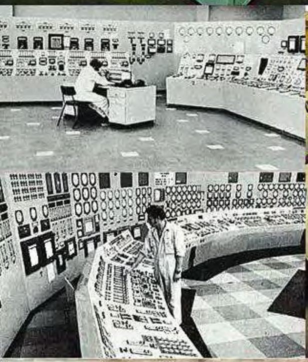
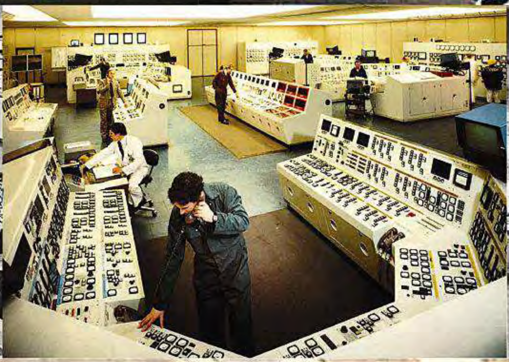
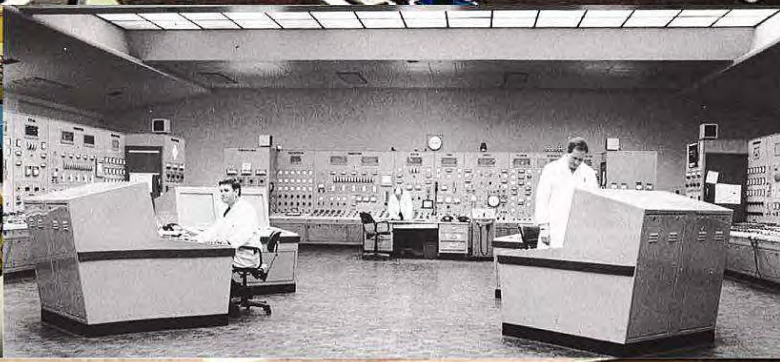
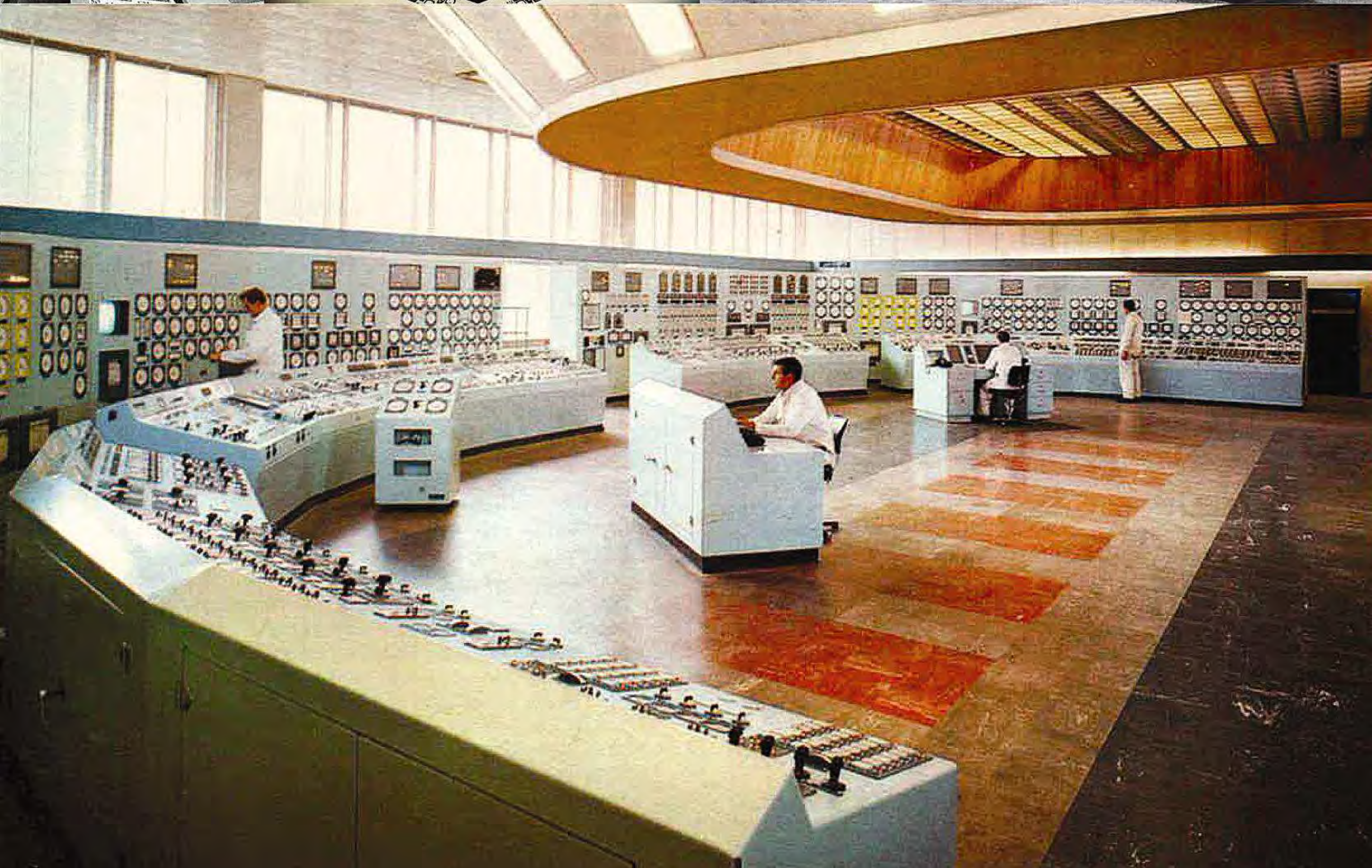

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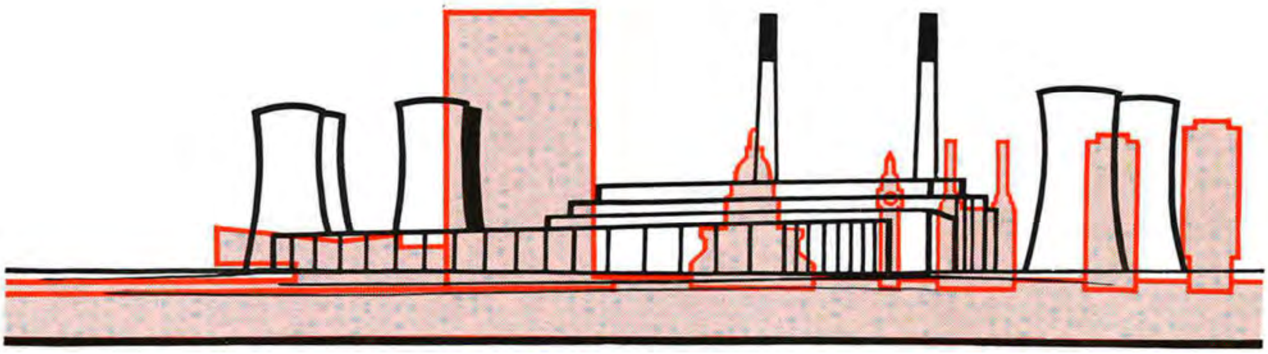
1. INTRODUCTION

Power stations with cooling towers are a highly threatened and increasingly rare building type. Following the demolition of the 12 towers at Lister Drive, Liverpool, in the 1970s (Britain's first, built by Mouchel and Partners from 1924), and the surviving two towers at Tinsley, Sheffield (known locally as the 'Twin Towers') in 1998, no natural draft hyperbolic concrete towers survive from the pre-war, or pre-Nationalisation era. The only survivors from the 1950s, at Willington, Derbyshire are currently under threat, having lost their associated 'A' and 'B' power stations in the early 2000s, and having been turned down for listing in 2007. The only natural draft hyperbolic concrete towers to survive with associated buildings are those groupings built as integral components of the 500 MW and 660 MW-unit coal-fried stations of the 1960s and '70s. This was the era when conventional power stations reached their zenith in generating output, efficiency and architectural scale - gargantuan complexes that burnt 'old-fashioned coal ... with a sophistication that mad[e] atomic power look primitive, and with an efficiency that substantiate[d] the too-often mythical "economies of scale"'.[1] By this period, it was irrefutably the cooling tower, rather than the turbine hall, that had become the defining visual feature of the power station. Visible for tens of miles around, and often obscuring the ground-hugging half-kilometre-long orthogonal power houses, these cloud-generating funnels in their setting encapsulate many of the developments in mid-to-late 20th thermal power generation and structural engineering: a concentration in inland rural locations that followed the arc of the Midlands, Yorkshire and Lancashire coalfields; the confidence, might and yet duty to amenity of the Central Electricity Generating Board; the strategic use of landscaping, colour, tone and texture to tame, accentuate or obscure, and the employment of an archetypical 20th-century material - reinforced concrete - in one of its purest, most optimised forms - the hyperbolic shell structure - to enhance site location options and lessen thermal pollution of the river environment. But above all they epitomised the leap in size from the previous generation of municipal 'brick cathedrals': one standard 375-ft high cooling tower could almost swallow Battersea power station (337 ft high; **Fig.1**), and the whole power station complex had an area the size of a town: 'placed on a map of London, a 2000 MW station would extend from St Paul's cathedral to Millbank, or possibly from Hyde Park Corner to Waterloo Station'.[2] It is perhaps fitting that what was the largest state-funded body, with the largest budget outside of Whitehall, should have produced the biggest monuments, and, as the largest patron of landscape architecture, with a nationwide 'supergrid' of transmission infrastructure, has left its mark on the landscape in a way only exceeded by road-building.

Given the urgency of this case, and the fact that the only English coal-fired power stations with associated cooling towers to survive are from the 1960s and 1970s, a historical overview of technical, administrative and architectural developments in power stations will consider only the Nationalised industry, with especial emphasis on the 1960s - the decade of most crucial relevance to what survives, technologically,



1. *The Scale of the 2,000 MW West Burton power station compared to (from left) the United Nations building in New York, St. Paul s Cathedral, Big Ben, Battersea power station, and the Vickers and Shell buildings in London* geographically and architecturally. Beyond matters of developmental pressures and physical survival, there is published-literature justification for this tight focus. Probably more has been written about the pre-Nationalised industry, with key texts including C S Peach 1904, LWW Morrow 1927; R H Parsons 1939; T H Carr 1941; 'The Modern Power Station', *RSAJ* 1943; L Hanah 1979; G Stamp 1979.[3] This chronological bias is also reflected in M. Trueman's, 1994 *MPP Step 1 Report*, for English Heritage: *Electric Power Generation*, which covers *Early Generation, 1878-88*; *Growth, 1888-1919*; and *Rationalisation, 1919-48* in greater depth than *Nationalisation, 1948-90* in its Historical Outline section.[4] Its appended tables of selected power stations worthy of further investigation or protection included a number of post-1948 candidates, but stopped at 1967. High Marnham, Retford (1959; demolished) which was Europe's first 1000 MW coal-fired station (using 5x 200 MW sets) was among these, but none of the new generation of 1000 MW and 2000 MW stations, based on the 500 MW set, were included.[5] It is these stations, designed to feed the 275 and 400 kV 'supergrid' - the first truly *national* inter-connecting grid - which exemplified the Central Electricity Generating Board's (CEGB) ambitious yet rationalised power generation programme of the 1960s and early '70s - that form the heart of this desk-top investigation. Far larger and more efficient than those of the late '40s and 1950s, it is these 'high merit', stations that have survived best in the post-1990 privatised era of power generation, bearing witness to the final chapter of one of Britain's great nationalised industries, electricity generation, and the imminent demise of another, the coal industry.

As Michael Shepheard, the Chief Architect of the CEGB, noted in 1968:

> Nothing to compare in scale with the 2000 MW power stations has appeared on the scene before and between 1960 and 1964 no less than thirteen major power stations were released for construction ... All but three of these were of 2000 MW capacity[6]

In order of date of release for construction these were:

West Burton, Nottinghamshire	(2000 MW)
Ferrybridge 'C', West Yorkshire	(2000 MW)
Eggborough, North Yorkshire	(2000 MW)
Kingsnorth, Kent	(2000 MW) (oil-fired)*
Fawley, Hampshire	(2000 MW) (oil-fired)*
Aberthaw 'B', South Wales	(1500 MW)*
Ironbridge 'B', Shropshire	(1000 MW)
Fiddlers Ferry, Cheshire	(2000 MW)
Ratcliffe, Nottinghamshire	(2000 MW)
Cottam, Nottinghamshire	(2000 MW)
Pembroke, Southwest Wales	(2000 MW) (oil-fired; demolished)*
Rugeley 'B', Staffordshire	(1000 MW)
Didcot 'A', Oxfordshire	(2000 MW)

Two further 'conventional' stations of, and exceeding this capacity, were released for construction in the mid/late 1960s:

Drax 1, North Yorkshire	(2000 MW) (3 x 660 MW)
Grain, Kent*	(3000 MW) (oil-fired)*

[*excluded from consideration]

This report is primarily concerned with England's (and Britain's) ten "large set philosophy" coal-fired power stations, dubbed by Reyner Banham as 'Hinton's Heavies' (after the CEGB's chairman, Sir Christopher Hinton) and accorded 'First Division Status' by the CEGB since they had they had high-merit, high-output plant with low operating costs generating 20,000MW from units cooled by the largest towers in the system. The three oil-fired stations (which were never provided with cooling towers) and the two Welsh examples have been disregarded since they lie outside of the requested scope of inquiry of this report. Both the Kentish oil-fired stations are covered in 'The Power Stations of the Lower Thames', RCHME (1995).[7] It considers these large-set survivors in the context of the Central Electricity Generating Board (CEGB), the creation of which saw, for the first time in the industry's long history, the creation of a team of in-house architects and landscape architects along with engineers. As well as looking at the individuals, teams and outside pressures that helped shape the approach of the CEGB and the design of its power houses and landscaped surroundings, the historical overview looks at cooling towers, which formed highly distinctive and emblematic components in their own right. Following recommendations for some further avenues of research and field investigation, are two appendixes. **Appendix 1** is a tabulated list of surviving English post-war power stations. Like the report preceding it, it is based on a synthesis of information derived or abstracted from mostly secondary sources, although pertinent minutes from the Royal Fine Art Commission (the forerunner of CABE, which exercised considerable say in power station siting and design) and information gleaned from the CEGB station opening booklets and Annual Reports were considered alongside contemporary and more recent published literature. The relevant RFAC minutes, relating to the power stations listed in appendix 1, have been transcribed and appended in full (**Appendix 2**).

2. HISTORICAL OVERVIEW OF THE POSTWAR ELECTRICAL GENERATION INDUSTRY

Nationalisation and the decade after, 1948 -58

On the eve of nationalisation on 1 April 1948, the electricity supply industry in the Britain consisted of some 560 separate supply undertakings, both private and municipal. Overseen, from a financial point of view by the government Electricity Commission (formed in 1919), and from an operational point of view by the Central Electricity Board (formed in 1926) this industry, whilst considerably more rationalised than that of the pre-1919 era, was by today's standards, chaotic. There was considerable diversity in the range and quality of supplies available to the public ranging from 100 V, 200 V, 240 V and 2000 V 50 Hz single phase supplies, to 415 V and 6600 V 50 Hz 3-phase supplies, and, in some cases, 250 V and 500 V dc supplies. The National Grid, which was built in an eight-year programme in 1927-35, was not *truly* national,[8] and operated at low voltages - primary distribution was at 132 kV with secondary at 66 kV and 33 kV. There was a similarly wide diversity in the size and arrangement of power stations, and in the boiler and turbine plant which generated the electricity. For the most part they comprised small stations of less than 50 MW output, with boilers operating at modest temperatures and pressures (typically 454 C and 45 bar) and overall thermal efficiencies of the order 20-23%. Despite some experimentation with larger 60 and 75 MW sets at stations such as Barking 'B' (1931-39) and Battersea 'A' (1929-33) - the latter the largest power station in Europe at the time of completion, such isolated examples were very much the exception.[9]

The 1947 Electricity Act saw the replacement of the CEB with a new body, the British Electricity Authority (BEA) which had a remit for England, Wales and South of Scotland. This was administered through 14 Area Boards and 12 Generating Divisions, arranged geographically, with each Area Board responsible to the central authority for retail distribution and each Generating Division responsible to the BEA for the generation and transmission. The construction of new power stations was under the technical direction of the BEA Chief Engineer V. A. Pask (1895-1969) at the London Headquarters,[10] who maintained and controlled departments which covered the design of power plant, transmission system design, future system planning and siting requirements. Some design work was done by the Headquarters organisation in consultation with external engineers, but detailed engineering and contract management was, in most cases, delegated to the Divisions on a geographical basis. The Divisions initiated a degree of standardisation of 30 MW and 60 MW plants which were individual boiler/turbine units instead of the more usual steam range systems. Between 1948 and 1952, some 5800MW of plant comprising 150 units of 30MW and 60MW was installed in 66 power stations.[11] By this time France and the United States were experimenting with more fuel-efficient 200MW sets, and this conservatism reflected Pask's scepticism about the advantages of larger sets, who favoured short-term, proven reliability rather than long-term efficiency and economies of scale.[12] As the immediate post-war crises in power shortages and blackouts abated, a less overly-cautious approach emerged, and the next key development was the design and construction of the first 100 MW non-reheat, single shaft turbine generator fed by a single 100 MW boiler connected directly to it. Six of these units were ordered for the power station at Castle Donnington, Leicestershire, in the early 1950s (commissioned 1956-8; demolished 1996), followed by similar 100 and 120 MW sets at several stations before the overseas benchmark was reached in the mid/late 1950s when five 200 MW units were ordered for High Marnham, Nottinghamshire.[13] At the time of its official opening in October 1962, this 1000 MW station (now demolished) was the largest in Europe, consuming coal from 17 collieries.[14]

Power station architecture in the BEA era, 1948-58

The creation of the British Electricity Authority was not accompanied by any significant reformulation regarding power station layout or architectural style, at least initially. The monumental 'brick cathedral' approach, with the two main visual components, the boiler house and turbine hall, attached in a side-by-side, or occasionally T-plan, configuration, persisted well into the 1950s. Epitomized by Scott at Battersea, it provided a tried-and-tested functional and stylistic idiom that happily accommodated the 30MW and 60MW sets, and, perhaps, reflected the conservative attitude of Pask, and the deputy chief engineer (responsible for power station construction), C. E. H. Verity. In London and the Thames Estuary, edifices such as Brunswick Wharf (1947-56; John Bruce and Farmer & Dark; *dem.*) and Tilbury "A" (1949-58; Sir Alexander Gibb and Partners and Merz and McLellan; *dem.*) and Bankside (1947-60; Sir. G. G.

2. British Electricity Authority 1948-1955, Bankside, London, © Wayne Cocroft

Scott and Mott, Hay and Anderson) exemplified this monumental tradition, a norm echoed in other English towns and cities (**Fig. 2**).

One prominent architectural critic of the period noted, 'Officialdom generally ... is said to like the 'brick cathedral' at least in towns where, as they put it architectural amenities matter.'[15]

Architects had been brought in on major power station projects before Nationalisation 'with the object of preserving municipal amenities', but under the BEA, 'what was previously an exception became a general rule'.[16] The BEA, like the CEB before it, was required to submit all new power stations to the Royal Fine Art Commission, for comment and advice before they were approved. This probably helped maintain a somewhat traditionalist mindset, although the consciously Modernist, fully glazed Barking 'B' and Dunston 'B', Gateshead, both by Merz and McLellan, consulting engineers, had shown there were rare exceptions. Hard economics, however, intervened. Brick cathedrals were costly, and October 1953 saw the publication of the recommendations of the 'Committee of Enquiry into Economy in the Construction of Power Stations' which had been set up by the Minister of Fuel and Power. This report urged the B.E.A. 'to encourage the experiment of new building techniques in the interests of economy' as well as recommending that architects 'be integrated as equal partners in the design team of each new power station'.[17] Farmer and Dark, who had established themselves in the1940s as the leading specialist architects with their traditional brick-clad designs 'became the heroes of the hour',[18] spearheading a more 'functional' approach to power station design. Enriched by the arrival of Architectural Association graduates Andrew Derbyshire and John Voelcker in 1952, their stations at Marchwood, Hampshire (1954-59), Belvedere (1954-60) and Willington, Derbyshire (1954-60) variously made bold use of bright colours, crisp aluminium cladding, glass and concrete blocks and a directness of formal expression of the functions and processes that extended to retracting the 'skin' from weatherproof plant.[19] Marchwood, 'architected ... in a skinny, modern, machine-aesthetic style'[20] and the "semi-clad" Willington 'A', 'a welcome change from the cathedral type of power station'[21]anticipated elements of the "high-tech" architecture of the 1970s. The former invited Robert

Furneaux Jordan to declare ‘the dross, the stylistic cage, has gone; the only major building left is the Turbine Hall',[22] but it was Willington that was more foretelling of subsequent developments. Located on the Trent, close to the Nottinghamshire/Derbyshire coalfields, it incorporated five enormous hyperbolic concrete cooling towers, which, whilst not wholly dominating the turbine hall with its multiple barrel-vault pre-stressed concrete roof, were major visual elements in their own right (**Fig. 3**). At preliminary design stage, in 1953, one report mused 'Whether the finished installation will become a blot on the landscape will depend to a great extent on siting, planting, and the external maintenance of the plant and buildings'.[23] Such concerns increasingly exercised the designers of the next generation of power stations in the era of the CEGB.

The Electricity Act, the CEGB and amenity, 1958-1970

The late 1950s saw further reorganisation of the electricity supply industry. Despite considerable achievements in its first decade of public ownership, including the commissioning of a new power station on average every two months, and the closure of 86 small, inefficient stations, there was criticism from many quarters. The independent, Government-appointed Herbert Committee tasked with enquiring 'into the organisation and efficiency of the electricity supply industry in England and Wales'[24] was critical of how the dual functions of generating power and supervising the industry had resulted in the over-centralisation of responsibility, duplication of effort and lengthy timescales in commissioning stations. Its draft legislation of 1956 was enacted the following year, and the year after saw the formation of the Electricity Council, which replaced the CEA and the Central Electricity Generating Board (CEGB) which superseded the short-lived CEA (formed in 1955 following the separation of the Scottish electricity), and which was responsible for generating power. The CEGB, the largest spender (outside Whitehall) in the British economy,[25] had two principal statutory duties: firstly, to develop and maintain an efficient, coordinated and economical system of electricity supply, and secondly, to minimize the impact of power stations and overhead lines on scenery, fauna and flora. The second duty, which was detailed in Section 37 of the Electricity Act, 1957, was unique at the time as a statutory goal:

3. Willington power station, Derbyshire (1954-60; only the cooling towers remain) © Historic England 28666/03 -

> Here was a major state industry, set up by Parliament to construct what was virtually a new national electric power system, working under statutory guidelines which required it not simply to produce electricity as cheaply as possible, with a little cosmetic landscaping tacked on in a gesture; but consciously to balance in each project the twin objectives of cheap electricity efficiently produced and respect for the environment.'[26]

Respect for the environment, enshrined in Section 37 of the Electricity Act - the so-called 'Amenity Clause' - was among the biggest changes to affect the electricity supply industry in its entire history. By the 1950s the public saw the countryside as increasingly precious if not sacrosanct, and the intrusion of nuclear and hydro-electric power stations into remote coastlands and national parks, and the extension of grid and supergrid transmission lines and towers ('tentacles of industrialization') across the country, brought matters to a head. The growing tendency for cooling-towered conventional stations to be relocated away from town centres exacerbated matters. The organizational structure that emerged under the CEGB attempted to balance the twin demands of economy and amenity. The 12 Generating Divisions were regrouped as five operating regions, each responsible for the generation and supply of electricity from stations within their respective areas. The design and construction of new stations was vested in three geographically specific Project Groups: Southern (based in Finchley, London), Midlands (Selly Oak, Birmingham) and Northern (Pendlebury, near Manchester), with a Headquarters' Generating Design Department in Sudbury House, Newgate Street, London.[27] Sir William Holford, a Professor of Town Planning at University College, London who had played a crucial role in getting landscape design built into the planning of post-war new towns, was appointed as a Part-Time Member of the CEGB (serving 1958-73) with special responsibility for architecture and the conservation of amenity. Previously he had served as Architectural Adviser to the BEA (1948-58), and he was a key figure on the Royal Fine Art Commission (RFAC) and the Historic Buildings Council. The Board's first chairman, Sir Christopher Hinton, a nuclear engineer, was also keenly mindful of the growing importance of amenity, and together they devised a development programme that identified the conflicts and problems, and set out principles and guidelines for resolving them, all detailed in a paper to the Royal Society of Arts in 1959.[28] Part of this strategy was the establishment of a three-man architectural liaison and development group located in the Headquarters' Generating Design Department under Michael H. Shepheard, the nationalised industry's first architect. Appointed in 1959, and serving until 1970, Shepheard 'saw his office grow from a three-man band to a team of eighteen architects and two landscape architects at head office, as well as a team of twelve (mostly landscape designers) working on transmission lines, switching stations and the like'.[29]Its principal function was to brief and advise Holford and the three Project Groups, as well as independent architects and landscape architects commissioned to supervise individual projects. Landscape architecture assumed importance from the outset, and increasingly so during Shepheard's term, with the appointment of specialists early on in the design process, and on occasion, before the appointment of civil engineering consultants, so they could have input at the site selection stage. Holford was very much supportive of this new direction; even before the confirmation of his appointment, he had met with leading landscape architect Sylvia Crowe, to discuss employing members of the Institute of Landscape Architects. Some of his fellow RFAC members proved harder to win over. When John Betjeman first learned of Shepheard's appointment with the CEGB, he reacted with 'horror in his round eyes' exclaiming 'Oh my God you poor chap. Not those dreadful people'![30]

Technological step change: the 500 MW Unit Programme

The pattern of increasing standard size of individual generating sets established in the latter years of the BEA continued, and during the late 1950s the CEGB was ordering combinations of 275, 300, 350 and 375 MW sets which gave more electricity from the same quantity of fuel. Problems of reliability plagued some of the new sets (the most dependable proved to be the 120 MW unit as installed at Rugeley 'A' in Staffordshire and Staythorpe 'B' in Nottinghamshire), and with demand for electricity doubling every eight years, and almost as long a period required to commission a new power station, the board, following technical appraisals with the principal plant manufacturers, decided in 1960 to standardise on single shaft machines at an unprecedented 3000 rev/min and 500 MW output. In 1961 contracts were placed for four units at West Burton, Nottinghamshire and for another four at Ferrybridge 'C' in West Yorkshire (**Fig. 4**),[31] Throughout the 1960s there followed further orders for the new standard 500 MW turbo-generators, which in all comprised 49 units at just 14 coal and oil-fired power stations in England and Wales (four at West Burton, Ferrybridge 'C', Eggborough, Kingsnorth, Fawley, Fiddlers Ferry, Ratcliffe, Cottam, Pembroke, Didcot; three at Aberthaw 'B', and two at Ironbridge 'B' and Rugeley 'B'). The rate of technical advance in

4. Ferrybridge Power Station in 1995 ©Wayne Cocroft

plant design, coupled with the economics of generation, resulted in a vastly different landscape of far numbers of much larger power stations.

Rising demand from domestic users and industry alike (with hire purchase agreements broadening the range of household equipment, and electric welding, arc furnaces and high-speed machine tools demanding more power), an exceptionally cold winter in 1962-3, and the construction of the new 400 kV super grid from 1963 were ample justification for the CEGB's 'large set philosophy'. The operational development, and success, of the 500MW unit led to the first 660 MW units being ordered in 1966 for the following decade's generation of fossil-fuelled power stations, Grain and Drax.

Power station architecture and landscape architecture under the CEGB, 1958-70

The new generation of 1960s conventional power stations were fewer in number (the total annual programme of construction being fulfilled by just three or four, compared to 20 or 30 in the 1950s), but their size and location called for new thinking and design solutions. In early 1961, with the first of the 'super stations' - West Burton and Ferrybridge 'C' - on the drawing boards, Michael Shepheard acknowledged that

> The power station with its cooling towers is beginning to approach half a mile in length. The power station building itself may be 800 ft. to 900 ft. long with a total height approaching 200 ft. The chimneys, usually one to each pair of boilers, if 600 ft. high, will be visible for fifty miles over level country. The cooling towers, handling in all 40,000,000 gallons of water per hour, will rise 375 ft. Tied as they are to large rivers for their supplies of water, and to the coal-fields for their fuel, the siting criteria give small room for manoeuvre; but the influence of these large stations on their surroundings is such that no pains are spared in finding the least objectionable sites from the point of view of their effect on local amenity. By concentrating 10 stations of 1950 vintage on a single site it also becomes economic to spend worth-while sums of money on landscape and planting.[32]

CEGB engineers at this time were 'scouring the riverbanks of England for potential [coal-fired] power station sites',[33] with sites on the Severn (Ironbridge 'B'), Mersey (Fiddlers Ferry), and above all, the Trent (West Burton, Ratcliffe, Cottam, Rugeley 'B') and Aire (Ferrybridge 'C', Eggborough) yielding promising, expansive and ultimately suitable sites. For the Trent Valley, Derek Lovejoy was commissioned to prepare what amounted to regional landscape plan;[34]by the close of the decade the CEGB's programme, building on that begun by the BEA in the mid-1950s, had resulted in a 'Trentside chain of stations contain[ing] examples of almost every technological step forward during those 15 years of dramatic progress - from 60 MW machines through 100 MW, 120 MW. 200 MW. and 350 MW to 500 MW' - the biggest concentration of power in Europe, dubbed "Kilowatt Valley".[35]

The approach and procedure for power station design, once the site was chosen, was refined over the course of the 1960s as experience was gained with each station. As members of the design team, consultant architects and landscape architects advised on site layout, the orientation and shapes of buildings, and the choice of colour and texture in the main visual components. Yet with a reputed budget of less than 2 per cent of the total investment,[36] the architectural contribution was necessarily constrained within certain parameters, such as advising on the relationship of cooling towers to the station, or, when two equally economic alternatives were available, the orientation of the switching station to the station. Unlike an earlier generation of sites, these gargantuan complexes were often remotely sited, with site boundaries typically preventing close-up appreciation of architectural detail. Shepheard recognized that, as among the largest of all man-made structures, they had no 'inherent scale relationship'[37] with their environs, although he possibly disagreed with Reyner Banham's observation in 1970, that 'there has been very little that architects could do about the shapes of the main forms or their grouping, and precious little that landscaping could do either, when the structures it was supposed to hide were between twice and 150 times the height of the tallest, deciduous greenery available'.[38] One of Shepheard's intentions was to use consultant designers 'to bring down these vast envelopes to human terms',[39] to ensure they benefited from architectural input at an early stage (thereby avoiding 'a styling job')[40]and above all, make them more palatable to the public and growing amenity lobby. Significant resources were channelled to this end, including articles in *The Guardian*,[41] an exhibition at the Henry Florence Hall of the RIBA in 1963 called 'The Architecture of Power',[42]attractive, souvenir booklets of the stations as they opened, and further talks and articles by Holford, Shepheard and others throughout the course of the decade and beyond. Although aspects of this giant PR-exercise were not new - echoing the BEA's series of coloured posters that illustrated 'how well these buildings lent themselves to elegant pictorial representation ... with the object of popularizing the use of electricity in industry and in the people's homes'[43] - the unprecedented scale of 'Hinton's Heavies', with their cubic and hyperbolic forms looking quite unlike the 'brick cathedrals', demanded a suitably large-scale response on many fronts.

Taken as a whole, it is possible at this preliminary stage of knowledge to deduce some of the main approaches to large coal-fired power station design in the 1960s, here grouped under the headings Architecture and Landscape architecture.

Architecture

By the early 1960s Shepheard and his architectural team at the CEGB, and the consulting architects, were fully ware that architectural character and expression could only be appreciated - grasped even - from middle or long-range viewpoints. The enormity of the standard components of a 2,000 MW station - typically one or two BT-tower-sized chimneys, eight even taller and considerably bulkier cooling towers, an adjoining turbine and boiler house covering 15 acres, switchgear buildings the size of aircraft hangars, office block, dust precipitators, coal stores and sidings encompassing 50-plus acres, and a private 'merry-go-round' rail loop to bring coal in and take pulverised fuel ash away - precluded otherwise. As such, character depended very much on the massing of the main blocks in relation to the chimney or chimneys, the grouping of the cooling tower field, and variation in the colour and texture of the cladding. Skilful, reflexive interplay of the constituent parts rather than vested monumentality in any one of them typified the era. In Shepheard's view, the architect's job was 'to simplify and clarify the elemental geometry'.[44]

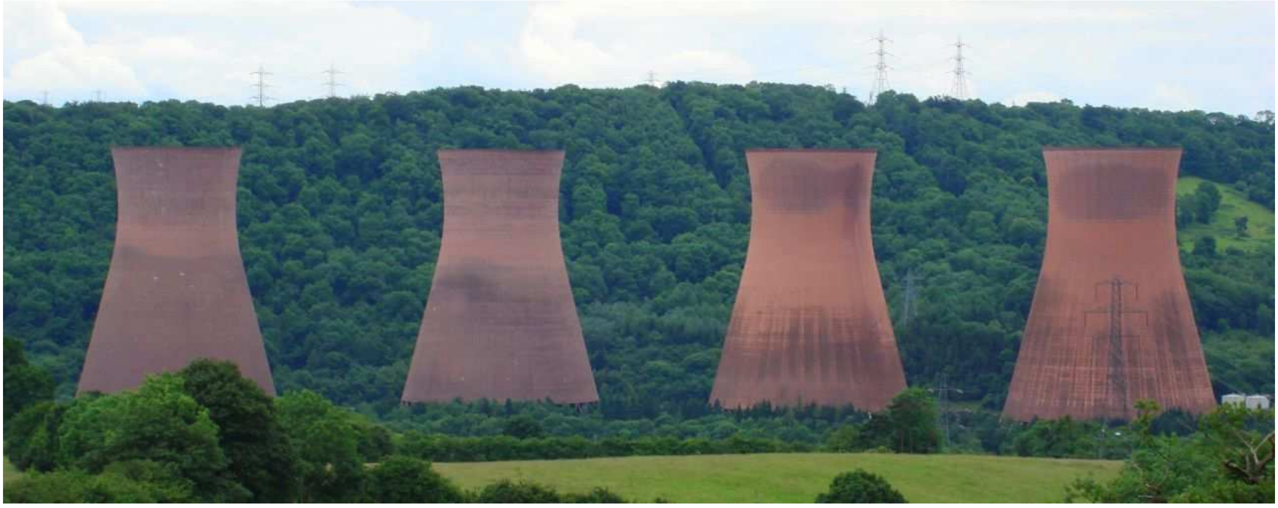
At Ferrybridge 'C', West Yorkshire (1961-7; Building Design Partnership), the two chimneys rose behind the boiler house and turbine house, with a lozenge array of eight cooling towers ranged to one side (**Fig. 5**). From certain viewpoints these elements combined to form a pictorial composition, but to traditionalists of the brick cathedral era, such as A. Trystan Edwards, their physical isolation precluded any sense of true architectural composition: 'the lay-out is in bits and pieces and no amount of care expended upon the design of these separate and individual items of plant can ever produce a unified architectural ensemble'.[45]

Far more successful in both architectural and pictorial terms was West Burton, Nottinghamshire (1961-67, Rex Savidge & John Gelsthorpe of Architects' Design Group), which also set two chimneys behind the boiler house and turbine house, but which achieved greater coherence and balance by the careful positioning of the cooling towers (see front cover). These were split into two groups at either end of the station (four in lozenge formation and four in a line) greatly improving views from the surrounding country of the 500 acre site. This grouping was arrived at following extensive model studies by Gordon Graham using a device called a heliodon to see how different groupings would appear at various dates and times of day. This method of approach, and the analytical work undertaken, laid the foundations for a less subjective and more logical criticism and assessment of visual design problems faced by the CEGB, leading by the late 1960s to the Zones of Visual Influence (ZVI) methodologies that are still employed by Landscape Architects (e.g. for the siting of Wind Farms and other visually intrusive infrastructure).

5. Ferrybridge 'C', West Yorkshire in 1967 -

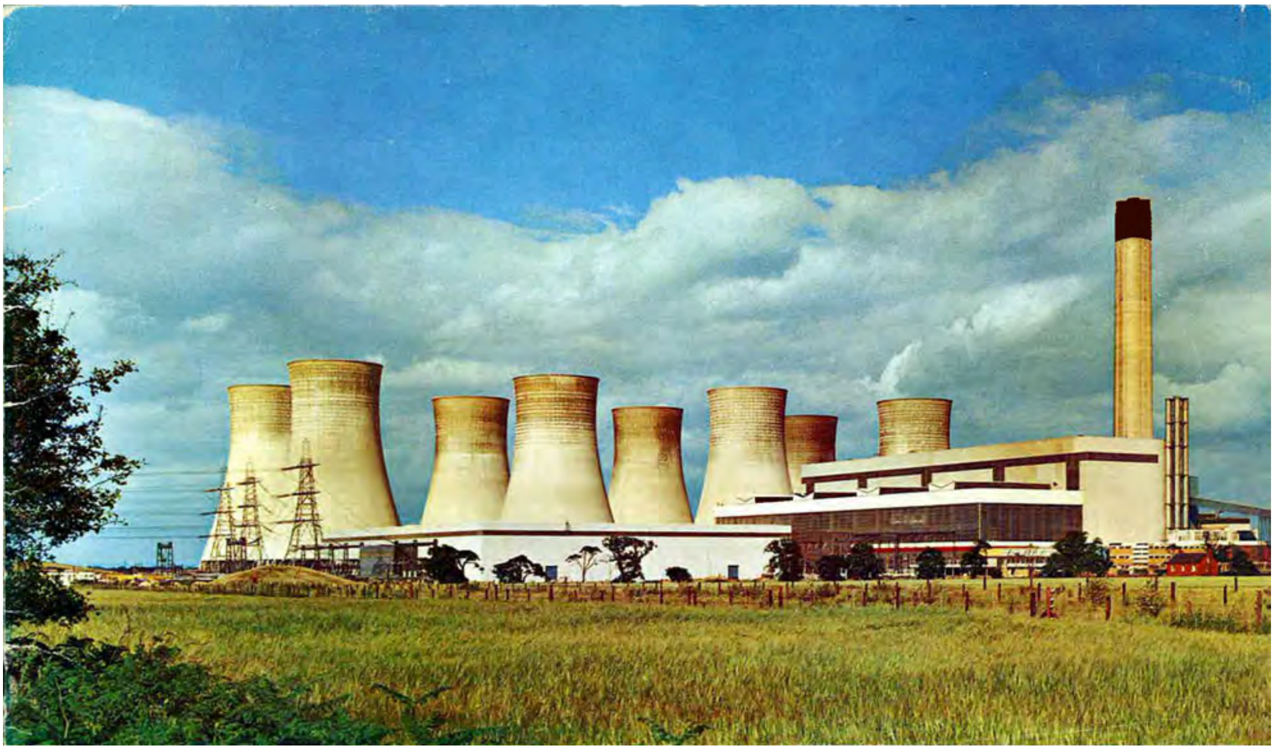
The approach used at West Burton, which also employed more realistic, coloured models (**Fig. 6**) was seemingly used in almost all subsequent 2,000 MW stations, including Didcot 'A' (1965-70) where Sir Frederic Gibberd, a member of the RFAC, split the six towers into two triangular groups half a mile apart to lessen their impact on the surrounding countryside. West Burton 'represented the first attempt to predict, in comprehensive and systematic manner, the visual impact of a power station',[46] and set the mould for subsequent design approaches, also particularly the use of colour and visual fulcrums. Savidge and Gelsthorpe used dark grey cement for two of the four towers in the lozenge group, which provided tonal contrast to the their neighbours and prevented the group coalescing, or 'blocking' in conditions of haze or mist, which would have increased their visual bulk. The boiler and turbine house were similarly treated, with large areas of contrasting black and white sheeting on adjacent sides of the buildings. More daringly, a muted yellow was used for the most northerly, and slightly offset cooling tower (creating a point of reference visible from multiple viewpoints around which the station could articulate and cohere) and brighter yellow-finished aluminium sheeting was used to clad the 400 kV switch house, the side walls of the crusher, and the ends of the triangular trusses above the black-sided turbine house. Whilst Gibberd privately dismissed such use of colour 'too arty, too trivial, too mannered and too inconsequential',[47] he made use of the fulcrum concept at Didcot, using the chimney in this role, around which the towers appear to move and change in number and scale, merging with each other or the main building. Coloured cooling towers were used at the broadly contemporary, but smaller, Drakelow 'C', Staffordshire (1961-3; Frankland Dark of Farmer and Dark; *demolished*) where one of the towers in each triangular group of three was coloured a warm red to bring them visually forward. At Rugeley 'B', Staffordshire (1964-70; L. K. Watson and H. J. Coates), the architect coloured two of the four towers a pinkish-red colour to heighten what he saw as the inherent femininity of the hyperbolic form.[48] Boldest of all are the four cooling towers of Ironbridge 'B' (1963-68; Alan Clark of Sir Percy Thomas and Son), set in a sweeping arc, were coloured

***6**. Model of West Burton power station* reddy-pink to imitate the local earth, forming a striking composition against the verdant, hilly backdrop (**Fig. 7**). After West Burton, the station to make the boldest use of colour in the powerhouse proper was Cottam, Nottinghamshire (1964-70; Yorke, Rosenberg & Mardell) where 'Cottam Amber' colour cladding wraps around the turbine and boiler house, emphasising its functional grandeur at the heart of the complex.



7. Ironbridge 'B' Cooling Towers

Surface finish and material texture was used in place of colour in other stations. At Eggborough, North Yorkshire (1962-67; George Hooper of Sir Percy Thomas and Son) large expanses of anodised aluminium cladding and dark glazing gave a cool and defining architectural expression that subtly contrasted with the warm concrete towers and black-capped chimney (**Fig. 8**). The 'parent' on Ironbridge 'B' (which was executed to half the capacity), this 400 acre complex exemplified an 'ideal' diagrammatic layout, with a clear relationship between the grid of the station's buildings, the 'merry-go-round' coal delivery by rail, and the cooling tower field. Ferrybridge 'C' (1961-67, Building Design Partnership) and its 'daughter', Ratcliffe, Nottinghamshire (1963-67, Godfrey Rossant & J.W. Gebarowicz of Building Design Partnership) each



***8**. Eggborough, North Yorkshire (1962-67; Sir Percy Thomas and Son)* employed white cladding to clearly differentiate the boiler house/turbine house and dust precipitators from the rest of the complex, including the extensively glazed and low slung 400 kV switch housed. In both cases, the end elevations of the boiler house/turbine house were given vertical bands of glazing to accentuate their verticality, and their four concrete coal bunkers projected above the roofline. Such 'functional' expression of the four 500 MW turbo-generators was a feature of other stations, including Cottam, Eggborough and Didcot. Those stations that had switching stations of the 'open' or fully exposed type, such as Didcot and Rugeley 'B', did so for reasons of practicality and economy (where local atmospheric conditions permitted), rather than explicit functionalism.

Although difficult to deduce in the absence of site visits, much design effort was seemingly lavished on the administration and office buildings, which housed the station's large workforces. At Ratcliffe (and ostensibly Ferrybridge 'C'), the two storey steel-framed administration/technical block was planned around a courtyard, designed to provide a more humanised, smaller-scale environment in contrast to the size and character of the gargantuan surroundings. It also, uncommonly, made use of open-air sculpture; an expressive piece by Richard Fowler called 'The Generators'. Reyner Banham singled out this element of 'Hinton's Heavies' for criticism, seeing them as overly-precious, egotistic statements by the consulting architects. Cottam's general idiom, 'a sensible combination of metal, glass and concrete block that is both sharp and cool' was, in his view, 'over-wrought and made gratuitously rhetorical' in the office block, '... the whole thing is raised on a sort of truncated brick pyramid to emphasise its status as the kind of artwork the rest of the buildings are not'. Banham was even more scathing of Drax, North Yorkshire (1967-71; Jeff King of Clifford, Tee and Gale), the first half of which had been substantially completed by 1970 (**Fig. 9**):

> Less a brick cathedral than a concrete bunker, it exhibits that obsession with ribbed surfaces and forceful projections that have their origins in Brutalism and their confirmation in that craze for the work of the Nazi's Todt Organisation that fluttered architecture's fashiony fringes in the mid-sixties. Not restricted to the office-block scale of buildings, it has also erupted on the control-room side of the boiler house with an uninhibited gaucheness rare in recent British design.[49]

9. Drax Power Station. © Historic England 28607_066

Nearly all of the consultant architects of the Trent and Aire group of 2,000 MW stations were friends of Banham. Interestingly, many of these were 'new blood, doing their first power stations'[50]- a broader point applicable to most of the fossil-fuel stations of the 1960s. Farmer and Dark, the specialist practice that dominated the field in the 1940s and '50s were no longer kings of the field in this decade, although they were consultants for Drakelow 'C' and helped design one of the following decade's foremost stations - the oil-fired Grain Power Station (1971-*c*1980) which for the Thames Estuary marked 'a return to monumentality without compromising on the functional expression of form and the elimination of superfluous detail'.[51]

Landscape architecture

After road building, electricity generation and transmission had perhaps the largest impact on Britain's landscape than any other activity in the 1960s and '70s. Until the CEGB era, and its duty to take account of the effect of its proposals on the natural environment, landscaping for power stations was for the most part cosmetic and low-key - flower beds in front of administration blocks; trees lining approach roads, planted by the Roads Beautifying Association. Only in a few isolated examples, such as the highly-sensitive hydroelectric schemes at Ffestiniog (completed 1963) and Rheidol (1957-1962) in Wales, and the nuclear station at Bradwell, Essex (1957-62) was anything more attempted.[52] This picture changed dramatically with the advent of the CEGB and especially with its capital-intensive 500MW programme of the 1960s, which saw it become the most prominent patron of landscape architecture in the UK.[53] As well as funding landscape design, the CEGB also advanced its methodological frontiers: new techniques were developed in the assessment of amenity, involving drawings, models, photomontage, and, in the 1970s, computers.

It was Brenda Colvin (1897—1981) and Sylvia Crowe (1901–1997) who early on helped shape the CEGB's attitude and approach to landscape design. Lifelong friends and colleagues from *c.*1945-1965, they practised from an office in Gloucester Place, London, although they never worked as formal partners.[54] Their design approach during the 50s and 60s, a period when minimalism was one unassuming simplicity and naturalness, with many of their interventions perceived as part of the natural order of things. For power stations, they thought it mistaken to attempt to humanise them, favouring large-scale open settings that accentuated the elemental quality of the giant structures, with artificial mounds and trees used to screen the untidier or unsightly components such as coal heaps.[55] In 1960 Crowe looked 'forward to seeing in perhaps ten year's time, a land free from wires, in which at decently long intervals magnificent power stations will rise as natural focal points of a clear uncluttered landscape'.[56] Colvin was the first to become directly involved with the landscaping of power stations, working in 1952 on Farmer and Dark's coal-fired stations at Keaby, North Lincolnshire and Stourport, Worcestershire, and then, more ambitiously, at Drakelow 'C' from 1959.[57] Crowe's work really began in the era of the CEGB, and was entirely restricted to nuclear power stations (Bradwell, Trawsfynydd (1959-65) and Wylfa (1963-71), and high voltage transmission line routing in southern England. However, her conviction that the 'garden treatment' of coal-fried stations accentuated the disparity in scale 'by interposing a scale even smaller than that of the surroundings' helped banish the older, cosmetic approach.[58] And like Colvin, she was well connected. She already knew Shepheard from working on Basildon New Town, and early on in her term as president of the Institute of Landscape Architects in 1957–9, Holford met with her to discuss employing members of the Institute of Landscape (see above). Thereafter, some of the most prominent names in the field became consultants for CEGB schemes of the 1960s and '70s , including Kenneth (d.1982) and Patricia Booth, Frederick Gibberd (1908-1984), Derek Lovejoy (1925-2000), Peter Shepheard (1913-2002), Peter Youngman (1911-2005), Cowyn Foulkes, Gordon Patterson, Arnold Weddle (1924-1997), Sheila Haywood and Milner White. Much of this work was co-ordinated by Shepheard and his first landscape assistant John Herbert, who had both landscape and town planning qualifications and who dealt with preparatory work and research outside of the consultants' commissions.[59] Herbert's successor, A. H. Murray, was the first Honorary Secretary of the interdisciplinary and still active Landscape Research Group, formed in 1967, organising its first symposium on Methods of Landscape Analysis, which Holford chaired.[60]

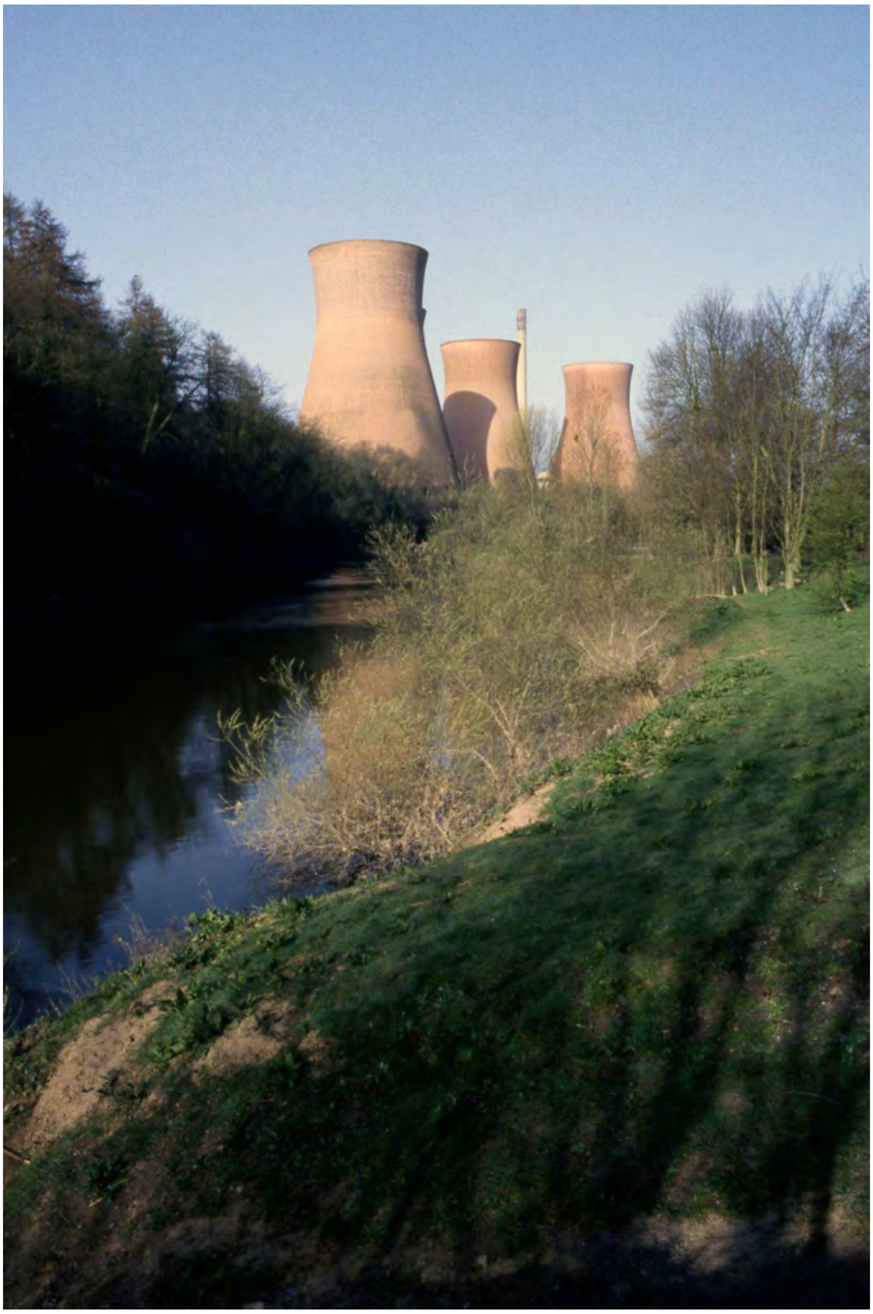
Derek Lovejoy landscaped West Burton, the first of the CEGB's new generation of power stations based on the 500 MW turbo-generator. Its situation in the Trent Valley - a predominantly flat agricultural landscape - meant that even minor vantage points afforded sweeping views. Rather than attempting to obscure as many views of the station as possible, Lovejoy's solution was to control them by judicious tree-planting outside of the station's site, and partial screening within it. Planting was carried out within a 3-mile radius around the station, with native trees planted in the centre of hedgerows, roadside verges and in fields so as to 'frame certain views of the station creating dramatic incidents from vantage points for pedestrians and vehicular traffic moving through the area'.[61] A large number of sketches, illustrating views of the station from nearby roads and viewpoints were prepared in advance of the final scheme. Lovejoy also employed an extensive water barrier in place of the usual - and much disparaged - security fences used by the board, which as well as excluding 'the unwelcome visitor' provided 'an imaginative setting for the station and cooling towers' which was floodlit at night.[62] Trees were also planted within the station boundary, although not in close proximity to the cooling towers, which would have dwarfed them, and had their draught impaired by them; their purpose was to provide a satisfactory environment for the employees. Long term safeguarding of the woodland was ensured through Tree Preservation Orders. Lovejoy's off-site approach extended far beyond the 3-mile circle around the station: his regional landscape plan (see above) was carried out and maintained by the County Council.[63]

Brenda Colvin recognised the impossibility, and in her opinion, undesirability, of screening the larger components, seeing the problem as one of how best to 'integrate and relate them to their surroundings'.[64] Her approach to the new generation of 1960s stations was to employ massed planting of trees and shrubs to give strong horizontal base lines that balanced the height of the cooling towers and principal buildings whilst concealing only the 'unsightly and nondescript'[65] low elements such as coal stores, railway sidings, car parks, sheds, stores and operational space. As well as screening such 'huddle and clutter', and proving horizontality, verdant horizontal belts also integrated with the field boundaries, helping graduate the scale

10. One of Brenda Colvin's models of the landscaped ash mound produced by Eggborough and Ferrybridge power stations (Gale Common As Disposal Scheme)

of the installation into the surrounding agricultural pattern. She applied these techniques at Drakelow 'C', an ambitious project that included planted woodland belts around the edge of the site, preservation of existing woodland, a wildfowl nature reserve on flooded former gravel pits (now an important site for overwintering birds), and a novel, award-winning 'nature walk'.[66] At Eggborough, she encircled almost the entire site with vegetation, paying special attention to the merry-go-round railway and coal store, which were screened below soil banks planted with trees. She was also brought in by the CEGB to provide a suitable landscape solution to its highly ambitious and seemingly unexampled ash disposal scheme at Gale Common. In 1962 some 700 acres of Gale Common, a former coal-mining site roughly midway between Eggborough and Ferrybridge power station, was purchased for the purpose of receiving their ash once excavations in the area had been filled. The Pulverised Fuel Ash (PFA) was to be pumped hydraulically in underground pipes and dried out in a series of lagoons. Over the course of the stations' 30-year lifespan, it was estimated the ash generated would create a hill some 150 ft. high, which with appropriate landscaping and levelling, would become a farmland plateau, with sheep grazing on the banks, and cultivation on the upper levels. Colvin's original intention of creating a terraced hill with steep banks, inspired by Maiden Castle, was ultimately abandoned because of practicalities that favoured more gradual slopes, but the final three-hummocked 'earthwork', now used recreationally for Motocross, bears witness to her planting, if not some of her original prehistoric landscape-inspired intentions (**Fig. 10**). At Rugeley 'B', Staffordshire, Colvin employed remote, offsite planting to mitigate its impact in the landscape. She employed the technique of shelter belt planting, incorporating existing trees, and her involvement seemingly continued until the station's completion in 1969, when she entered into partnership with Hal (Harry Traherne) Moggridge (1936-), formerly an assistant to Sir Geoffrey Jellicoe, creating Colvin and Moggridge.[67]

Colvin was able to avoid extensive, and often expensive, ground modelling at Eggborough and Rugeley because of the abundance of trees in the landscape. She though her approach would probably work in a treeless environment, with ground modelling alone. In the verdant but highly sensitive environs of Ironbridge 'B', Kenneth and Patricia Booth had one-and-a-half million tons of earth shifted in a scheme that employed both tree belts and ground modelling. Following preliminary visual analysis using models and maps, with circles representing distances of up to four miles applied, site inspections were conducted at key points to assess the visual impact, particularly as viewed from the west. As a result, tree belts were planted near Leighton and Cressage to minimise the visual impact on those living and travelling on both sides of the Severn valley. Booth, working closely with Clark, created a series of plateaux below the station, one incorporating the horizontal conveyor. These embankments were planted with trees and shrubs, and an artificial hill, formed from excess spoil, was used to screen the coal stocks from the site's western



***11.** Ironbridge 'B' in 1995, with the Booth's woodland landscape fully matured © Wayne Cocroft*

perimeter.[68] Stands of conifers were sited closest to the browny-red cooling towers, to avoid clogging by leaf fall, but on other slopes thick planting of deciduous trees softened the impact of the buildings, which, because of the 'colours used, pinky browns and dull green-greys, cause them to merge into rather than stand out from the landscape' (**Fig. 11)**[69] Kenneth and Patricia Booth also used wooded ground modelling techniques for Cottam Power Station, where a 50 ft-high tree-clad ridge was constructed to shield Cottam village from the visual mass and noise of the station. One end of the ridge linked with a new road over-rail bridge, allowing it to read as a continuation of the land form and not as an isolated structure. Wooded embankments were used in other places to screen the switching compound, and off-site, some 6,000 trees were planted on both public and private land within a radius of two-and-half-miles of the station.[70]

By the time of Gibberd's landscape proposals for Didcot - the last of the 2,000 MW coal-fired stations, techniques of visual analysis, planting and ground modelling were highly evolved. His approach was very much in alignment with Colvin's, apparent in his early thoughts on the matter:

> The scale and height of the buildings is so large that tree planting on the site is ineffective from distant valley views; closer to, it becomes significant as it both screens the lower structures and forms a green base for the larger ones linking them to the valley floor.[71]

Gibberd responded to the ordered, rectangular grid of the site (a former Ordnance depot), planting five square blocks of woodland within the rectangular site, with each one placed in relationship to particular buildings as well as to general prospects of wider compositions within the site and from surrounding fields. The effect, once the trees reached maturity, was to open up or close up views and create a series of distinct visual compositions as the viewer approached, or moved around the site. A wooded earth mound was used to limit the view of the 40ft-high coal store from the nearby road and railway. Shingle, which was both hard-wearing and easy to maintain was used to create the hard surfaces around the main building group and switchgear compound: visually this cohered the buildings, structures and roads, providing a pleasing contrast to the concrete, glass and metal environment within the site, and green fields beyond.[72] Colvin, who objected to its siting, was impressed at the way Gibberd had eased the station's giant structures 'into this inappropriate and resentful setting'. She liked its simplicity, the screening of 'inevitable clutter' by earth mounding and planting, and the balance and contrast the trees gave to the towers' scale and 'mechanical forms'. She was less convinced by the choice of rectangular groups of trees - one of the most innovative aspects of Gibberd's design - stating 'perhaps a sinuous flow of less staccato character in the vegetation of the base line might have related the concrete structures more decisively to each other'.[73] Nevertheless, Didcot, like Cottam and West Burton before it, all received landscape honours.[74]

The CEGB, reorganisation and change, 1971-1980

In 1971 the CEGB reorganised to give more delegated authority to the five operating regions, and over the period 1971-3 the three project groups and the London Headquarters specialist departments including the Generation Design Department were merged into the Generation Development and Construction Division (GDCD). Based at Barnwood, Gloucester, the GDCD was responsible for the design, development and construction of new plant and the design and construction of new power stations.[75] Howard Mason, who had joined Michael Shepheard's office in the early 60s took up the position of CEGB Architect following Shepheard's departure in 1970, serving until his death in 1979 after which Rex Savidge, the consultant architect for West Burton took up the position.[76]Lord Holford retired in 1973. Having served 15 years as a part-time member of the CEGB, perhaps his crowning achievement was in maintaining the quality of design standards, having used 'the ever-rising level of public disquiet as a political stick to impel the Board towards the aesthetic carrot of improved design and location'.[77]

Although coal remained the main fuel (accounting for 58% of Britain's electricity in 1972, compared to 27% oil, 11% nuclear, 2% gas and 2% hydro-electricity), the 1970s saw the construction of the last of England's coal-fired stations of the 20th century. Natural gas firing was used from 1967, and following the oil crisis of 1973 the main trend was a decrease in the percentage of oil burnt and an increase in the level of nuclear generation.[78] Environmental concern over contamination and pollution of the land, water and atmosphere increasingly overshadowed questions of visual amenity.[79]

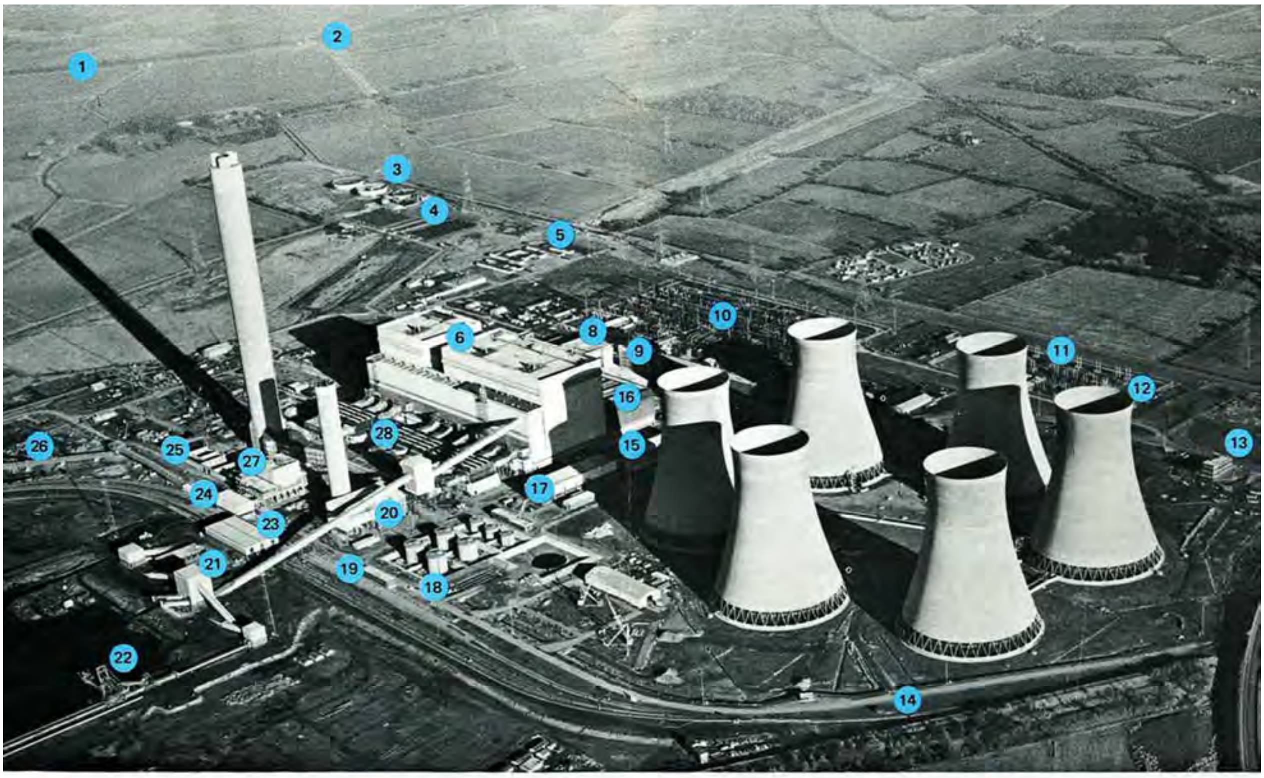
Power Station Architecture and Landscape Architecture under the CEGB, 1971-80

The architect's section, headed by Howard Mason, continued to act as the main internal judgment on matters of architecture, landscape and amenity generally, functioning as interpreter to the Board by presenting matured schemes from consultants. However, following the formal creation of a house style steering committee in the late 1960s, and 'disenchanted with its unprofitable role as a kind of internal pseudo Fine Arts Commission, trying to vet external architects work', the in-house Architectural Division increasingly transformed itself into 'a highly competent design and development team'.[80] As a result, the CEGB began forging a stronger house style and design profile that extended from ancillary buildings at power stations to items of furniture, fencing, livery, colour (flame orange) and district offices, training centres and so forth. On the landscape front, Ronald Hebblethwaite managed a small team of landscape staff who undertook research on how trees might be established on hardened pulverised fuel ash, computer techniques of visual analysis, and occasional 'executive commissions' hitherto the preserve of consultants.

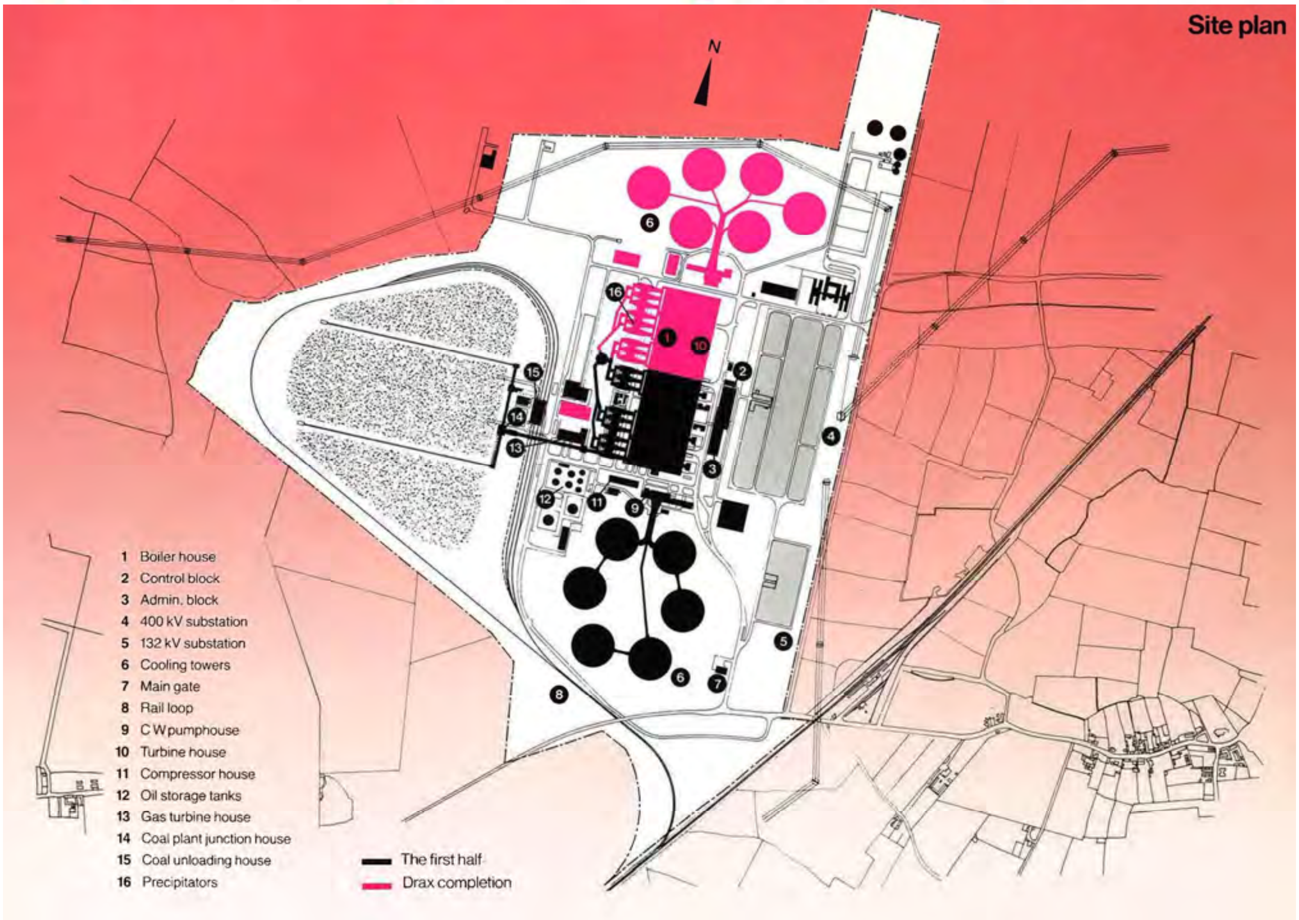
However, this did not extend to the full landscaping of power stations, and the same remained so for the in-house architects, who never designed a power station, at least a large coal-fired one.[81] The two principal (conventional power station) projects of the 1970s, Drax and Grain, involved external firms, respectively Farmer and Dark and Clifford, Tee and Gale, the latter landscaped by Arnold E. Weddle. Both stations marked the grand conclusion of the CEGB's 'large set' philosophy; Grain was the largest oil-fired station in Europe, and possibly the world - when completed in 1979, and Drax, built in two stages (1965-74 and 1978-86) the largest coal-fired station in Western Europe. Both housed a new generation of 660 MW turbo-generator units; five at Grain and Six at Drax.[82]

***12.** Drax, Phase 2, North Yorkshire (1978-86) nearing completion in c.1985. Then largest coal-fired station in Western Europe, its turbine house and boiler house is 433m (1421 ft) long and the entire site is 368 hectares (909 acres)*

The dimensions of the 4000 MW Drax scheme were unprecedented in power station design, and its location on the same flat plain on which Eggborough and Ferrybridge were sited demanded that especial consideration was taken with appearance and setting (**Fig. 12**). To modulate and break up the enormous building envelope, executed in large part in concrete, Jeff King of Clifford, Tee and Gale employed giant louvers at high level in the boiler house and along the east front of the turbine house. The idiom carried through to the elevational treatment of the precast-concrete administration block, where strip windows project under splayed canopies, imitating louvers. The whole complex is framed at either end by two visually striking groups of cooling towers, one in a circular array of six, the other in a diamond-shaped pattern of six. Banham remained unconvinced (see p.), stating also 'whatever Michael Shepheard, the CEGB's chief architect, may have hoped that consultant designers could do to "bring down these vast envelopes to human terms" has clearly been frustrated at Drax by the consultants' inability to resist what he calls "the temptation to be grandiose."[83] (Reyner Banham, 1970). Yet Weddle's landscaping scheme, employing strategic tracts of woodland to avoid the vast complex dominating nearby villages won commendation from Sir Geoffrey Jellicoe and the rest of the Royal Fine Art Committee.[84] Its cooling towers can be clearly seen from the Eggborough and Ferrybridge to the west, and its 258m (850ft) high chimney, which would dwarf the BT Tower visible for miles around.



1 RIVER OUSE
2 C.W. MAKE–UP PUMPHOUSE
3 SEDIMENTATION PLANT
4 SLUDGE LAGOONS
5 PURGE JUNCTION CHAMBER
6 BOILER HOUSE
7 C.W. PURGE PUMPHOUSE
8 CONTROL BLOCK
9 ADMIN. BLOCK
10 400 kV SUBSTATION
11 132 kV SUBSTATION
12 COOLING TOWERS
13 MAIN GATE
14 RAIL LOOP
15 C.W. PUMPHOUSE
16 TURBINE HOUSE
17 COMPRESSOR HOUSE
18 OIL STORAGE TANKS
19 OIL UNLOADING PUMPHOUSE
20 GAS TURBINE HOUSE
21 COAL PLANT JUNCTION HOUSE
22 BUCKET WHEEL MACHINE
23 COAL UNLOADING HOUSE
24 DUST CONDITIONER HOUSE
25 ASH PITS
26 DUST CONVEYORS
27 DUST BUNKER
28 PRECIPITATORS



3. HISTORICAL OVERVIEW OF COOLING TOWERS

The concrete cooling tower was the most emblematic component of mid-to-late 20th-century thermal power station, both in Britain and in many other parts of the world. It is almost a century since the first hyperbolical cooling tower was erected at Emma colliery, Limburg, Netherlands to the revolutionary designs of (Professor) Frederick K. van Iterson (1877-1957), a Director of the Dutch State Mines, and Gerard Kuypers, civil engineer. Since then the form has enjoyed both refinement and considerable success (tempered by occasional failure and collapse), with an attendant large body of technical and cultural literature. It is not the intention here to recount the history and functioning of cooling towers, since this has been variously touched on and explored in a number of accessible articles and books, many of which are listed in the bibliography, below. Rather, the intention here is to emphasise some key points, bring some new research to bear on the British firms involved, clarify some misunderstandings, and make some suggestions for future research. For additional illustrations, see Appendix 1.

History in Britain and worldwide comparisons

L.G. Mouchel & Partners, Civil Engineers, of Westminster introduced the first hyperbolic reinforced concrete cooling towers to the UK in 1924, at Lister Drive Power Station in Liverpool. The firm's senior engineer, A.T.J. Gueritte, persuaded the City Engineer, P. J. Robinson, to consider the new form, as pioneered by van Iterson and Kuypers in Holland, and as a result five were built at site (with a further seven added in the 1930s). The success of this experiment saw the firm win further contracts with the City Electrical Engineers for Wolverhampton, Birmingham (Wolverhampton and Hams Hall Power Station, in 1925), Coventry (1927), and Leicester and Croydon (before 1930).[85] Although small by later standards, the largest of these early pioneers, at Hams Hall, stood an impressive 215 ft high with a diameter exceeding 175 ft at the base. Besides offering numerous advantages in terms of maintenance, fire-resistance, longevity, and structural strength compared to either timber-walled or ribbed reinforced concrete alternatives, hyperbolic concrete shells were considerably more efficient at their job, keeping pace with increasing boiler and turbine capacity. Princes Power Station 'A', Necheils, Birmingham, required 45 timber cooling-towers when built in the early 1920s, circulating some 7.8 million gallons of water per hour. Princes Power Station 'B', commissioned in the early 1950s, required just three hyperbolic cooling-towers, circulating 9.6 million g.p.h.[86] Mouchel & Partners had, by 1930, erected 40 hyperbolic towers in Europe, South Africa and the Far East. These varied greatly in size and capacity; the smallest circulated just 44,000 g.p.h. and the largest up to 5 million gallons g.p.h.[87] In the UK, Mouchel dominated the market for hyperbolic concrete cooling towers until the early 1960s, receiving 157 commissions in the UK, and 209 in Europe, Africa, India and China, some rising to 500 feet in height with a base diameter of 400 feet.[88] These 366 commissions resulted in over 600 Mouchel cooling towers worldwide by the early 1960s, with the majority in the UK - which could be described as the second (after The Netherlands) 'cooling tower land, i.e. a landscape with the hyperbolic shape marking the skyline of an industrial area ... with van Iterson towers the symbol for power generation in particular or for industry in general'.[89] Mouchel could not hold the field for long, and the other pioneer of reinforced concrete construction, Monier, introduced the form in its sphere of influence, a belt extending from Germany through Austria to Hungary. This spread was relatively minor, and may have been related to fear of patent infringements. In some other countries, other factors militated against their take-up. In America, for example, the early success of fan-assisted cooling towers delayed the appearance of natural draught hyperbolic cooling towers until the 1960s.[90] In Britain, it would seem that companies such as Davenport Engineering Co., Ltd, and Film Cooling Towers (1925) Ltd (both of which built 'traditional' timber towers in the early 20th century), began moving into the thriving hyperbolic concrete field in the post-war years.[91] Film Cooling Towers (1925) Ltd had by 1940[92] managed to patent a concrete tower that differed only slightly in its geometry from the van Iterson type. According to the firm, these non-hyperbolic cooling towers were constructed with conical/toroid geometry for 'constructional simplicity'.[93] A more recent assessment suggests 'that this was merely the case of evading the patents of van Iterson and Kuypers'.[94] The company won the contract for erecting the four natural draught cooling towers for Rugeley 'A' Power Station, Staffordshire in 1958 - probably the first use of the cone-toroid type by the CEGB;[95] and went on to erect (as Film Cooling Towers (Concrete) Ltd) among others those at Thorpe Marsh, Ferrybridge 'C', Ironbridge 'B', Cottam and Didcot.[96] Davenport Engineering Co. Ltd., of Bradford designed and built the towers at West Burton and Eggborough;[97] Bierrum and Partners those at Ratcliffe, Rugeley 'B' and Drax Phase 1.[98] It is unclear in the present state of knowledge whether those built by Davenport Engineering Co. Ltd and Bierrum and Partners were constructed to the hyperbolic or cone torroid form; their appearance would favour the former although their exact geometries may possibly place them between the two.

The collapse in high winds on 1 November 1965 of three of Ferrybridge 'C's eight cooling towers resulted in a number of recommendations and minor changes in design. The investigating committee found weaknesses in the specification prepared by the consulting engineers, C.S. Allott & Son, although the CEGB accepted that 'full responsibility for the specification and design of cooling towers rests formally with its Civil Engineers'.[99] In essence the CEGB's own specifications and guidelines under-estimated the reinforcement necessary to resist severe wind loadings, and the use of single layer reinforcement was considered inadvisable. Bill Hannah, the CEGB's Chief Engineer and investigating secretary later recalled 'I was horrified to discover that the widely used design specification had just evolved from a 1920s Dutch development and that, in practice, nobody had been designing the towers from scratch. We discovered other towers throughout the country in a much weaker state than the ones that collapsed'.[100] The CEGB, which had been the prime mover in research into cooling towers before the collapse, continued its studies and investigations more intensively, leading to an understanding of the dynamic stresses arising from turbulence and the effects of tower groupings. In the immediate aftermath, those towers in the course of construction at other sites - Eggborough, Ratcliffe. Fiddlers Ferry, Ironbridge B and Cottam - were modified wherever the particular structure had not progressed too far. At Ferrybridge, for example, the upper half of one of the towers was completed with the 127mm thick shell of the original design, but with two layers of reinforcement and with the upper rim increased in size. At Ironbridge 'B', steel struts were inserted at the base to augment the original concrete ones. Subsequent towers were built with thicker shells (178mm) and with double (two layer) reinforcement. Otherwise the dimensions and appearance remained the same for the hyperbolic and cone torroid form, which for the 'First Division' stations considered in this report were the largest in the system, standing 375ft high (114.3m). In January 1984 the aforementioned Fiddlers Ferry tower collapsed in gusts of wind exceeding 80 mph. This time the cause was a minor imperfection in the shape of the shell (an outward circumferential bulge above the ring beam). This event occurred after the time-span considered in this report, but in essence 'led to further improved construction techniques and helped create a corps of engineers able to export their world leading technology'.[101] Furthermore the CEGB's urgent assessment of the likelihood of further collapses prompted another audit of extant cooling towers, which, tangentially, chronicled a sharp decline in numbers from the previous audit in 1966.

Declining numbers and rarity

The Ferrybridge inquiry identified 241 hyperbolic or cone torroid towers existing in England in 1966. The post-Fiddlers Ferry audit of 1984 found a total complement of 139 towers in England and Wales, 74 of which were the largest 375ft high (114.3m) size, cooling the 'First Division' stations with high-merit plant (500 MW and 660 MW turbo-generators). Thirteen of these towers had 127 mm thick shells which had been built, or partially built, at the time of the Ferrybridge failures and had not been strengthened. The remaining 65 towers varied in heights down to 76 m.[102]

Among the losses in the period between the two surveys was the Lister Drive group in 1972, the UK's first hyperbolical concrete towers, 'minute by the standards of their majestic Trent valley successors'[103] Following Privatisation in 1990 the pace of demolition has increased as the least energy efficient stations, or those that were too costly to retrofit, were decommissioned and disposed. The demolition of Tinsley Towers in 2008 ostensibly marked the end of the pre-Nationalisation era towers; currently the only pre-CEGB era cooling towers are the group of four at Willington, Derbyshire, although the rest of the complex has gone. Seemingly all the losses since the 1984 audit have been those that cooled the CEGB's 'Second and Third Division' stations (in terms of economic importance),[104]and those that currently stand are the full complement of 375ft high (114.3m) towers - perhaps not unsurprisingly since they are components of the CEGB's 'First Division' stations of the late 20th century.

At the time of Michael Trueman's MPP Step 1 report in 1994, he found that early wooden cooling towers were extremely rare (high individual importance), that early ferro-concrete cooling were also rare, and of high individual importance. The importance of those cooling towers not in these categories was 'otherwise moderate'. Rates of attrition in the 19 years since have likely increased the high individual importance of those 20th-century examples that survive, irrespective of construction material and date. Despite their high individual importance, it is arguably their assemblage that gives cooling towers visual coherence and cultural meaning; currently the 74 examples are distributed in 9 complete groupings ranging from four towers (at Ironbridge 'B') to 12 (at Drax).

Cooling Towers: structural and aesthetic considerations

It is difficult to overstate the significance of hyperbolic towers to engineering history. Poised somewhere between Vladimir Shukov's graceful steel lattice hyperboloid water towers, radio masts and pylons of the 1890s-1920s, and the reinforced concrete shell roof structures of Eduardo Torroja, Felix Candela and other architect-engineers of the 1920s-60s, few structures combine such geometrical purity, structural optimisation, (unselfconscious) architectural form, and purpose-driven function. Their double curvature gave them superior stability to outside forces (such as wind), intrinsic strength (thinner walls economised on materials) and their wider base, narrower throat and wider mouth created a larger surface area for evaporation, enhanced the natural updraft and facilitated atmospheric dispersal. In 1968 one publication recognised that

> Since the Ferrybridge cooling towers collapsed in 1965, the hyperbolic cooling tower has become of about the same historical significance to structural concrete as the Tacoma Narrows suspension bridge became, after its collapse in 1940 to structural steel.[105]

More recent appreciation, in 2008, explained how

> Cooling towers are probably the most iconic image of the power industry. Few even amongst the engineering community appreciate their daring and sophistication. Their ratio of shell diameter to wall thickness is less than that of an egg.... the tower shape is derived purely from structural optimisation. Cooling towers are probably the only structures which take advantage from shell action having a doubly curved surface with the geometry of a hyperbolic paraboloid. The shape was patented in 1916 and later refined.[106]

Interest and admiration among the engineering and heritage community is growing with, *inter alia*, international symposia on 'Natural Draught Cooling Towers' and attempts to document examples and numbers in different countries.[107]

Aesthetically, without further research, it is difficult to state with confidence how perceptions of cooling towers have changed since their introduction, in hyperbolic concrete form, in the 1920s. Certainly by 1945 Sir Charles Reilly could pen a short piece in Country Life explaining 'The Problem of the Cooling Tower'. Alarmed at the prospect of two giant towers overpowering Lincoln's townscape and Cathedral, he nonetheless appreciated the 'interesting hyperbola curve of their silhouette', considering 'A group of them on a plain in the country can be an inspiring sight'.[108] Of course when they did start relocating to the country, and particularly, 'Deep England', there was considerable opposition. But opinion among even Didcot's original opponents seems to have mellowed with time,[109] and the scale of local opposition to the demolition of Tinsley Towers is perhaps indicative of how cooling towers have become identified with place and memory.[110] Sir Neil Cossons encapsulates the zeitgeist: '... yesterday's eyesore is tomorrow's monument. The great cooling towers that dominate the Trent Valley are already approaching the end of their lives; history tells us that when the time comes the defence of these great temples to the carbon age, now mellowed by time and familiarity, will be fought with the same passion that secured the gasholders of St Pancras and led to the listing of the Post Office Tower and Jodrell Bank'.[111]

4. RECOMMENDATIONS FOR FURTHER RESEARCH / INVESTIGATION

Aerial Survey

An aerial photographic survey of all the surviving 1960s and 1970s coal-fired and oil-fired power stations. This would document them, and their wider landscapes, whilst they survive as a complete and coherent set of CEGB 'First Division' stations, all based on the 500 MW and 660 MW turbo-generator set. Those sites in an uncertain state of survival, such as the four cooling towers at Willington, Derbyshire, should be similarly recorded. Those recently closed, or due for closure in March 2013 should be photographed first as a matter of urgency, to capture them in a complete or even working state. Aberthaw B Power Station might be recorded in consultation with RCHAMW.

Kingsnorth Power Station
Coordinates 51.418947°N 0.602702°E [Closed December 2012]

Didcot A Power Station
Coordinates 51.62363°N 1.26757°W [Closure March 2013]

Fawley Power Station
Coordinates 50.816696°N 1.328881°W [Closure March 2013]

West Burton Power Station
Coordinates 53.365°N 0.8194°W

Ferrybridge C Power Station
Coordinates 53.71740°N 1.28058°W

Eggborough Power Station
Coordinates 53.7116°N 1.1269°W

Ironbridge B Power Station
Coordinates 52.63005°N 2.511999°W

Fiddlers Ferry Power Station
Coordinates 53.372°N 2.687°W

Ratcliffe Power Station
Coordinates 52.865268°N 1.255°W

Cottam Power Station
Coordinates 53.304°N 0.7815°W

Rugeley B Power Station
Coordinates 52.756°N 1.916°W

Drax Power Station
Coordinates 53°44'9"N 0°59'47"W

Grain Power Station
Coordinates 51.445181°N 0.715028°E

Willington Cooling Towers
NGR SK2928

Aberthaw B Power Station
Coordinates 51.387312°N 3.404866°W

Drakelow C Power Station *(fully demolished 2006?)*
Coordinates 52.773608°N 1.656805°W
NGR SK231196' Power Station

Site visits

A strategic programme of site visits to the power stations for the purposes of recording and/or designatory assessment. Recording should include ground-based photography, and ideally, film/video of key processes and interviews with working staff. A series of illustrated site reports, incorporating historical research and statements of significance would provide a fitting record of this last chapter of one of Britain's largest nationalised industries. Access can be coordinated through the current owners/operators:

British Energy
Eggborough Power Station

EDF Energy
West Burton Power Station

E.ON UK
Kingsnorth Power Station
Ironbridge B Power Station
Ratcliffe Power Station
Grain Power Station

International Power
Rugeley B Power Station

London Energy
Cottam Power Station

RWE npower
Didcot A Power Station
Fawley Power Station
Aberthaw B Power Station

Scottish and Southern Energy
Ferrybridge C Power Station
Fiddlers Ferry Power Station

Further research

Many aspects of 1960s and 1970s CEGB's 'Landscapes of Power', including power stations, sub-stations and other highly-visual, designed components would repay further investigation. In respect of the former, further detailed investigation of the surviving power stations, using primary archival sources supplemented with interviews of the surviving engineers, architects and landscape architects, both within and consultant to the CEGB, would shed light on the thinking, challenges and compromises behind the different stations, as well as opinion on how successfully they had been realised. Only through delving deeper into the history, architecture and engineering of each station, in a manner similar to that undertaken by Michael Stratton for Ironbridge, can their true character, significance and completeness/intactness be revealed and understood. One particularly interesting, and potentially fruitful area of study, is the degree to which the consulting architects attempted to stamp their own 'house' signature or style on those buildings they had design influence over. How does ADG's work at West Burton, BDP's at Ferrybridge and Ratcliffe and Sir

Percy Thomas and Son's work at Ironbridge and Eggborough for instance relate/rate in terms of their other works? Published biographies/monographs of firms and individuals could be useful in helping answer this, but only further primary documentary research and interviews with the protagonists is likely to unearth how ideas were shared, diffused or guarded among the different design teams and offices, some of which might have been working on more than one power station project at a time. Were power stations seen as prestigious, exciting architectural opportunities, or, by virtue of their necessarily constrained nature, as offering little prospect of architectural expression?

Archive Repositories

The following archives and repositories might yield answers to some of these questions, although it should be noted that many of the original architectural drawings, if they survive in original or microfilmed form, are likely to reside with the consultant architectural practices (for example, Clifford, Tee and Gale still have their drawings/documentation for Drax).

Archive of the University of Liverpool
Holford Papers: Central Electricity Generating Board

(Papers of William Graham, Baron Holford of Kemp Town). -
Reference D147/EB -
Dates of Creation 1958 - 1972 Central Electricity Generating Board -
including: -

Reference D147/EB2/3 -
Physical Description (2 bundles) -
Architects (1964 and 1969-1973) -

Reference D147/EB3 -
Notes and correspondence with M H Shepheard (CEGB Architect to Oct 1970) (1965-1970) -

Reference D147/EB3/1 -
Physical Description (25 items) -
Notes of meetings (including details of visit to East Midlands Region, May 1971) and correspondence with H N Mason (Acting Architect from Oct 1970; appointed CEGB Architect Aug - 1972) (1964 and 1969-1973) -

Central Electricity Generating Board Minutes (Jan 1960-Dec 1965, Jan 1966-June 1973) -
Reference D147/EB5/1 -
Physical Description 2 boxes -
Board Papers (Jan 1965-Dec 1966 Jan 1967-Dec 1967) -
Reference D147/EB5/2 -
Physical Description 2 boxes -
Central Executive Committee Minutes (Jan 1963-Oct 1965) -
Reference D147/EB6 -
Physical Description 1 file -
General Correspondence (1957-1974) -
Reference D147/EB7 -
Physical Description 755 items -

Reference D147/EB10/4 -
Physical Description (3pp typescript) -
Landscape Architects (1958-1968) -

Reference D147/EB11 -
Correspondence with M Shepheard F H S Brown and D Clark (Chief Planning Engineer) on appointment of Landscape Architects for Power Station Sites, with particular reference to: - Drakelow C, Dungeness, Fawley, High Marnham, Hinkley Point, Isle of Grain, Oldbury, Sizewell, Tilbury B, West Burton B, West Thurrock, Wylfa (1958-1968) -

Reference D147/EB11/1 -
Physical Description (39 letters) -
WGH notes for undated Landscape Architects meeting at CEGB (Not dated) -

Reference D147/EB11/2 -
Physical Description (6pp manuscript) -
Landscape Research Group (1967-1971) -

Reference D147/EB12 -
Programme for symposium on Methods of Landscape Analysis (WGH in chair in afternoon and - made notes on programme) (3 May 1967) -

Reference D147/EB12/1 -
Physical Description (1 item) -
Correspondence with A Murray (Principal Assistant Architect) of CEGB (Honorary Secretary of - Landscape Research Group) (1967-1969) -
Reference D147/EB12/2 -

Physical Description (8 letters) -
Correspondence with D Poole and D Rymer (Administrative Secretary of Landscape Research Group) on WGH subscription to Landscape Research Group, (1968-1971) -

The National Archives

Whilst relevant minutes the RFAC were examined for the purposes of this report (BP 1/11 (1955) to BP 1/19 (1971), and some other material, further research should focus on the POWE series. Taking West Burton as an example, the following files are indexed/available:

POWE 14/616 West Burton 1953-1964
POWE 14/1575 Application for consent to build generating station: CEGB; extension to West Burton, Notts 1966-1972
POWE 14/2472 Power station: representation by the National Coal Board concerning the fuelling (e.g. coal, oil, nuclear etc.) of Killingholme, Drax B and West Burton B power stations 1971-1978

POWE 54/96 - Proposed second coal-fired generating station at West Burton, Notts. 1968-1969

POWE 54/96 - Proposed second coal-fired generating station at West Burton, Notts. 1968-1969

Besides files relating to all the individual power stations named in this report, there are many of a more general nature that could provide valuable context, viz:

POWE 67/93 CEGB power stations: comparative costs of nuclear power and coal; `Never Again a Coal Station?' 1968

POWE 67/80 CEGB report: Power Station Construction 1968

Company and Institutional Archives

At privatisation the CEGB library, including some archive material, passed to National Power's Swindon headquarters. This survives now as the library of RWE Npower PLC, Swindon (Suzanne Botter, Librarian), although public access is difficult or prohibited. Apart from the opening brochures on individual power stations consulted for this report, it houses indexed material on the activities of Electricity Commissioners, the CEB, BEA, CEA and CEGB, a large book collection and journal runs, files on individual power stations including press cuttings and photographs.

The Greater Manchester Museum of Science and Industry holds the archive of The Electricity Council, which includes material previously held by regional distribution boards, a large number of books and journal runs together with more files on individual stations containing photographs, written material and drawings.

The fate of any material formerly held by the CEGBs regional offices remains uncertain. Much of it should have ultimately passed - in theory at least - to the libraries of the current energy suppliers: British Energy (East Kilbride); EDF Energy (Exeter); E.ON UK (Coventry); International Power (London); London Energy (subsidiary of EDF); RWE npower (Swindon); Scottish and Southern Energy (Perth).

The Institution of Engineering and Technology (formerly The Institution of Electrical Engineers) Library and Archives, 2 Savoy Place, London, holds a specialist collection of books and journal runs covering the post-war period, only material relating to a few older power stations - principally Croydon A, Stepney Battersea and Deptford power stations.

NHPP 5A3 Responsive Designation

The coal-fired power stations looked at in this report are representative of the nationalised industry at its peak. Potentially, further survey and investigation might form part of a much broader evaluation of the electricity power generation industry, encompassing oil, nuclear, gas and renewable sources (hydro-electric power, pumped storage and other sources such as wind and solar power), as advanced by the MPP Assessments undertaken by Michael Trueman and Gill Chitty in 1994-2000. The HPR Review of Past and Present Thematic Programmes undertaken by Martin Cherry and Gill Chitty (October 2009) concluded that

> The way that candidates for listing came forward in the MPP selection process for electric power generation was unsatisfactory and led to the suggestion of a thematic listing study. This remains unfinished business. An important group of later 19th and 20th-century power stations and houses of architectural merit is identified which could be considered nationally or possibly through a regional study of the generating stations of particular companies and local authorities. This theme could equally well form part of a wider public utilities thematic study.[112]

5. BIBLIOGRAPHY OF POST-WAR COAL-FIRED POWER STATIONS AND COOLING TOWERS

AAJ Architectural Association Journal
A&BN The Architect and Building News
AR Architectural Review
Br The Builder
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
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

Individual Power Stations

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