NYS8376
NYS8377
NYS8378

LANCASTER
UNIVERSITY
ARCHAEOLOGICAL
UNIT

MONUMENTS PROTECTION PROGRAMME

ELECTRIC POWER GENERATION

STEP 1 REPORT
STEP 3 REPORT
STEP 3 REPORT UPDATE

Commissioned and funded by.

English Heritage

LANCASTER UNIVERSITY
ARCHAEOLOGICAL UNIT

June 1994

MONUMENTS PROTECTION PROGRAMME

ELECTRIC POWER GENERATION

Step 1 Report

Commissioned and funded by

English Heritage

MONUMENTS PROTECTION PROGRAMME
ELECTRIC POWER GENERATION

Step 1 Report

Michael Trueman

for
English Heritage
Monuments Protection Programme

Lancaster University Archaeological Unit
Storey Institute
Meeting House Lane
Lancaster
LA1 1TH

June 1994

CONTENTS

Acknowledgements 3

1. INTRODUCTION 5

2. TECHNICAL OUTLINE 7
2.1 Generation 7
2 1 1 Types of power station 7
2 1 2 Coal-firing 8
2 1 3 Oil, gas and waste fuels 9
2 1 4 Diesel and gas turbines 10
2 1 5 Hydro-electricity 10
2.2 Transmission 10
2.3 Administration 11

3. HISTORICAL OUTLINE 13
3.1 Background 13
3.2 Scientific Investigation, to 1831 13
3.3 Technical Innovation and Early Innovation, 1831-78 13
3.4 Early Generation, 1878-88 14
3.5 Growth of Industry, 1888-1919 15
3.6 Rationalisation, 1919-48 17
3.7 Nationalisation, 1948-90 19
3.8 Privatisation, from 1990 20

4. ARCHITECTURAL CONSIDERATIONS 21

5. REGIONALITY 23

6. COMPONENTS 25
6.1 Power Station 25
6.2 Transmission Site 30
6.3 Administrative Site 30

7. SOURCES OF INFORMATION 31
7.1 Published Works 31
7.2 Regional Works 31
7.3 Contemporary Works 32
7.4 Primary Records 32
7.5 Museum Collections 33
7.6 Sources for Step 2 Data and Consultation 33

8. PRIORITIES AND RECOMMENDATIONS 35

BIBLIOGRAPHY 37

APPENDIX 1 - Tables 45
1 Power station types . 47
2 Growth in number of power stations, 1889-1912 47
3 Increase in output of standard generating sets, 1956-1970 47
4 Selective power installations, to 1888 48
5 Selective power stations, 1888-1919 49
6 Early use of refuse destructors for electricity generation . . 50
7 Selective power stations, 1918-1947 51
8 Selective power stations, 1947-1967 ... 52
9 Power stations in use in 1993 . ... .53

APPENDIX 2 - Illustrations 55
Figure 1 Typical cross-sections of *coal-*, *oil-* and *dual-fired power stations* (CEGB 1971, 33) 57
Figure 2 Typical cross-sections of *nuclear*, *pumped storage* and *gas turbine fired power stations* (CEGB 1971, 34) 58
Figure 3 Typical site layout for a 2000MW *coal-fired station* (CEGB 1971, 62) . .. .59
Figure 4 Power station layouts of Barking 'B', Battersea and Dunston 'B' (Pearce 1939, 325) 60
Figure 5 Power station layout of Neptune Bank and Carville (Merz and McLellan 1904, 710-11) 61
Figure 6 Typical cross section of power station with 500MW units (CEGB 1971, 68) 62
Figure 7 Typical cross section of power hall and boiler house (CEGB 1971, 68) 63
Figure 8 Plan of Powick (1894) *hydro-electric station* (*Electrician*, 33, 5 Oct 1894) . . . 64
Figure 9 Cross section of Llanndudno refuse destructor and generating station (*Electrical Engineer*, 22, 1898, 647) . 65
Figure 10 Comparative sizes of turbo-alternators, 1895-1940 (Pearce 1939, 328) 66
Figure 11 Ferro-concrete cooling tower (CEGB 1971, 247) 67
Figure 12 Maps showing extent of *National Grid* in 1932 and 1960 (Dunsheath 1962, 206) . . . 68

APPENDIX 3 - Address list for circulation 69
Individuals, Museums, National Organisations 71
CBA Regional Industrial Archaeology Panels . .. 72
Association for Industrial Archaeology Affiliated Societies . ... .73
County Archaeologists and SMR Officers . 76

ACKNOWLEDGEMENTS

This report has been researched and written by Michael Trueman Jason Wood acted as line manager and read and commented upon an initial draft A large number of individuals and organisations willingly gave information which contributed greatly to the writing of the report Lenore Symons and staff of the IEE archive, Mike Williams (RCHME) and Dr Patrick Strange all gave invaluable assistance and advice Similarly I am grateful to Janet Atterbury (RCHME), Brian Bowers (Science Museum), Richard Dagger (National Power librarian), Philip Ellis (English Heritage Records Office), Keith Falconer (RCHME), Shane Gould and David Cranstone (Cranstone Consultancy), Anne Jones and Elizabeth Springer (GMMSI), John Newton (Southern Electricity Museum), John Norris (Milne Museum), John Powell (Ironbridge Gorge Museum), Mike Stratton (Ironbridge Institute), Tom Sherriff, David Stocker (English Heritage), and Peter Wakelin (Cadw)

I must also express my considerable thanks to all those who responded to my questionnaire: Sites and Monuments Record Officers and National Park Officers, representatives of AIA affiliated societies, staff of the National Monuments Record, staff of English Heritage's Scheduling Division, David Alderton, Geoffrey Cantor (British Society for the History of Science), Nigel Crowe (British Waterways Board), W S Quinn-Robinson (Business Archives Council), Jane Hatcher, Stafford Linsley, John Norris (Milne Museum), Clive Ellam (Newcommen Society), Chris Lester, B R Minnitt, Peter Stephens (PHEW), and Richard Holder (Victorian Society)

1. INTRODUCTION

The electric power generating industry is essentially concerned with providing electric current for lighting, heating and a wide range of other uses It effectively began with the discovery of magnetoelectric and electromagnetic induction by Michael Faraday in 1831 Electricity was subsequently used for telegraphs systems and lighthouse illumination before the onset of generation for a wide range of uses including public lighting, traction and powering industrial machinery in the 1880s Electricity consumption rose dramatically in the early part of the twentieth century, becoming one of the foundations of the modern world Development of the industry took place on an international stage with Britain, the USA, Germany and France all playing important roles Remains in England must be viewed in this context and are of major importance

There is a considerable literature on the history of the electricity industry. This has been focused mainly on technological and business history. Limited outline studies of field remains have been undertaken in certain areas (particularly in the 1970s) and varying observations on numerous individual sites have been reported in a wide variety of local journals and other publications It must be stressed that in studying electricity supply, we are dealing with a relatively modern industry Its broad history, particularly technological, is fairly well documented This is supplemented by museum preservation of many examples of the equipment and machinery from its early development Surviving archaeological remains are mainly buildings, often of considerable scale Their value lies in the potential to explain the specific architecture of the industry, its regional and company variation and the way in which electricity generating technology was put into practice Surviving *in situ* machinery is rare and, where it occurs, considerably enhances the value of remains To the authors knowledge, no overview of the archaeology of the industry has previously been compiled

The purpose of this report is to set a framework for the Electric Power Generation industry in the 'identification, recording and evaluation of industrial monuments and, where applicable, their selection for statutory protection under existing legislation', in accordance with the approach set down by English Heritage Archaeology Division (1992) Specifically the framework includes a technical and historical outline, a breakdown of the archaeological components one would expect to encounter; an attempt to specify sources for identifying sites, and a statement of anticipated priorities for the industry In achieving this, and in view of the dispersed nature of accessible source material, it has been useful to partially pre-empt the data gathering process of Step 2 by circulating a questionnaire to potential contacts. The responses to this have formed a valuable source in compiling this report

Following English Heritage guidance, the report deals specifically with the generation of electricity by fuels other than nuclear It does not deal with the transport of fuel to power stations or consumption The manufacture of generating equipment has also been excluded. These subjects, together with offshoots of the electricity generating industry such as telegraphs, lighthouses, electroplating, street lighting, should be considered in separate reports. Although, since the 1920s, the electricity industry has been operated as a national ***British*** resource, this report is geographically limited to England. It does not attempt to cover the important hydro-electric supplies in Scotland and Wales. Nevertheless, in order to allow informed judgements to be made, it has been deemed necessary to make reference to these other areas of study.

In line with previous MPP reports, classes of site are indicated by the use of CAPITALS, whilst structures and features identified as components are **highlighted** throughout the report. In addition components which are plant are differentiated by use of ***highlighted italics***. Other technical terms are printed in *italics*.

2. TECHNICAL OUTLINE

This section summarises the processes involved in the generation of electricity The purpose is to identify the function of <u>components</u> (including *<u>plant</u>*) which are to be used in the site assessments, together with other *important terms* Items are described under three class headings generation (POWER STATION), transmission (TRANSMISSION SITES) and administration (ADMINISTRATIVE SITE)

2.1 Generation (POWER STATION)

Electricity may be generated as alternating current (electric current where the direction is reversed at regular intervals, generally following the pattern of a sine wave) or as direct current (electric current flowing in one direction only) The differences in field components for systems operating ac and dc are minor and mainly concerned with plant They are pointed out in the text where appropriate

Early experimentation which established the nature of electricity and developed the technology to use it was carried out in <u>laboratories</u> in the eighteenth and nineteenth centuries Early electricity generation took place in small <u>power houses</u>. Such small-scale production continued until nationalisation in 1948 in a range of circumstances, including lighthouses, country estates, industrial sites, hospitals and early rural supplies

2 1.1 Types of POWER STATION

POWER STATIONS may be grouped in two main ways The first mode of categorisation is by the use made of the electricity This was particularly important to the mid 1920s, when technological improvements in both generators and transmission systems were combined with political will to build the national grid. As a broad rule, early *isolated stations* were built to supply a variety of specific functions including private and public lighting; traction (trams and electric railways) and motive power (particularly in coal mining, iron and steel, textiles and engineering) Increasingly from the 1890s, larger *central stations* generated power for transmission over wide areas to a range of customers

The second mode of categorisation is according to the motive force used to drive the prime mover. This divides generating sites into three broad groups: fuel-fired steam generation, water-powered generation and combustion-powered generation. The specific types within these groups are summarised in Table 1.

The majority of large-scale generation for most of the industry's history in England has been in *coal-fired power stations* However, *hydro-electric power stations* (including at least one pumped storage power station) played an important technological role in the early industry of the 1880s and 1890s. More important in terms of capacity, *refuse destructor-fired power stations* provided between 10% and 20% of the output of power stations between 1890 and 1914. *Gas engine-fired power stations* were also important for some early public supplies and, along with *waste heat and gas-fired power stations* (including the use of town gas), appear to have played a significant role in the generation of electricity for industry. *Oil-fired power stations*, *dual-fired power stations*, *nuclear power stations*, *diesel engine-fired power stations* and *gas turbine-fired power stations* were all introduced to England in the 1950s Natural gas was first used in 1967, and gas-fired stations employing the *combined cycle gas turbine (CCGT)* process, where waste gas from gas turbines is then used to produce steam for conventional turbines, are being widely built in the 1990s. Most of the major components which make up a power station were established by c1900. Much of the generating and distribution plant is common to the different types of station, the main differences are in the fuel handling requirements and the mechanism of the prime mover

2 1 2 Coal-firing

For a *coal-fired power station*, the need to bring coal to the site and prepare it for burning was present from the beginning Any station therefore required a coal store to ensure continuous running of the plant as required For early small stations, the inability to transmit long distances meant locating the station close to the *load centre* and coal could be delivered by horse and cart Increasing scale made it essential to locate stations to allow coal to be brought in quantity. Railway sidings therefore soon became a common feature Riverside and canal-side locations also became important, with a coal jetty (or wharf) providing the facility for unloading. A weighbridge would be used to monitor quantities Coal handling plant was necessary to deliver coal to the boiler house. A variety of systems have been used for this including: skip hoists, bucket elevators, belt conveyors, trucks, tipplers, cranes, wagon hoists, grad line buckets, winches and bulldozers (Say 1968, 2/16). Conveyor systems were certainly in use at the beginning of the twentieth century and mid twentieth-century stations located on coal fields had direct feeds from collieries

The boiler house contained plant for generating steam for the prime mover, and incorporated *coal bunkers*, *coal weighers*, *pulverising mills* (from the early twentieth century), *furnaces*, and *boilers* (Electricity Council 1966, Say 1968, 2/5-9) The boiler generally incorporated an 'economiser', using furnace waste heat to reheat condensate From the 1920s, a 'reheater' would also be incorporated above the economiser to reheat steam from the first chamber of a turbine before passing it to the next chamber (Electricity Council 1981) Immediately adjacent lay the power hall (or 'generating hall', or 'engine house' or later 'turbine house') containing the steam driven *prime movers*, the *generators* and (in later stations) *condensers* A *generator* essentially consists of coils of wire which cut or are cut by a magnetic field, causing electricity to flow in the wire (see Bowers 1982, 70-100) Of the early *generators* that by Gramme, from 1870, was widely used There were many variants on it, including the Crompton-Burgin generator from 1879 (used in the House of Commons) and Brush generators (used at Brighton in 1882) The Siemens brothers built and sold generators from the 1860s, initially for firing mines and for telegraphy

To 1884, most generators were belt driven from a *reciprocating steam engine* (Corliss engines were a common example) In 1884 a British engineer, P W Willans, patented an enclosed, high-speed, steam engine for direct coupling to generators. High speed engines were, to c1910, the standard prime mover and *Willans engines* became the most common Of longer term importance, again in 1884, Charles Parsons built the first *steam turbine* and *turbogenerator*. The first turbine was used commercially from 1890 and, as generating sets became larger, took over as the standard prime mover (Bowers 1982, 166-8; Byatt 1979, 110-11; Trinder 1992). Step up *transformers* are used to convert current produced by generators up to the very high voltages used in transmission (see below). As output increased, transformers became very large and required assembly on site (CEGB 1968). A battery room would be used for battery storage of generated current. In early dc stations, this may have been used to feed the *electricity main* when the generators were not operating In ac stations batteries were used as backup systems for driving auxiliary station equipment, such as *pumps*, *fans*, etc (CEGB 1968, 462-3).

Switchgear consists essentially of *circuit breakers* used to control power output (see Bowers 1982, 178-81) Early stations used simple knife switches mounted on slate or marble *control panels*. As higher voltages were achieved, this *switchgear* was placed behind the panels to protect the operators Further refinements included *circuit* *breakers* of the *magnetic blowout* type (pre 1900), *oil-immersed* type (pre 1910), *air blast* and *oil blast* types (1920s/30s), *sulphur hexafluoride* type (1940s) and the *vacuum* type (c1930 for low currents, 1965 for high voltage motor controllers) The importance of large switchgear was recognised from the early twentieth century and increasingly large switch houses were used The practice of operating switchgear remotely from a central control room, previously developed in the USA, was introduced to England by Charles Merz in 1904

Early steam generating power stations were non-condensing Higher steam temperature and pressure led to the need to use condensers Condensed steam (or 'condensate') could then be fed back to the boilers The coolant required for this operation was drawn by pump (often housed in a pump house) from a river or canal Dependent on the size of the river, the water might be pumped directly back More commonly, given the generally small size of English rivers, the water was itself cooled and re-used Hence both cooling ponds and cooling towers were in use before the end of the century The cooling tower occupied a smaller area, and used convection as well as evaporation to dissipate heat Early towers were wooden with a rectangular plan tapering slightly with height. A later development was the ferro-concrete tower, with a hyperbolic profile, which came to dominate in the mid twentieth century. Some of these are multi-deck In the 1960s, the dry cooling tower was devised in Hungary In this design the water circulates in a closed circuit through heat exchangers at the base of a wider but conventionally shaped tower (Hatcher 1985, 53-4; Say 1968, 2/22-3)

Ash handling plant was used to dispose of ash from the furnace Furnace ash was collected in hoppers Removal of the waste from there became an ever larger logistical exercise as stations increased in size A variety of plant has been used including ash wagons, skips, aerial rope-ways, conveyors, pneumatic suction and water sluicing (CEGB 1968, 15, 57, 137, Say 1968, 2/17) In the latter, ash slurry would be piped to large settling ponds

In early stations, exhaust material from the boiler was passed directly to a chimney, possibly with a *fan* providing forced draught. From the 1920s, increasing concern over the amount of smoke emissions from ever larger stations located within towns led to the installation of flue gas cleaning plant Modern stations use *electro-static precipitators* to remove dust and grit from the exhaust gases (CEGB 1968, Say 1968, 2/9)

Additional components of a power station may have included an administrative block, with *offices*, *canteen* and *toilets*, workshops, for on-site repairs to plant, stores, for spare parts, repairs materials, protective clothing etc; a laboratory for carrying out routine chemical tests, and a car park (CEGB 1968). In addition a generating site would have some form of boundary with entrance gate

2 1.3 Oil, gas and waste fuels

Gas-fired power stations, gas engine power stations, and waste heat and gas-fired power stations, were all in use from the 1890s. The main change in components was that in place of coal handling and storage, there was *gas producing plant*, gas holders, and *gas handling plant*. In addition, either gas-fired *boilers* or gas engines were used to provide the motive power. Refuse destructors were widely operated in Britain from the 1870s to World War I. Their use to provide steam for electricity generation was first demonstrated in 1882, and many were operated commercially in this way from the 1890s, with the first purpose-built combined station dating from 1897 (Tucker 1977d) In *oil-fired* and *dual-fired* stations, the major difference from coal-fired stations is the use of oil storage tanks.

2 1 4 Diesel and gas turbines

Diesel engine power stations and *gas turbine power stations* are generally smaller in scale and lack a boiler house The diesel engine was developed in 1892 (Trinder 1992) In England its use as the basis of a *diesel engine-fired power station* dates from 1954 (Electricity Council 1981) However it is also widely used as the basis of automatic backup systems in steam-fired and hydro-electric stations (Say 1968, 2/49) The gas turbine has been used for electricity generation on a small scale in Britain since 1952 mainly as standby and experimental units (Electricity Council 1981; Say 1968, 2/54-5)

2 1 5 Hydro-electricity

Hydro-electric power stations were important m the early decades of the electricity industry in England The Godabning supply of 1881 was provided by a hydro-electric installation set up by adapting an existing mill with water-wheel In addition to the buildings, a wheelpit and leat are the likely survivals of these stations This appears to have been a typical arrangement for early supplies and early rural supplies. *Pumped storage systems* seem to have been rare, an early example being that an Lynmouth in 1890 (Tucker 1977c) Water turbines were developed by Foumeyron in 1827 and became widely used for electricity generation from the 1880s Many varying designs were used in Britain, including the *Pelton wheel* (by the American L A Pelton in 1889)

2.2 Transmission (TRANSMISSION SITE)

Early transmission systems were generally localised, urban and used *underground mains* in preference to overhead wires (Bowers 1982, 173, Hannah 1979, 5) Cables were normally used, often directly buried, others in specially laid cable ducts (or *conduits* or *troughs*) which could be carried over open spaces on cable bridges For the purposes of the MPP, *non-cable* systems such as Crompton's strip main, which used copper strips held on insulators in ducts, are included under these headings Major developments in cable technology were concemed with increasing the voltage that could be carried by cable The main problem here was devising appropriate insulation Early types included vulcanised bitumen, jute and vulcanised indiambber. In 1890, Ferranti devised a circular main, with paper as the insulator, which was capable of transmitting 10,000 V. Further developments were the *belted cable*, the *screened or H-type cable* (from 1928), the *oil-filled cable* (from 1920), and the *gas-filled cable* (from the 1930s) *Pvc insulation* was introduced in the 1950s and became virtually universal (Bowers 1982, 147, 172-8)

Overhead wires were not generally favoured in early systems although they were employed in the North East Their widespread use only came with the constmction of the *national grid* from 1928. A main of steel cored aluminium wire was carried on pylons erected at 300 yard intervals They were designed by Sir Reginold Blomfield RA and constmcted of steel (Bowers 1982, 178; Hannah 1979, 79, 116-17, Wright and Marshall 1929, 693-4). Secondary transmission lines for local distribution were carried on wooden poles Approaches to towns used *underground mains*. The national grid also saw the establishment of seven regional control centres (Glasgow, Newcastle, Leeds, Manchester, Birmingham, Bristol and London). The Newcastle office was the pre-existing office of the Newcastle-upon-Tyne Electricity Supply Company (NESCo) (Hannah 1979, 124; Linsley 1976, 12, Electricity Council 1981).

Transformers are used to alter the character of a supply (usually from ac to dc) or to increase (*step up*) or decrease (*step down*) the voltage (of ac or dc). For the purposes of this report *transformer* is taken to include the dc *rotary motor-generator* (see Bowers 1982, 140, 144, 146, 181-5). A sub-station is a term applied to varying sites but is essentially a satellite of a power station which receives electrical power from source and distributes it to customers (see Parsons 1939, 21-2, 64-5, Peach 1904, 281, 306-8, Say 1968, 6/34-6) In this report it is used to cover all non power station sites that housed *transformers* It may also have housed *switchgear* In early dc systems, such as the Oxford system, high voltage transmission was converted in a basement substation located with each customer Similar arrangements existed for ac supplies With increasingly large electrical supply systems in the 1890s, substations came to be more usually housed in purpose-built, and often architecturally distmctive, stmctures In addition to *transformers*, *switchgear* and *mains chambers*, such stations could include *office accommodation*, *staff toilets* and *stores* Some stations also had battery rooms Modem substations are generally in the form of open compounds

2.3 Administration (ADMINISTRATIVE SITE)

Early power companies such as NESCo had administrative offices and showrooms, as did the Central Electricity Board and its successors These constitute an important part of the generating industry set up which should be given further consideration

3. HISTORICAL OUTLINE

3.1 Background

Michael Faraday's discovery of magnetoelectric induction in 1831 established the basic physical procedure still used to generate electricity the relative movement of a wire and a magnetic field to induce a flow of electncity m the wire The technological history of electric power generation is essentially one of refinement and increase in scale of that process A considerable literature exists on the history of the industry, focusing largely on technology and business in relation to the mainstream industry (see Bowers 1982, Dunsheath 1962, Electncity Council 1982a/b, Hannah 1979, 1982) There has been relatively little investigation of physical remains. Tucker (1977b) and Linsley (1976) provide rare exceptions, which are essentially restricted to identifying sites rather than basing analytical studies on those remains Little work has been published on the generation and use of electricity for trams, for mining, for the iron and steel industry, for textile mills, for private estates, and for hospital use. A historical summary in terms of field components is therefore difficult to provide However the history of the electricity industry does appear to break down into a series of periods of development that are reflected in the surviving remains

3.2 Scientific Investigation, to 1831

The period to 1831 is characterised by laboratory-based scientific investigation of electrical phenomena, cuhninating in Faraday's work Prior to Faraday, electric current could only be derived from batteries, the original 'voltaic cell' being invented in Italy in 1800 by Alessandro Volta These cells were used by experimenters such as Humphrey Davy who, at the Royal Institution in London in 1802, demonstrated the principle of an *arc lamp*, that a brilliant light can be produced between two pieces of carbon comnected to a high voltage supply The devices invented and used in this period are generally well documented and many are preserved in museums

3.3 Technical Innovation and Early Innovation, 1831-78

The period 1831-78 saw technical innovation carried out in the laboratory, with numerous attempts to improve (and take out patents on) *generators* and arc lamps, together with early practical applications including the *telegraph*, *electroplating*, *lighthouse illumination* and *mining* uses

During the 1830s and 40s, an army of experimenters devised a variety of magnetoelectric generators ('*magnetos*') From 1837, these machines were used commercially to power telegraph systems (notable figures were Charles Wheatstone and William Cooke in the UK and Samuel Morse in the USA) Magnetos were also used at this time in establishing electroplating as a commercial industry. In 1867 the *self exciting generator* was developed independently by Charles Wheatstone, Wemer Siemens and S A Varley. In 1870, Z T Gramme (Paris) made the first really practical *generator* where fluctuation of output was considerably reduced from that of earlier machines *Arc lamp* designs were improved in the 1840s and 50s sufficient for lighthouse use and later for street lighting, for example by the Russian Paul Jablochkoff in 1876 and, in England, by REB Crompton in 1878. Numerous experimenters attempted to devise a practical *filament lamp* in this period. Joseph Swan (England) and Thomas Edison (USA) independently achieved this in 1879.

F H Holmes demonstrated a magneto and arc lamp for *lighthouse* use in 1857 The following year, two Hohnes magnetos and Duboscq lamps were installed at the South Foreland lighthouse. A further installation at Souter Point lighthouse used from 1867 to 1900 is preserved in the Science Museum, London By 1893, stx British hghthouses had electric lighting, compared to thirteen in France (Komesaroff 1979) Mining applications of the new technology were also explored at an early date Trafalgar colliery in Gloucestershire was using *electrical signalling* devices in 1866, and was probably also using *electrical fuses* for blasting m the 1870s

3.4 Early Generation, 1878-88 (see Table 4)

The period 1878-88 saw the developments of the previous 60 years given practical application It is characterised by the use of a site *generator*, producing direct or alternating current, either as part of a portable set or in a power house or a small power station These systems were mostly coal-fired, but with *hydro-electric* schemes, employing the established technologies of *water-wheels* and *water turbines*, playing a distinct part. Early supplies were for street lighting and public supply schemes, lighting for specific sites (public buildings and private houses), private estates, and industrial use (for example winding and pumping engines at mines). The period saw relatively restricted growth of public schemes (compared to the USA and France), largely due to inhibiting legislation in place from 1882-88. However it also saw three very important technical developments. the *Willans engine*, the invention by Parsons of the *turbogenerator*, and the first use of heat from a refuse destructor to generate electricity.

Between 1880 and 1910 a large number of electricity companies were established Amongst these, REB Crompton was a leading figure. In 1879, he began importing and selling generators and arc lamps (manufacturing both within two years). In 1881 Crompton also became the chief engineer for Joseph Swan's Electric Light Company, which, in 1883, merged to form the Edison and Swan Electric Light Company. The latter held important patents for filament lamps Equally important were the Siemens brothers (British company formed in 1881) and the Deutsche Edison Gesellschaft, the precursor of AEG, formed in 1883. These two companies competed and co-operated, in particular AEG built power stations where Siemens turned to specialising in technical equipment Some of the other companies and names associated with the early industry are given in Table 4

The sudden growth in demand which these and other companies formed to supply, is reflected in the number of bills before parliament for powers to supply electricity Three Acts were passed in 1879 and four in 1880 In early 1882 there were a further 28 bills (7 new companies, 8 gas companies, 13 local authorities) This resulted in a general Electric Lighting Act being passed in April of that year A great deal of weight was given to defending the position of local authorities and existing gas companies A local authority, company or person could supply electricity, but required a licence (up to 7 years, renewable with permission of the relevant authority), provisional order or special act. Local authorities had a compulsory purchase option on any business, with the right to buy at cost of plant (ie not as a business). Although the act seems to have hampered growth of the industry in Britain between 1882 and 1888, the period did see established patterns of supply and use that were to dominate in Britain until after World War I.

Numerous supplies were set up in this period. The earliest (short-lived) street lighting schemes date from 1878. The first long-lived schemes, soon extended to provide public supplies were set up in 1881. Crompton provided arc and filament lamps to light the markets and adjoining streets in Norwich. Several others followed (see Table 4) Godalming was the first 'public' supply in that householders could buy a supply Holborn in the same sense was the first steam powered public supply. Brighton was the first to become a continuous supply. Site lighting for specific events, public buildings, railway stations and so on, using portable generating units and more permanent set-ups, also began 1878, along with installations at private estates and on industrial sites.

A textile mill was using a *generator* for bghtmg in 1877, surface llghting at a coal mine was used in 1878 and electrical winding and pumping was used by 1882

3.5 Growth of Industry, 1888-1919 (see Tables 2, 5 and 6)

1888-1919 saw the real growth and establishment of the electricity industry in Britain The period was characterised by a variety of organisational and technical practices The small scale power house and 'isolated' power station for specific functions (lighting, trams, industry) and restricted areas contrasted with larger, central power station generation and distribution for a range of customers There was also considerable supply variation (ac/dc, voltage, frequency), fuel variety (*coal*, *refuse*, *gas engine*, *hydro-electric*, *waste heat and gas*), and a major change in the type of prime mover used for steam generation, the *steam turbine* replacing the *reciprocating engine* Optimum designs for increasingly large power stations was discussed and experimented with, and the basic components of such stations were established Merz introduced the 'unit' system of constmction, where plant in the boiler house, power house and switch house was divided into several independent units (Byatt 1979, 119, Merz and McLellan 1904). Transmission was mostly carried in *underground mains*

The 1888 Electric Lighting Act removed the earlier disincentives against private companies (now giving a 42 year lifetime before the option of local authority purchase at the value of the business) and rapid take up of electricity supplles followed, both by companies and by municipal authorities Hence to c1900 a pattem of supply (mainly lighting) developed where large towns were supplied by local authority undertakings and smaller towns were supplied by private companies Both were predominantly based on isolated power stations with small distribution areas (by 1903 all bar 2 towns of 100,000+ population had a supply) Rural areas were generally without electricity, the exception being private estate installations There was continuing wide variation in the type of supply with dc and ac systems at different voltages and frequencies.

Although bghting still dominated, both traction and industrial use expanded in the last two decades of the nineteenth century Following experiments with electric railways and tramways in the early 1880s in Britain and abroad, tmly practical tramway systems were establlshed in the USA and on the continent in the late eighties. England followed in the 1890s, although take-up was slow (1897: USA 88% of tramways were electric, in Britain the figure was 9%). Limited electrification of railways also began (London Underground, Liverpool overhead railway) Supply was generally dc supplied by a station specifically for that fimction, two thirds of them mn by Municipal authorities. In industry there was a slow spread of electric power, usually generated on site Electric lighting was gradually expanding in a range of industries In the 1890s, it became widely used in larger textlle mllls, iron and steel works and coal mines (mainly surface but some underground). Power uses were less important at this stage but included auxillary machinery at steel mllls, cranes in ship yards (from 1880s) together with coal cutting, winding and haulage on mines (see Table 5)

In 1890 Ferranti had pioneered the concept of large scale ac production and transmission with the abortive Deptford scheme. Over the next ten years, the advantages of this approach gained wide recognition, especially with the success of the NESCo system under Charles Merz. Subsequently, between 1897 and 1905 a series of private Acts set up about 20 large power companies covering most of England outside the existing municipal authority supply areas. The first two decades of the twentieth century saw these companies and the municipal authorities developing larger power stations and larger distribution areas London remained an exceptional case as the only area where open competition had been allowed and there had developed a large number of suppllers with widely differing supply systems. An attempt to rationalise this in 1905 (when there were 12 local authorities and 14 companies supplying electricity) with the County of London Electric Power Bill, put together by Merz, was defeated.

During this second half of the period, lighting remained the main public supply provided by these undertakings Gas company competition was stlll fierce and the mvention of the gas mantle in 1885 ensured this contmued well mto the twentieth century. However, improvements to filament lamps (tungsten filament in 1906) and ımprovements in efficiency to electricity supplles helped tip the balance towards electricity In addition, new domestic appliances made their first appearance (including washing machines, vacuum cleaners and refiigerators) Traction and industrial use expanded considerably Electric tramways were massively extended and many tramway companies built their own power station Limited rallway electrification was also carried out Industry saw growing adoption of electricity for power appllcations, as opposed to lighting (in 1907, 10% of power consumption in industry was from electricity, in 1912 25%, in 1924 50%) This in part reflected a move from early use of the *dc motor* to the more rellable ac *ınductıon motor*. Textlle nülls had begun to use electric motors to drive machinery by the first decade of the twentieth century, some making use of a power house, others buying from the local mains (Wllllams and Famie 1992, 134-6). In the North East, collieries were connected to the NESCo network via a series of standard sub-stations (Linsley 1976, 11) In addition, collieries and, in particular, iron and steel works made use of waste heat and gas for generating electricity (Pattenden 1979). A major boost in demand for electricity for steel works came with the adoption of the *electrıc arc furnace*, during the Worid War I

Steam driven prime movers remained the dominant motive force in Engllsh power stations Coal was the main fiiel, reflecting the plentifiil supplles avallable In the 1890s, the high speed *reciprocating steam engine* became the standard prime mover used In 1897 over 50% of generators had such engines, 70% of these were Willans engines There was however a limiting practical size to these engines As larger generators became possible in first decade of the twentieth century, *steam turbines* became by far the dominant prime mover The last reciprocating engines were installed in 1906

Hydro-electricity was important in that several early schemes made use of this power source, either adapting an existing water mill and *water wheel* or installlng a *water turbine* However, the limited capacity for water power in England inevitably meant it could not make a major contribution as generating stations grew bigger. That at Powick, Worcester (built 1894) was, at 350kW output, the biggest publlc hydro-electric station at this period. Hydro-electricity did continue to be important for the small-scale private estate supplies and small mral supplles

The other major fiiel of the time was refuse Between c1876 and c1914, *refuse destructors* were bullt and used in Britain Although the first production of electricity using steam from a destmctor was at Nottıngham, its general use only came about in the 1890s (see Table 6) In 1912, there were c350 *refuse destructors* in Britain, and 80 of them were combined destmctor/generator stations forming c20% of publlc supply stations. After World War I, very few new combined destmctor/generator stations were built This reflected the continuing move to bigger generating stations and the llmited production capacity of destmctors (20MW being about the llmit achieved)

The first public power station using *gas engines* was bullt in 1892 Several others followed, but these early examples were generally replaced by steam after a few years (Parsons 1939, 152). *Gas engines* were also used widely at ironworks from the tum of century (Andrews and Porter 1909, 3) and in waste heat and gas stations (Pattenden 1979) The latter also made use of gas-fired *boilers* and waste steam from iron works and collieries (Pattenden 1979).

An important choice for electricity undertakings in this and the subsequent period, was whether to generate altemating or direct current. The period to the tum of the century saw the so-called 'battle of the systems', where the merits of each were debated In ac systems, *transformers* could easily step up or step down voltage as required and tap changing allowed fine adjustment In contrast, dc systems could employ *batteries* to allow continuity of supply when *generators* stopped or broke down, and early dc *generators* were easier to operate in parallel than were ac *generators*, and so were easier to extend to more customers (Bowers 1982, 141) However in terms of field components the set up was essentially the same Current was generated at a power station and carried in a main (usually in an underground cable duct) to one or more sub-stations These installations were often situated in the basements of customers premises Some dc supplies employed batteries to accumulate charge for customer use Other dc supplies and ac systems employed *transformers* (the dc equivalents were termed *rotary motor generators)* to reduce voltage to an appropriate level for customer use (Bowers 1982, 142-51) Technical developments in the USA, in particular the invention of the reliable, easily maintained and cheaply produced *induction motor* by Tesla in 1888, dictated the ultimate primacy of *ac polyphase* supplies An ac polyphase supply is one where several ac currents are transmitted together with their waveforms out of step A field coil given such a supply produces a rotating magnetic field The essence of an *induction motor* is that a metal disc placed in such a field will rotate (Bowers 1982, 253)

3.6 Rationalisation, 1919-48 (see Table 7)

Following the watershed years of World War I, the British electricity industry underwent a period of dramatic rationalisation The years 1919-48 were dominated by the building of the *national grid* combined with strong national co-ordination of privately owned industry The grid was dominantly in the form of overhead cables carried on pylons to local sub-stations with a series of regional control centres co-ordinating transmission A majority of the isolated and small power stations were gradually closed down in favour of existing and new large central power stations These were built and operated by private undertakings to closer standards and making use of technological advances, although a wide variation of frequency and voltage of the generated supplies remained throughout the period

The combination of increased efficiency from wartime controls with increasing demand produced a drive to rationalise the industry Britain at the start of the period was technologically and organisationally well behind the USA and Europe, where large generators and high voltage ac transmission systems were the norm (Hannah 1977, 1979) The role of the Central Electricity Board, from 1926, proved to be a very successful exercise in selecting best practices and putting them into place to give Britain an effective electricity supply industry.

The 1919 Electricity Supply Act created the Electricity Commission who established a series of Joint Electricity Authorities. The purpose of the JEAs was to encourage co-operation in each area The limited powers of these authorities resulted in a very limited effect with some local supplies becoming inter-connected and a series of larger powers stations authorised in favour of small. The evident failure of a voluntary system in effecting rationalisation increased the pressure for statutory powers and, following the recommendation of the Weir committee in 1925, the 1926 Electricity (Supply) Act was passed. This created the Central Electricity Board with a threefold remit: to construct a 'gridiron' system of high voltage transmission lines; to 'select' power stations (operated by private undertakings) to supply the grid; and to buy electricity from selected power stations and resell to authorised suppliers.

The 'gridiron' became the *National Grid* with primary distribution at 132,000 V and secondary distribution at 66,000V and 33,000V Built in an eight-year programme in 1927-35 the grid was designed to operate in seven regions: Glasgow, Newcastle, Manchester, Leeds, Birmingham, Bristol and London, each with its own control centre As demand rose in the 1930s, operation of the grid came to be on a national basis In 1937 the northem and southem regions were regularly mn as two main systems and in 1938 a national control centre was established at Bankside, London From that time the grid was normally operated as one inter-connected system From the beginning of Worid War II it operated continuously as smgle unit

The generation of electricity became dominated by the national network The Weir committee had recommended that there should be 58 selected stations consisting of 43 existing stations and 15 new with 432 stations being closed down In fact, by 1935, the CEB took electricity from 148 selected stations (of which 28 provided the base load). To the mid 1930s, the CEB encouraged the expansion of existing stations. However some new stations were bullt and, from the mid 1930s, this was the norm Hence between 1920-9, 4,291 MW was added to the country's generating capacity and between 1929-37 2,313 MW was added All bar one station were power company owned and mn, and the majority became 'selected' stations

The CEB exerted strong influence on design by insistence on efficiency through increased set capacity and standard sizes Between 1927-42, 172 new sets were authorised, about half of which were 30MW or 50MW, although there was some experimentation with bigger sets at stations such as Barking 'B' and Battersea 'A' and 'B' (see Table 7) This policy effectively reversed Britain's technological backwardness, so that whereas in the 1920s Germany had larger sets than Britain, in the 1930s, Battersea power station was largest in Europe

Technological progress during this period was essentially one of using higher steam temperature and pressure, together with the introduction of the *reheat cycle* in 1921. The environmental effects of increasing smoke emissions also became of concem, especially with the continuing policy of locating stations near to the main load centres (ie towns) As a result in some stations *flue-gas cleaning plant* was added to reduce emissions (see Table 7)

Two particular standardisation problems were not really solved until the end of the period the *supply frequency* and *supply voltage* In 1927, the European standard frequency was set as 3-phase, 50Hz ac In Britain at this time, 77% of the supply was 50Hz, most of this being 3-phase Significant exceptions were the North East (40Hz), Glasgow, Birmingham, South Wales and London (all 25Hz) The CEB adopted the European standard, but this was only finally achieved for the whole country in 1947 Voltage was even more variable. In 1935/6 there were 642 supply undertakings of which 282 were ac, 77 were dc, and 283 were ac/dc. These supplies were provided at 43 different voltages varying between 100-480 V The major problem here was that standardisation would mean the need to change customer apparatus The standard 240V ac was only finally set in 1945

The undertakings from whom the CEB bought electricity consisted of a series of large power companies, together with some publlcly owned JEAs (grouping existing stations and bullding more). In addition there remained a large number of small operators providing specific supplies and to an extent co-operating with the CEB, either buying electricity or selling their own for peak time use. Beyond this, although industry increasingly bought electricity from the grid, industry specific generation did continue and many industrial concerns maintained backup generators (see Pattenden 1976, 19-23) Large country estates also continued to install their own supply with a variety of fuel sources and plant. Many hospitals installed their own generators in the 1920s/30s, often using small, high speed, vertical steam engines (Cossons 1987, 228)

Urban tramways died out in the 1920s, to a limited extent being replaced by trolley busses, but both being squeezed out by the motor car. Rallway electrification saw selective expansion of suburban llnes in the South East, on the London Underground, and in Manchester, the Wirral and Tyneside A standard of 1500V dc was adopted in 1920 (remaining until 1950s) After 1922, existing railway company generating stations were enlarged and modernised (at a non-standard frequency of 25Hz), but no new ones were built. The new technology of *rotary converters* and *rectifiers* allowed cheap conversion of 50Hz *ac* grid supply to *dc* for railway use In 1942 London Underground stations were connected to the national grid (see Hannah 1979, 161-9)

A further important development was the growth of rural electrification In 1923, some towns with a population of 10,000 were still without an electricity supply Rural areas (with 20% of the population) generally had no supply In part this was due to the unwillingness of undertakings to extend into less economically attractive areas, and in part the common distribution voltage of 6 6kV was, in the early 1920s, insufficient to carry the supply to these areas By 1931, supply franchises had been granted to cover most rural areas and inter-war electrification progressed in the most densely populated areas by charging more than in urban areas By 1929 there were 3700 miles of low voltage main, but by 1939, this figure had risen to 20,000 miles. By the start of the World War II, all villages with a population of greater than 500 had mains electricity However, low density areas were still without a supply. Hence only 12% of farms had electricity by this date, although wartime needs had boosted this figure to 32% by 1948 (see Hannah 1979, 189-92,1982, 73-4)

One effect of the increasing scale of generation in England was to ensure that *coal* remained by far the dominant fuel for power stations. Refuse destructors were limited (to about 20MW) in their capacity to generate electricity and virtually disappeared after World War I Similarly *waste heat and gas* could not ultimately compete with the large stations, although many continued to the mid 1930s. *Hydro-electricity* continued to play a very small role in England, boosted slightly during the World War II with many corn mills converted to generate electricity

3.7 Nationalisation, 1948-90 (see Tables 3 and 8)

World War II provided a second major watershed for the electricity industry The period from 1948 to 1990 saw the industry state-owned with construction of ever bigger power stations at site locations dictated by fuel source and water supply (rather than load centres), including *pithead stations*. New fuels and technological advances were introduced (oil, natural gas, nuclear) The *grid* was extended and a *supergrid* built again as overhead cables carried on pylons to sub-stations.

In the immediately post-war period, capacity was well down on demand and there was an urgent need to correct this One strategy adopted was the enforcement of generating standards In 1947 a Ministry of Supply order had restricted the construction of turbo-alternators to two sizes, 30 and 60MW. In the same year the Electricity Act nationalised the industry with effect from 1 April 1948 (see Hannah 1982; Electricity Council 1982)

The Act replaced the CEB with the British Electricity Authority, to be responsible for generation and transmission The authority was divided into 14 generating divisions An equivalent grouping of 14 Area Electricity Boards were set up to carry out retail distribution to customers and there were also 14 Electricity Consultative Councils. The North of Scotland Hydro-electricity Board which had been created in 1943, was also absorbed into the BEA However, in 1955 the Scottish electricity industry was separated off and the BEA was renamed the Central Electricity Authority. The 1957 Electricity Act replaced the CEA with Central Electricity Generating Board, created the Electricity Council and gave a greater independence to the Area Boards

There was a capacity crisis in the late 1940s, due to shortages of fuel and new plant Between 1948-54, the strategy employed to correct this focused on the construction of new plant using the well establshed technology of 30MW and 60MW sets with standard steam conditions (The first station with standard 60MW sets and steam condıtions was Staythorpe 'A') The reluctance to take on technical advances and build the bigger sets being used in other countries, meant that Britain fell technologically behind France and the USA However, in the mid 1950s there was some move to bigger sets with the use of 100MW. After 1954, this move became stronger. 120MW sets were first used in 1958 and there followed a decision to use 120MW as standard rather than 60MW. This pattem of increasing standard size continued, putting station design back on a technological par with other countries (see Table 3)

The siting of power stations became dominated by the source of fiıel and water supply A series of new Trent valley stations, with banks of large cooling towers, came to form the hub of the system In addition, a number of pithead stations were buih, llnked directly by *coal handling plant*

The national grid continued to be extended, partly reflecting a mral electrification programme (which between 1953-63 connected 85% of farms), partly the constmction of a supergrid, first at 275,000V, begun in 1953, and secondly at 400,000 V from 1963 In addition a dc sub-marine cable llnk between England and France was laid in 1961.

Coal remained the main fuel, although the last *coal-fired* stations to have been built date from the 1970s Concems in the 1950s over potential shortages produced a move to experiment with other fuels (distinct from the use of *hydro-electric* power that continued to develop in Wales and Scotland) *Oıl-fired* stations began in 1952 and an oll burning progranune commenced in 1954 *Natural gas* firing was used from 1967. *Gas turbines* were also being used in 1952 and *diesel engines* in 1954. The other main new technology of the period was the begiming of commercial *nuclear power* in 1956 (see Tables 8 & 9) In 1972, 58% of Britain's electricity was produced by burning coal, compared to 27% oil, 11% nuclear, 2% gas and 2% hydro-electricity. From that date the main trend was a decrease in the percentage of *oil* bumt (following the oil crisis of 1973), and an increase in the level of *nuclear* generation (Electricity Association 1993, 26-7)

3.8 Privatisation, from 1990 (see Table 9)

In 1990 the British electricity generating industry retumed to the private sector. The enactment of the Electricity Act in that year abollshed the CEGB with its regional offices and equivalent distributing boards Power generation passed to three new companies National Power, Power Gen and Nuclear Electric, with the National Grid Company pic becoming responsible for transmission In addition the Electricity Association was set up as a trading association and lobbying body. National Power and Power Gen were floated on the stock market in March 1991 (the Scottish companies were floated in May 1991). This most recent development has gone hand in hand with a major change of policy, to lessen the dependence on home-produced coal and to bulld a series of stations based on the combined *cycle gas turbıne process (CCGT)*. At the same time there has been a surge of new small generating companies employing a range of fiıels including landfill gas, sewage gas, chicken llter, waste, wind, gas (CCGT), oll and coal (see Table 9 and Electricity Association 1993, 19-27, 47-51)

4. ARCHITECTURAL CONSIDERATIONS

The architecture of power generation is touched upon in general architectural history texts, but appears to have received little specific attention beyond celebrated monumental sites such as Battersea (eg Brockman 1974, 100-2) Given the recent nature of the industry and the likelihood that structures and plant will form the major field survivals, there is clearly a need for the MPP assessments to respect the architectural range of the industry

There have been a range of influences on power station architecture at different dates which should be catered for in the MPP selection process These include the functional nature of the industry and its need to operate efficiently, its continually increasing scale of production and therefore prominence in first urban and then rural landscapes, design variation to accommodate competing technologies (ac vs dc, *reciprocating steam engines* versus *turbines* and *combustion* engines etc), the effect of available building materials and structural technology of the day, and the effect of the organisation and ownership of the industry at different dates

In the very early period of 1878-88, most generating installations were small scale Employing portable plant, they were often set in temporary structures or in existing buildings Some early stations were purpose built, and designed with architectural merit to blend into local surroundings With the massive growth of the industry from the late 1880s to World War I, the variety of ownership in the industry had a strong effect There was a particular contrast between Municipal authorities, employing classical revival and other historical styles, and the power companies and tramway stations, more usually employing an engineering style of architecture The role of power station architecture in the local landscape is particularly important for this period

This variety continued in the 1920s and 30s with additional influences coming into play Power stations became ever larger as part of the national grid yet remained in urban settings Steel framed construction became widely used with different finishing materials The electricity industry was also increasingly seen as the power house of the nation The CEB strongly influenced station specifications, but design was still left to electricity undertakings Hence stations could vary from the overtly functional, steel framed, glass curtain wall construction of Dunston 'B' in 1931 to the 'monumental' brick finished architecture of Sir Giles Scott's Battersea station in 1933

After 1948 responsibility for building new stations rested with the state owned CEGB In addition the still larger stations moved away from urban settings towards coal-fields A predominantly functional architecture came to dominate typified by the large steel-framed concrete constructions with massive cooling towers of the Trent valley

5. REGIONALITY

The electricity industry has an essentially national and international setting in terms of the development of its technology In that sense, regional variation is less pronounced than for other industries Nevertheless some discussion of 'region' is important as the organisation and application of that technology prior to nationalisation had a distinctly regional flavour

The nature of the early industry in powering lighting and traction, meant that electricity generation was concentrated on towns Within this urban setting there was a notable division between Municipal authority undertakings in large towns and private power companies in the smaller towns In rural areas, early supplies were concentrated on private supplies for large country houses where individual wealth could afford it Following the series of acts between 1897 and 1905 that resulted in about 20 large power companies covering those areas of Britain not supplied by Municipal authorities, supplies were slowly extended to cover larger villages In addition, some rural areas developed their own supplies prior to World War I Inter-war rural electrification resulted in the majority villages with a population of over 500 having a supply Wartime needs boosted supply to farms, but completion of rural supplies was only achieved by the nationalised industry after World War II

Two specific regions may be highlighted prior to nationalisation In the North East, NESCo grew from its inception as a local company in the 1880s to be the main supplier in the region using large scale efficient power stations and a high voltage polyphase distribution system to a wide range of customers (domestic, public lighting, industry, trams and railways) In many ways this system pre-empted the national scheme of the 1920s onwards London was the extreme contrast to this Much of the early development of lighting schemes took place in London Subsequently, it was the only area in England where undertakings were allowed to actively compete for customers This resulted, in the period to World War I, in a large number of inefficient and differing types of supply

Between 1926 and 1948, the establishment of the national grid allowed large scale generation to become dominant under the direction of the CEB From start of World War II, this grid operated as a single unit and from 1948 was part of a nationalised industry. The main 'regionality' factor here was in the location of power stations, particularly in relation to coalfields and water sources for cooling Hence the Trent valley power stations developed as the hub of the system

6. COMPONENTS

Surviving components are grouped into three classes POWER STATION, TRANSMISSION SITE and ADMINISTRATIVE SITE Components are listed alphabetically within each class Terms used are defined for MPP purposes, but have been chosen in an attempt to reflect the terminology used in the industry The general importance of each component in isolation is given, the importance of a particular example depending on its date, condition and typological/regional variation Plant is especially important within the electricity industry and major items have been included in the list. They are distinguished from structure and feature components by the use of *italics* Early plant, as a general rule, rarely survives other than as museum pieces, and therefore *in situ* examples are rated high The value of any component containing original or notable plant would be enhanced over and above the ratings given here

6.1 POWER STATION - This term is used to cover any site associated with the generation of electricity irrespective of the fuel used or the use to which the electricity is put Components will include associated administrative and transport features

Administrative block	Staff offices, canteen toilet etc of a power station
Date range	1890s? - present
Importance	Low technological importance, but may be significant as part of a site
Ash handling plant	Plant for extracting ash from the furnace
Date range.	1880s - present
Importance	Early *in situ* examples are high, otherwise dependent on typological variation
Battery room	Room with batteries for storing dc current May be part of a power station or be part of or adjacent to a power house
Date range	1880s - present
Importance	Moderate to high
Boiler house	Houses coal bunker, coal weigher, pulverising mill, furnace, boiler
Date range	1880s - present
Importance	Early examples are high Later examples depend on typological, regional and architectural factors
Boiler	Plant for raising steam to be used to drive a steam engine or turbine. Generally incorporated an 'economiser' and, from the 1920s, a 'reheater'.
Date range	1880s - present
Importance	Early *in situ* examples are high, otherwise dependent on typological variation
Car park	Motor vehicle parking area for power station employees and visitors.
Date range	C20
Importance	Low individual importance, unless as part of early site

Chimney	A tall stack for dispersal of fumes from a boiler fumace
Date range	1880s - present
Importance	Often high visual unportance and sometimes with architectural merit Technology unstudied, some examples may be important for illustrating development
Coal bunker	Plant for delivering coal from the coal handling plant to the coal weigher
Date range	1890s - present
Importance	Eariy examples are high
Coal handling plant	Plant for conveying coal from store to boiler house
Date range	1890s - present
Importance.	Early examples are high
Coal jetty	River or canal berthing for receiving coal deliveries from ships and barges.
Date range	1880s - present.
Importance	Early examples are high
Coal store	Area (yard or building) for storage of coal
Date range	1880s - present
Importance	Early examples are high
Coal weigher	Device to ensure correct quantities of coal are delivered to the boiler furnace
Date range	pre 1920s - present
Importance	Early examples are high
Condenser	Plant for condensing exhaust steam from a *turbine*
Date range	1880s - present
Importance	Early *in situ* examples are high
Control panel	Panel with controls for operating any aspect of power house or power station May be isolated or part of a control room
Date range	1880s - present
Importance	Early *in situ* examples are high
Control room	The central control room was introduced to Britain by Charies Merz at Carvilie Prior to this instmmentation was scattered around the station
Date range	1904-present
Importance	Early intact examples are very high
Cooling pond	A pond used to dissipate heat (by evaporation) from a steam generating power station coolant.
Date range	1890s - 1930s.
Importance	High
Cooling tower	A stmcture used to dissipate heat (by evaporation and convection) from a steam generating power station coolant.
Date range:	1890s - C20.
Importance	Early wooden towers are extremely rare, high individual importance. Early ferro-concrete are also rare, high individual importance Otherwise moderate

Diesel engine	Engine producing mechanical power by internal combustion of diesel and air
Date range	1892 - present
Importance	*In situ* example are high
Entrance gate	Entranceway to power station compound
Date range	1880s - present
Importance	Varies, dependent on architectural quality
Fan	Fans are required at various points around a power station, eg base of chimney, boiler
Date range	?1880s - present
Importance	If *in situ* as part of fuller electrical plant, high
Flue gas cleaning plant	Plant for extracting dust and grit from boiler house exhaust fumes before passage of fumes to chimney
Date range	1930s on
Importance	Early *in situ* examples may be high
Furnace	Chamber for burning fuel to heat boiler
Date range	1880s - present
Importance	Early examples are high
Gas engine	Engine producing mechanical power by internal combustion of town gas or waste gas and air
Date range	1860s - ?
Importance	*In situ* examples are high
Gas handling plant	Plant for directing and controlling flow of gas
Date range	Used in relation to electricity generation from 1880s
Importance	Early examples are high Otherwise moderate
Gas holder	Structures used to store gas (town gas, waste gas or natural gas)
Date range	Used in relation to electricity generation from 1880s - present
Importance	Early examples are high Otherwise moderate
Gas producing plant	Plant used to generate gas to be fed via gas holder to gas engine
Date range	Used in relation to electricity generation from 1890s.
Importance	Early examples are high Otherwise moderate
Gas turbine	Prime mover where a series of blades are caused to rotate by force of gas (such as air) against them
Date range	Early C20 - present
Importance	*In situ* examples are high
Generator	Device for generating electricity May be for direct or alternating current. From 1890s generally an integral part of a turbogenerator
Date range	1830s - present
Importance	Early *in situ* examples are high. Later examples dependent on specifications

Laboratory	For period to c1900 a place for experimentation concerning the nature and use of electricity Subsequently a component of a power station where on-site tests and checks could be made
Date range	C18 - present
Importance	Any examples of experimentation laboratories are high Power station laboratories vary
Leat	A horizontally graded watercourse carrying water for power supply
Date range	Used for electricity generation, 1870s - present
Importance	Individually low, but important as part of hydro-electricity site
Oil storage tanks	Stmcture for storing oil
Date range	1950s - present
Importance	Any surviving early examples moderate, otherwise low.
Power hall	Alternatively called engine house, generator hall, turbine hall or turbine house Houses the prime mover (*reciprocating steam engine*, *steam turbine* or *water turbine*), *generator*, *condenser* and water treatment plant within a power station
Date range	1880s - present
Importance	Eariy examples are high Later examples depend on typological, regional and architectural factors
Power house	Structure containing generating equipment to supply a specific site Small scale compared to a power station
Date range	1870s - present
Importance	Early examples are high Later examples varies with type and site being served
Pulverising mill	Plant for producing *pulverising* coal ready to feed to a fimace
Date range	c1900 - present
Importance	Early *in situ* examples are high
Pump	Pumps are required at several locations m a power station, functions including circulation of coolant and condensate
Date range	1880s - present
Importance	Early in *situ* examples may be high
Pump house	Housing for pump or pumps to circulate coolant
Date range	1890s - present
Importance	Early examples may be high
Railway sidings	Part of iron rall system used to bring fuel to a power station
Date range	Used in relation to electricity generation from 1880s - present
Importance	Low individual unportance, unless as part of early site.
Reciprocating steam *engine*	Prime mover where steam is produced and used to cause back and forth movement of a piston in a cyllnder.
Date range	Used in electricity generation, 1850s - 1930s
Importance	Rare survivals in early power station and therefore high Probably more common in *power houses*, where importance will vary with date and type

Refuse destructor	Installation for burning refiise Only examples used to generate steam for generating electricity in a power hall are considered
Date range	Mainly 1880s - 1920s (some examples to present)
Importance	Generally high, dependent on architectural and regional factors Particulariy important where generating station survives alongside
Settling pond	Excavated area used for settllng ash waste
Date range	1880s - present
Importance.	Low technological importance but may be significant spatial component of site
Steam turbine	Prime mover where a series of blades are caused to rotate by force of steam against them Generally an integral part of a *turbogenerator*
Date range	1884 - present
Importance	see *turbogenerator*
Stores	Area for storage
Date range	1880s - present
Importance	Low individual importance, unless as part of early site.
Switch house	Open compound or enclosed building housing *switchgear* (circuit breakers) Point where electricity generated by station is fed to user or into grid.
Date range	1880s - present
Importance	Early examples are high
Switchgear	Plant consisting of circuit breakers for switching supply on and off
Date range	1880s - present
Importance	Eariy in situ examples are high.
Transformer	A device for boosting (stepping up) or reducing (stepping down) the voltage of an electricity supply (may be for ac or dc) Step up transformers are located adjacent to power stations Step down transformers are housed in sub-stations appropriate locations for local distribution
Date range	1880s - present
Importance	Early devices *in situ* are high
Turbogenerator	Unit for generating electricity with steam turbine as prime mover. Term may cover generation of *dc* and *ac* (later also called *turboalternator*).
Date range.	1884 - present
Importance.	Early *in situ* examples are high, otherwise moderate, depending on technological development
Water turbine	Prime mover where a series of blades are caused to rotate by force of water against them.
Date range:	1820 - present, used for electricity generation from 1870s.
Importance.	Early examples are high
Water wheel	Prime mover where a series of blades are caused to rotate by force of water against them
Date range:	Used for electricity generation from 1870s - present
Importance:	Early *in situ* examples are very high.

<u>Weighbridge</u>	Plant for weighing incoming fuel, may be located on railway tracks or roadway
Date range	1890s - present
Importance	Early examples are hıgh
<u>Wheelpit</u>	Stone-hned pit or above ground housmg for a waterwheel
Date range	Used for electricity generation from 1870s - present
Importance	Generally high
<u>Workshops</u>	Area for carrying out on-site repairs
Date range	1880s - present
Importance	Low individual importance, unless as part of early site

6.2 TRANSMISSION SITE - This term is used to cover any sıte associated wıth the transmission of electncıty, irrespective of scale or system

<u>Cable bridge</u>	Stmcture carrying underground mains cable through open area
Date range	1880s on
Importance	Early *ın sıtu* examples are high
<u>Cable duct</u>	A conduit or trough carryıng underground mains electricity
Date range	1880s - present
Importance	Eariy *m sıtu* example are high
<u>Control centre</u>	A building housing plant for controlling a transmission network
Date range	C20
Importance	Any pre-national grid systems would be high May be a case for preservation of a sample of national grid centres
<u>Pylon</u>	Metal pylons for main transmission lines, wooden poles for lower voltage Distinct design chosen for these
Date range	National grid pylons from 1928 - present
Importance	Any pre-national grid systems would be high May be a case for preservation of a sample of national grid pylons
<u>Sub-station</u>	Building or compound for local distribution of current Will contain <u>*transformer*</u>(s) and <u>*switchgear*</u>
Date range	1880s - present
Importance	Early examples generally high technological value, and may have high architectural value

6.3 ADMINISTRATIVE SITE - This term is used to cover any site associated with the central administration of electricity supply, by power company municipal authority or nationalised industry

<u>Office</u>	Building used for administrative purposes of an electrical undertaking
Date range	1880s on.
Importance	Eariy examples may be high. Later examples depends on historical associations and architectural considerations.
<u>Showroom</u>	Building or rooms used by an electrical undertaking to present information about its services to the publlc.
Date range	C20
Importance	Early examples may be high. Later examples depends on historical associations and architectural considerations.