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Mexico City, 31 July to 12 August 1961

SOME ECONOMIC CONSIDERATIONS IN THE DESIGN, COMMISSIONING AND OPERATION OF POWER STATIONS CONTAINING LARGE GENERATING UNITS

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Note: This text is subject to editorial revision.

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AND
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Summary

The paper discusses briefly the alternative types of generating plant to be considered when extensions to an electricity supply network are in mind, and then concentrates in detail on the economics of supply from oil, coal or gas-fired steam-electric plant. A number of matters to be considered when determining the size of new units are described and examples are quoted. A table of the new generating plant units of 100 MW or more ordered by the Central Electricity Generating Board in Great Britain is given, and is illustrated graphically. The paper goes on to discuss both the costs of new plant over the range of size from 30 MW to 550 MW and the efficiencies that can be expected. Curves representing the results of practical experience are given.

The Author's firm are consulting engineers responsible for the design and construction of the first station in Great Britain to use 120 MW reheat units. Two design investigations, one of methods of disposing of ash and dust from this coal-fired station and the other of the circulating water system, are described in some detail to illustrate the nature of the work for which the designers of new installations become responsible. A description of the steps taken by the plant owners to train the operating staff is followed by notes on commissioning and starting procedure and early operating results.

A station which will be the largest steam-electric power station in Latin America is now under construction in Buenos Aires. The paper describes the form of the contract between the purchaser and the principal manufacturers and of the organisation specially set up to deal expeditiously with the design and construction work and concludes with descriptions of the design of the station and of the major plant items.

Planning Extensions to an Electric Supply System

Determination of the most economic way of meeting the demand for electricity involves consideration of many different schemes. Diesel-electric, oil, coal, or gas fired steam-electric, nuclear, and hydro-electric generating plant may each need to be considered in the circumstances of the particular project before any firm decision about the type of plant to be employed can be made, and of course each may involve the preparation of alternative schemes.

The costs of diesel-electric and oil, coal or gas fired steam-electric plants vary within reasonably well defined limits and diesel plant is suitable only for relatively small stations; the costs of the latter are considered in more detail later in this paper. The costs of hydro-electric plants depend on the site and cannot be generalised. Nuclear plant costs are proving substantially higher than was at first expected; it was recently stated that the first commercial nuclear station in Britain, now nearing completion, will cost $540 U.S. per KW sent out, including the initial fuel charge although later stations will cost less. Such costs in the country of manufacture do not offer great prospects for the use of nuclear plant in less highly developed countries where capital is usually more difficult to obtain and more expensive.

The decision to construct a large steam-electric power station close to the centre of Buenos Aires was made as a result of such considerations. The nearest hydro-electric site involves several hundred kilometres of high voltage transmission, and awaits a joint project with Uruguay, while nuclear plant would entail abandoning a site adjacent to the load.

Oil, gas, or coal are all available in Argentina and which will be used will depend on cost.

One of the earliest decisions to be made by the engineers responsible for the building of new steam-electric generating units is to determine the output capacity of the new units. Numerous studies of this type have been published by power supply engineers and of course many more studies have been made*. The problem can be considered in the form of an abstract study in the manner of Kirchmeyer or of Donkin and Margen, but the severely practical problem of deciding what size to specify for the next unit usually calls for detailed comparison of a number of particular cases.

Kirchmeyer suggests that the capacity of each new unit should be somewhere between a seventh and a fourteenth of the total output capacity of the system and this broad rule is borne out by the experience of the author's

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* See, for example :-

Kirchmeyer, Mellor, O'Mara and Stevenson, "An Investigation of the Economic Size of Steam-Electric Generating Units", A.I.E.E., 1955.

Donking and Margen, "Economic Plant Sizes and Boiler Set Groupings on the British Grid", I.E.E., 1951.

Elce, "Economic Basis and Character of Steam-Turbine Design", I.E.E., 1955.

Haldane and Blackstone, "Problem of Hydro-Electric Design in Mixed Thermal-Hydro-Electric Systems," I.E.E., 1955.

Brown and Booth, "Coal and Oil Fired Power Stations", British Electric Power Convention, 1957.

firm in many parts of the world. However, when the system is large it is often the case that no plant is available of sufficiently large size to conform with the rule or the interconnection is not adequate for the whole system to be considered as one. An example of this situation is provided by the 3,000 MW system owned and operated by the Central Electricity Generating Board in Britain. To secure the greatest economy the Board is continuously pressing manufacturers to design and manufacture plant of increasing size and efficiency. Table 1 lists in approximately datal order the new power stations to be commissioned by the Board in the decade 1956/65 and fig. 1 illustrates the manner in which the size of units ordered is growing. Two stations of particular interest are Drakelow C, to operate with supercritical pressure, and Thorpe Marsh, where the only two line (cross compound) units proposed by the Central Electricity Generating Board are to be installed.

The principal advantages that accrue from use of the largest units and the most advanced steam conditions are, of course, a reduction in cost per kilowatt installed and an improvement in efficiency. Fig. 2 shows the costs per kilowatt for plant installed in Britain for the range of boiler/turbine unit sizes from 30 MW to 550 MW. Numerous units in the size range from 30 MW to 120 MW have been commisioned by British manufacturers and in this range the curve represents the results of much experience. For larger sets costs are based on a small number of units and stations and the curve in this region is not so certain.

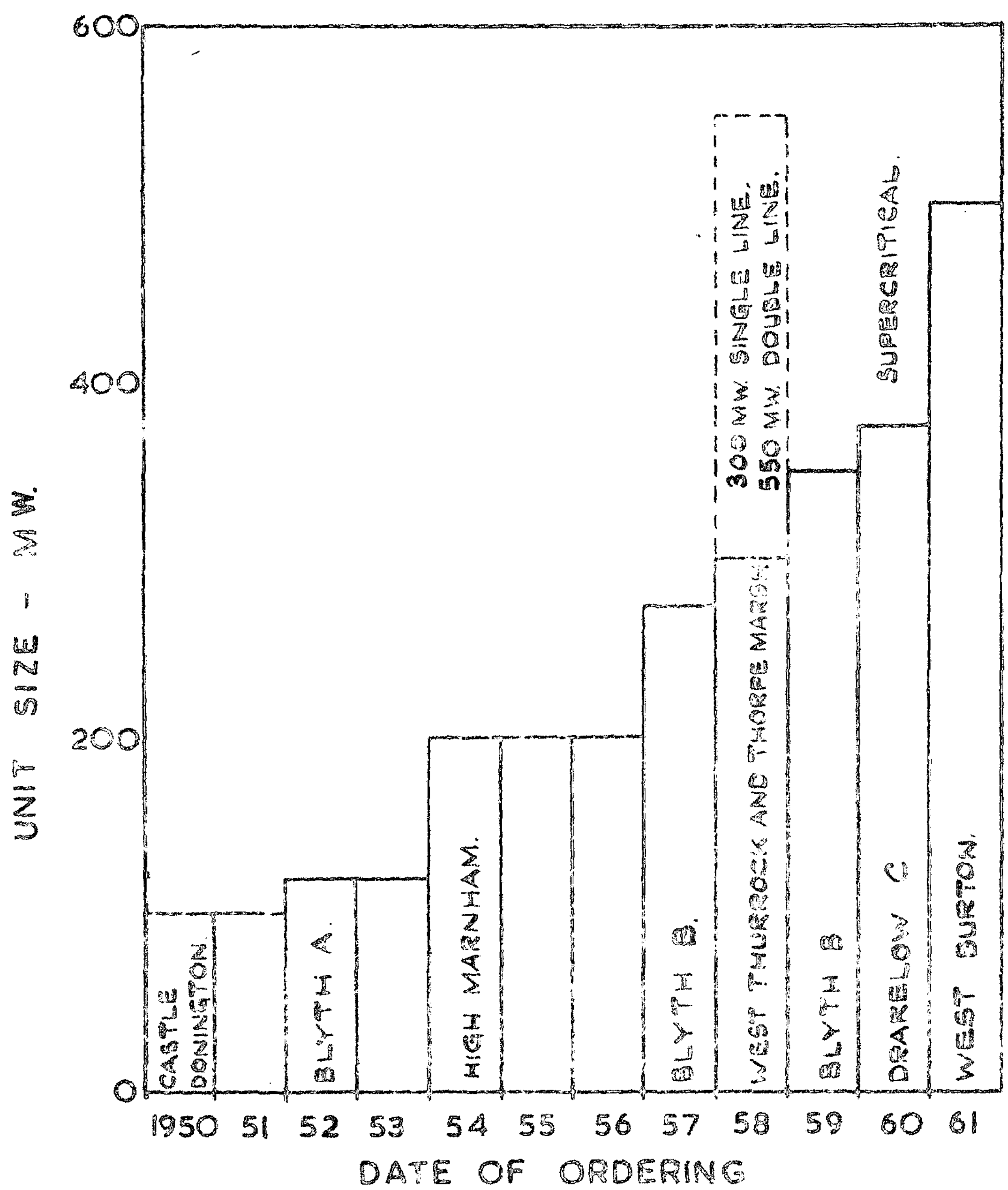
TABLE I

CENTRAL ELECTRICITY GENERATING BOARD COMMISSIONING PROGRAMME

Numbers and sizes of units in MW

Power Station	Date first unit run	Final installation No. x size	Steam Conditions kg/cm2	°C
Castle Donington	1956	6 x 100	105	565
Ferrybridge B	1957	3 x 100	105	524/510*
Willington A	1957	4 x 100	105	565
Blyth A	1958	4 x 120	105	537/537
Aberthaw	1959	6 x 100	105	524/510
Agecroft C	1959	2 x 120	105	537/537
Drakelow B	1959	4 x 120	105	537/537
High Marnham	1959	5 x 200	165	565/537
Belvedere	1960	2 x 120	105	537/537
Northfleet	1960	6 x 120	105	537/537
Rugeley	1960	5 x 120	105	537/537
Skelton Grange B	1960	4 x 120	105	537/537
Staythorpe B	1960	3 x 120	105	537/537
Uskmouth B	1960	3 x 120	105	537/537
Padiham B	1961	2 x 120	105	537/537
West Thurrock	1961	2 x 200	165	565/537
Willington B	1961	2 x 200	165	565/537
Blyth B	1962	2 x 275	162	565/565
Richborough	1962	3 x 120	105	537/537
Bankside B	1963	1 x 120	105	537/537
Thorpe Marsh	1963	2 x 550	162	565/565
West Thurrock	1963	3 x 300	162	565/565
Blyth B	1964	2 x 350	169	565/565
Drakelow	1964	2 x 350	169	568/568
Drakelow C	1965	2 x 375	246	593/565
Tilbury B	1965	4 x 350	162	565/565
West Burton	1965	4 x 500	162	565/565
Not yet announced	1965	4 x 500	162	565/565

* Where two temperatures are quoted the second is the temperature of reheated steam.



ADVANCE IN SIZE OF GENERATING UNITS ORDERED IN BRITAIN.

FIG. 1.

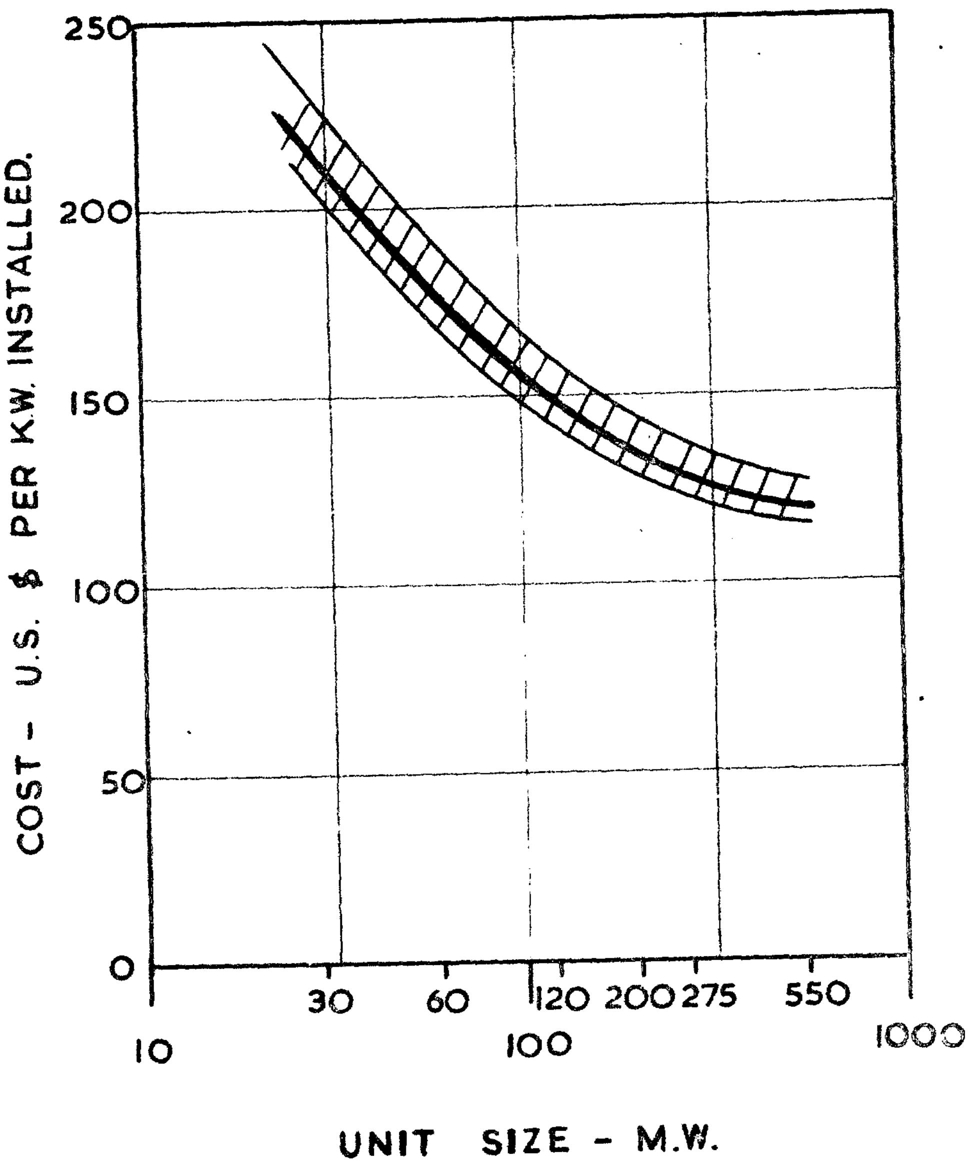

250
200
150
100
50
0
COST - U.S. $ PER K.W. INSTALLED.
30
60
120
200
275
550
10
100
1000
UNIT SIZE - M.W.

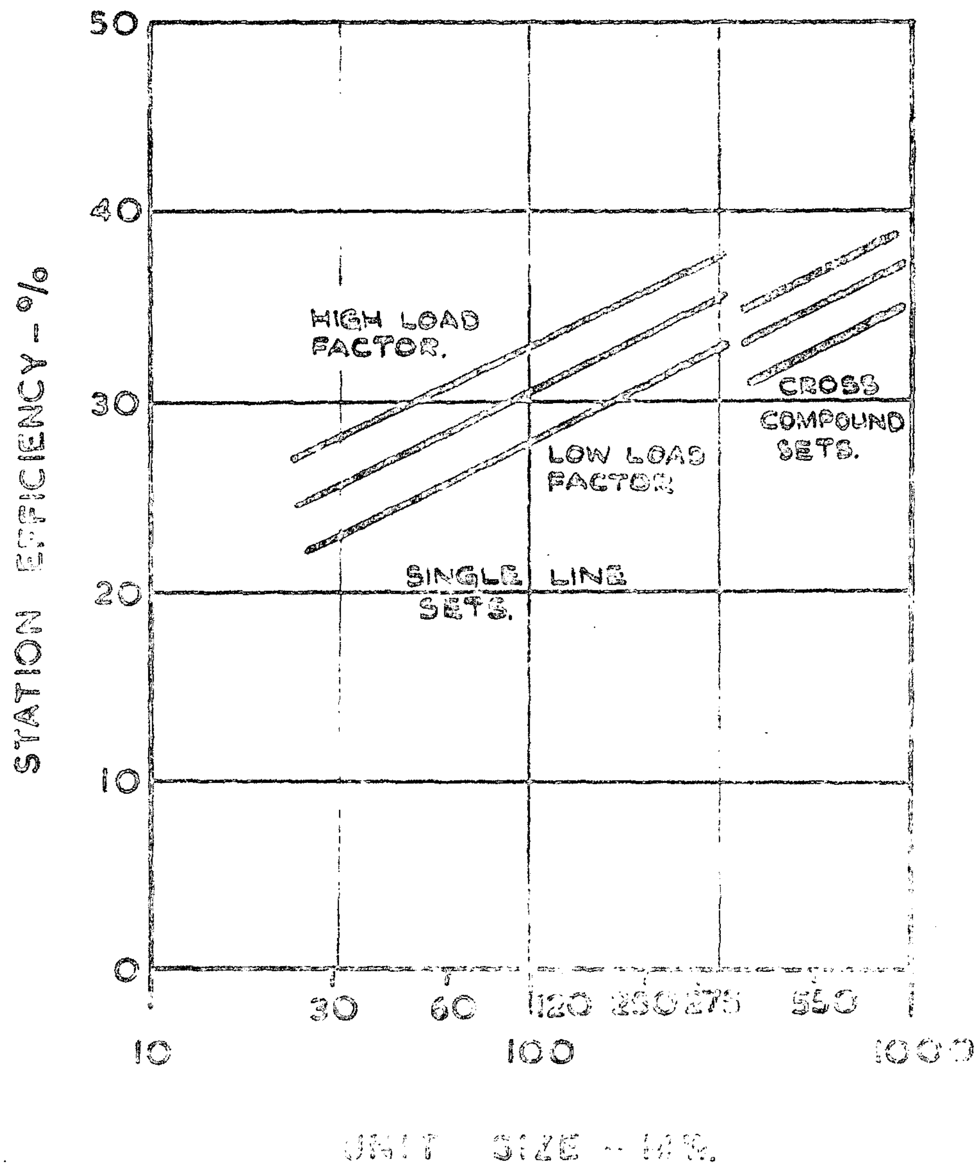
FIG 2

Costs of the very largest units are complicated by adoption of double furnace boilers and two-line units which do not give such a large saving as an increase to the same output capacity on a single line. Eight single-line 500 MW units have recently been ordered in Britain. Appropriate additions in costs for transport and erection should be made when the total cost of new plant to a Latin American purchaser is needed.

The range of station efficiencies that have been experienced and are expected in Britain is shown in fig. 3. One effect of adding highly efficient plant to a supply system and running it as extensively as possible is to reduce the energy output of the existing stations with the result that the mean efficiency of generation by the system as a whole is improved. This is illustrated in fig. 4 which shows the efficiency of generation at the station which happened to be the most efficient in Britain during each of the last 10 years and the mean efficiency of generation of the whole system.

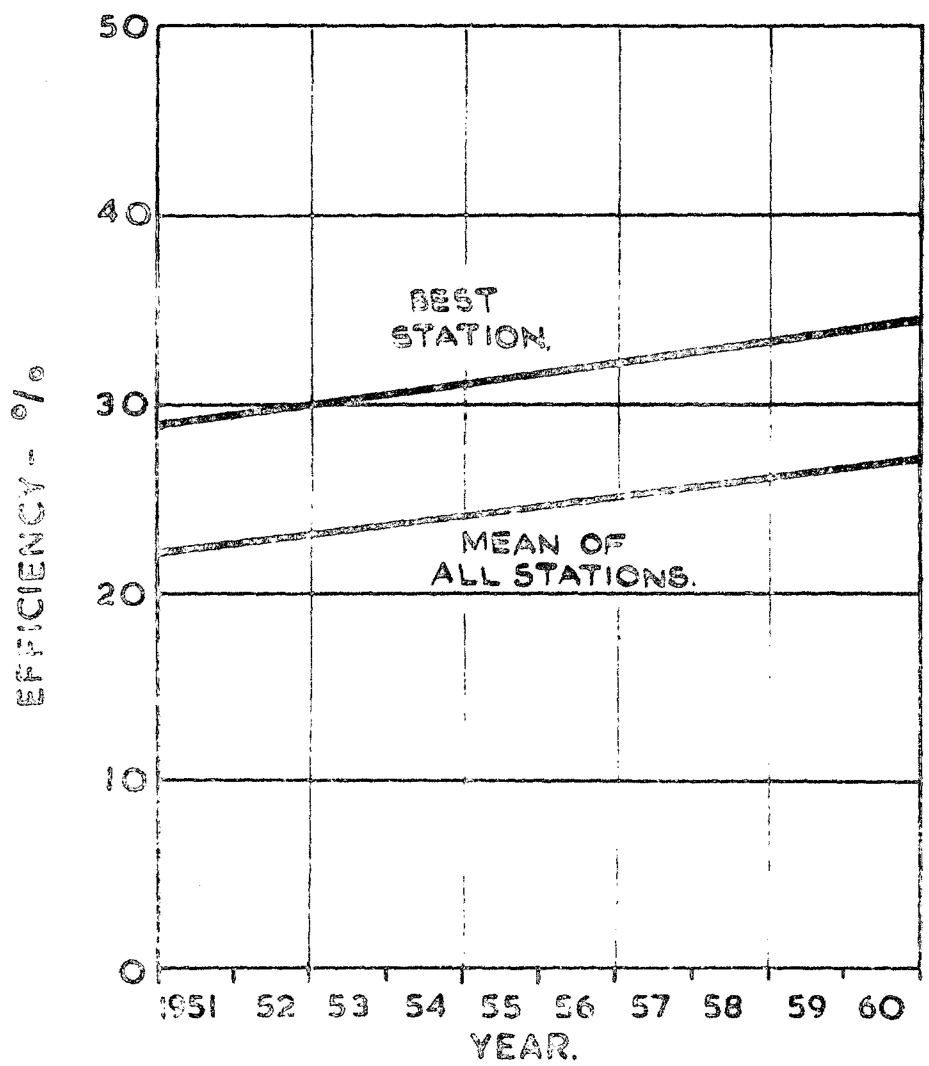
When the system to be extended is of the order of sizes prevalent in Latin America a detailed study should be made of each extension before reaching a decision.

Starting with estimates of the rate at which the load is likely to grow the planning engineer will consider the way in which units of two or three different sizes can be integrated with the system throughout the plant's life and calculate the present value of any differences in operating costs. Though new units may be more efficient than those existing it is rarely possible to take full advantage of the improvement during every hour of the plant's life. Spinning spare must be available to meet the load in



STATION EFFICIENCY - %
50
40
30
20
10
0
HIGH LOAD FACTOR.
LOW LOAD FACTOR
SINGLE LINE SETS.
CROSS COMPOUND SETS.
30
60
120
250
275
550
10
100
1000

FIG 3



BEST AND MEAN GENERATING EFFICIENCIES IN BRITAIN.

FIG 4.

the event of sudden breakdown, causing part load operation to a greater or less degree of all synchronised plant. As the amount of spare must generally be related to the size of the largest set synchronised there may be a need to install extra plant to give a bigger margin of spare when an alternative involving larger sets is studied. Routine maintenance and cleaning of the boiler and turbine must also be taken into account in the estimates of annual cost, and also the difference between practical and theoretically optimum operation. Base-load plant generates less, and peak-load plant substantially more, than the theoretical amounts. Much study is being directed to this matter, and several analogue and other computers have been developed in Britain to bring operation near to the optimum.

The shape of the daily load curve must be considered. A steady system load gives conditions suitable for operation with economy, but a variable load represented by a peaky daily load curve may detract from the economy and modified operation costs on both the proposed and existing plant will result. It is clear that considerations of installation cost and efficiency are not the only factors to be taken into consideration when specifying new plant and that it is rarely possible to enjoy the whole benefit apparently conferred by increase size and enhanced steam conditions.

A particular matter which must be taken into account in Latin America arises from the extremely rapid development which is occurring there. Generating sets which are large compared with the system at the date of installation will appear comparatively small within very few years and thus it will almost certainly be justifiable to instal in Latin America sets relatively larger than would be installed on a less rapidly expanding system. If this is done at the expense of security of supply, however, there will be a tendency to increase private generation rather than the public supply system. Systems extended with an eye to prestige rather than economy can be very expensive, whether the prestige be a matter of size or of steam conditions. When one station for which the Author's firm are consulting engineers in Britain in an area of high fuel cost was extended it was considered that doubling the set size and making use of higher steam conditions was justified. For extensions at a similar station in South Africa, where fuel is comparatively cheap, doubling the set size was justified but the saving in operating cost obtained from higher steam conditions was not sufficient to outweigh the benefits to be obtained from interconnecting steam and water pipework.

The effect of details of the station design may be important. For instance, in one investigation of a station using 60 MW sets it was shown that use of steam and water interconnecting pipework between units would be financially beneficial in maintaining station output when any one boiler and any one turbo-alternator set were out of service at the same time. In a study to show whether, say, 120 MW reheat units without interconnecting pipework were preferable to 60 MW sets with interconnecting pipework there would be a debit item to put against the case for the larger units, since at high temperatures and pressures interconnection is not practical.

The inability of steam-electric generating units to conform closely with variations in the system load is not shared with hydro-electric generating units which can be started and stopped easily. Hydro-electric plants can often be designed for operation at low load factors and are therefore ideal for meeting demands of a system with quickly varying load. In the absence of a suitable hydro-electric project the use of pumped storage is worth consideration. Water is stored during light load periods and the load on steam plant is maintained at a more constant level throughout the day. Two pumped storage projects now being constructed in Britain are those at Cruachan, 400 MW, and at Ffestiniog, 300 MW.

Design and Operation of New Power Stations

For the 600 MW station at Buenos Aires referred to above these and other considerations were taken into account in deciding the broad outline of the station design. A mass of much more detailed considerations had to be borne in mind in the detailed design of the station. The Buenos Aires station is closely related to a number of stations in Britain, of which Blyth A (for which, as for the B station, the Author's firm acted as consulting engineers) was the first to go into service. It was the first in Britain to use 120 MW reheat units; Blyth B will be the first to use 275 MW and 350 MW units and when completed the two stations on one site will represent the greatest concentration of generating plant in the world. It is impossible in a paper of this length to give a complete description of the design of these stations but some notes on two detailed economic investigations carried out by the Author's firm are of interest. They are typical of many such investigations made by the firm.

Ash and Dust Disposal When Blyth A and B stations are complete the maximum amount of dry ash and dust to be disposed of daily will exceed 3500 tonnes and the average amount will exceed 2500 tonnes. On inland sites this refuse must in general be disposed of by dumping on any convenient land, but one of the main attractions of a coastal site such as Blyth lies in the possibility of disposing of the refuse at sea. The conventional method of doing this for British stations is to carry it beyond the 35 metre line in self-propelled hopper-bottomed barges, as is done from three nearby stations. A very full economic and hydraulic investigation was made of an alternative in which the dust and ground ash were conveyed as a slurry to the circulating-water outfall and there injected into the main discharge of cooling water to sea. This method is comparatively new but is known to be used successfully at Casablanca in Morocco. Float and model tests were made under the supervision of Messrs. Lewis and Duvivier and investigations were made into the size grading of beach sand and into the dispersal of colliery refuse dumped on the foreshore at places near Blyth. It was shown from this work that the refuse would be carried out to sea and would not remain on the beach. The Central Electricity Generating Board was advised that the effect on inshore fishing would not be such as was feared by opponents of the scheme. The capital costs of the barging and injection methods would be about $5,400,000 and $410,000 respectively, and the annual costs (including capital charges) would be about $550,000 and $47,000 respectively. In view of this difference in the costs the necessary clauses were included in a private Bill placed before both Houses of Parliament to obtain the necessary approval for the injection of the refuse in the circulating water. The Bill was introduced in the Lords and passed but the refuse disposal clauses were removed before the Bill was passed by the Commons, and it became necessary to design for disposal of the ash by barge.

In order to determine the size and number of barges required, local records were examined in order to find the maximum number of successive days on which weather conditions would prohibit barging, this being the deciding factor in fixing the size of the emergency store. The barges already serving the other nearby stations provided records of availability and the necessary spare barge capacity could be shared. It was finally decided that three 1000 tonnes deadweight barges would provide adequate capacity both to carry the normal make of refuse from the A and B stations and to clear the silos and emergency storage ponds rapidly after a hold-up due to bad weather. The barges are loaded at a barge dock specially built at the North end of the Tidal Basin in Blyth Harbour.

Cooling Water Exhastive investigations were carried out to decide the most economical method of supplying the cooling water. The use of the harbour as a cooling pond into which the warmed water was discharged was ruled out by the size of the station and the large temperature rise which would have occurred and which would have had a serious adverse effect on the heat rate of the station.

Two main alternatives were considered. These were, firstly, to site the intake and pump-houses for the A and B stations at the North end of the existing Tidal Basin in Blyth Harbour; secondly, to site the pump houses adjacent to the power station site drawing their water direct from the harbour to the West of the present Tidal Basin. If ash disposal were to be by barge, the intake and pump-house work would be combined with a barge dock or quay. Discharge of circulating water for either scheme would be direct to sea.

Since there was negligible land water flow study had to be made of the effect of withdrawing large quantities of cooling water from the Tidal

Basin on water velocity in various parts of the harbour. The tidal flow was determined from the rate of change of water level during tidal cycles together with surveys of the area of the estuary at various water levels and velocities were measured also by means of floats. For the A and B stations of 1730 MW now authorised and at the maximum cooling water requirements of about 65 cumecs the superimposed velocity at the entrance to the Tidal Basin will be about 5.2 cm/sec and at the Pilot's Jetty 7.3 cm/sec. The maximum neap flow at the entrance to the Tidal Basin before the construction of the station was only 1.8 cm/sec, and at neap tides therefore the tide from the Basin will ebb through the circulating-water system once the station is complete. Any slight additional silting either of the Basin or of the harbour will be kept under review during the operation of the station by noting changes in the amount of dredging, and estimated costs for this were included in the economic comparison. The changes of velocity were considered to be of negligible importance to navigation.

The first of the alternatives has been adopted and the pump-house and intake works have been combined with a specially constructed ash barge dock opening from the Tidal Basin. Much thought was given to the most economical velocity in the culverts etc.

Other economic investigations which were made before the design could be finalised included the arrangements for coaling the station as affecting both the coal handling plant and the bunker capacity; the most economical voltage and situation for the auxiliary switchgear and transformers; the most economical condenser surface; an economic comparison of different methods of ash and dust handling; the relative advantages of different methods of corrosion protection and of the use of plastics in place of cast iron for condenser water boxes; in addition there were of course very many investigations of steam cycle and high-temperature materials, size of plant unit etc. for the whole group of stations with 120 MW sets which are now under construction in Britain; and innumerable investigations by the designers of all the items of plant installed in the station.

Particulars care has been taken at Blyth A to operate the station in the most economical way possible. Some brief notes on the principles involved will be of interest. Without care of the kind described even the best of stations will not produce the cheapest electricity.

The purchaser of new plant undertakes responsibility for efficient and safe operation from the commissioning day throughout the plant's life. Particularly where the plant is bigger and potentially more efficient than any hitherto employed on the system is care and forethought needed in planning staff appointments and training. As Blyth A was the first such station no staff with direct operational experience was available and consequehtly the training of staff and the future operation of the station for maximum economy was considered in close detail by the operators, the North Eastern Division of the Central Electricity Generating Board.

The Station Superintendent was appointed some six months before the first machine was commissioned and his senior assistants about a month later. The shift Charge Engineers and a nucleus of the industrial staff began work on the site some three menths and two months respectively before the commissioning

The two unit control rooms at Blyth each control two boiler/turbine sets. They are both under the direction of one supervising engineer, and his operating team for each pair of units consists of the following men :-

One Unit Operator in control of two units

Two Assistant Unit Operators, assisting with two units

Two Auxiliary Plant Attendants, each operating the auxiliaries of one unit

One Shift Labourer - common to two units.

Staff Training It was considered essential that a comprehensive system of staff training should be introduced which would recognise the two fundamental aims of the Station Operator, that is safety of personnel and plant and the need to produce electricity as cheaply as possible. Training prior to commissioning was planned in four distinct phases :-

1. Lectures were gien by specialists from the major contractors on the design and operation of their repective plants. These lectures were given on site and had the advantage that any queries raised at the lectures regarding the plant could be checked practically.

2. Station senior staff gave lectures to explain in more detail the operation of the plant at Blyth.

3. The Unit Operators were given the opportunity of visiting major power stations to study, with the help of Blyth technical staff, operating conditions and plant items similar to those anticipated at Blyth Power Station.

4. Emphasis was laid on the importance of training Plant Operators on the practical side of their jobs. Prior to actual commissioning operators were divided into teams to explore fully the boiler and turbine.

All operating personnel were issued with a brochure containing drawings and descriptions so that the main technical details were in the possession of the station personnel, and more detailed technical information was given to all members

13. Electrical Tests

14. Synchronise

15. Loading (Initial) 70 -80 MW

16. Hydrogen fill, lubrication oil change and bearing inspection

17. Loading (Final) Maximum Continuous Rating

18. Hot settings on pipe line supports.

<u>Starting Procedure</u> During initial running at Blyth 'A' three main problems arose which affected starting procedure.

1. The reheat temperature was too low and the rate of rise of reheat temperature following synchronising and initial loading was too high.

2. The drainage quantities were excessive.

3. The airheater gas outlet temperature was too low.

A period of experiment has led to the present technique in which the reheat temperature is initially kept as high as possible by increasing the air flow using the uppermost burners, increasing the gas flow across the reheater and by raising the main steam temperature so ensuring higher inlet temperatures to the reheater. The reheat temperature following synchronising is limited by opening the topping economiser and shutting the reheat dampers just as the machine commences final acceleration.

Development of the starting technique has led to substantial reductions in the time taken to run up to full speed with as one result a substantial reduction in drainage losses.

In order to raise the gas outlet temperature the main economiser gas by-passes and the air heater re-circulating dampers are kept open during start of the technical staff in the form of a data book. As experience of operation of plant accumulates a series of 'Operation Codes' are being prepared and issued instructing the station staff in the methods of operation that have been found most satisfactory and efficient.

Commissioning the Plant The successful commissioning of any power station within a tight time schedule calls for careful planning and prompt and effective execution of these plans together with the utmost co-operation between consultants, contractors and operators.

Following the commissioning of the water treatment plant the sequence of events leading to the final synchronisation and loading can be summarised as follows :-

1. Boiler hydraulic test
2. Initial alkaline boilout, acid clean and final alkaline boilout
3. Casing air tightness test
4. Cold settings on pipe line supports
5. Creep datum measurements on main and reheatt steam pipes
6. Blow through steam line to atmosphere
7. Float safety valves and final steam line blowing
8. Turbine oil system flushing
9. Flushing of condensate and feed system including steam side of heaters
10. Raises vacuum
11. Run machine up to speed, test overspeed trips, governor valve and emergency valve operation, protective gear tests and check bearings
12. Dry out alternator

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In order to raise the gas outlet temperature the main economiser gas by-passes and the air heater re-circulating dampers are kept open during start up. In addition one half of the air heater and one of the two precipitator casings are isolated and the entire gas flow is taken through the other air heater half and precipitator.

A very compreshensive series of tests involving many hundreds of instruments is at present in hand in order to develop a quick-starting procedure which will enable the station to be operated with maximum economy when it is used for two-shaft working i.e. is shut down each night and for weekends.

TABLE 2

BLYTH 'A' POWER STATION

Operating Results

		1959	1960	1961 (to 30 April)
Thermal efficiency	%	34.15	34.46	34.08
Running plant load factor	%	91.4	97.8	97.3
Station load factor	%	46.9	50.4	80.5
Gross calorific value of fuel (coal)	kcal/kg	5274	5208	5195
Auxiliary consumption	%	6.65	5.95	5.47

$$\text{Running plant load factor} = \frac{\text{Units generated}}{\text{Sum of M.C.R. of each machine x hours run}}$$

$$\text{Station load factor} = \frac{\text{Units sent out}}{\text{Max. demand sent out x hours run by station}}$$

Commissioning dates

No. 1 set 23rd December 1958 No. 2 set 16th June 1959

No. 3 set 26th November 1959 No. 4 set 20th June 1960

Design of Buenos Aires Central Power Station

The present and planned generating capacities in the several supply areas in Argentina are :-

	1960	1969
	MW	MW
Greater Buenos Aires	1142	2769
Cordoba	115	267
Meduza	65	207
Tucuman	32	74
Resistencia - Corrientes	12	53
Alto Valle del Rio Negro	8.5	26

It will be seen that in all areas the rate of growth is high, particularly so perhaps in the smaller systems. A very large increase in capacity is called for in the Greater Buenos Aires area and work is already in hand on plant to supply part of the deficiency. It will be seen from the figures above that plant units of 120 MW can be used now with economy in the Greater Buenos Aires system and larger units in 1970 or earlier if the Greater Buenos Aires area is interconnected with one or more of the other major areas. When the first 120 MW unit is commissioned at Buenos Aires it will at first meet at times of peak load about one-tenth of the demand but this proportion will fall quite quickly. When complete the station will be the largest steam-electric power station in Latin America. A description of the contractual arrangements made for its construction, and of its design, will therefore be of interest.

A specification for a complete thermal power station having a total capacity of 600 MW was issued by the Water and Electrical Energy Department (AyEE) of the Argentine Ministry of Commerce in 1956, and a contract with the selected tenderer was signed in January 1958. The size of plant unit was left open for the tenderers to put forward their most economic designs, and the guaranteed performance called for is that of the complete station. The station is now being constructed on reclaimed land at the entrance to the Dock Sud at Buenos Aires, about five kilometres from the centre of the city. A plan of the site is attached.

The specification includes construction of the whole of the Civil Engineering works other than the wharves, river walls, and land reclamation. For the preparation of their tender the successful Tenderers - a Partnership of the British Thomson-Houston Export Co. Ltd. and International Combustion Ltd. - engaged the services of two firms of consulting engineers who were responsible for the layout, the co-ordination of the design, and the preparation of estimates for all items which were outside the normal scope of the manufacturers forming the Partnership. A tender for the civil engineering work was obtained on behalf of the Partnership from a consortium of civil engineering contractors to a specification and bill of quantities prepared by the Consulting Engineers.

The completed tender included for the services of the same Consultants; Merz and McLellan for the mechanical and electrical engineering work and for over-all co-ordination, and Sir William Halcrow & Partners taking responsibility for the civil engineering work.

During the execution of the Contract the Consulting Engineers carry out their normal duties. Their services are available to AyEE for discussions on the designs or layouts, and for interpretation of the specification. They serve both Purchaser and the Contractor by approving designs on behalf of the Purchaser, inspecting and testing the materials and plant during manufacture and erection, supervising the acceptance tests on site and the progressing of all the works.

The inquiry specified that the completed station should have a total capacity of 600 MW, to provide which the Tenderers were at liberty to quote for any number of units within the limits of six 100 MW and four 150 MW units, with a steam temperature of the order of 550°C - a requirement which could only be met by generating plant of the most modern design. The steam raising plant was to be suitable for burning fuel oil, natural gas, or coal. The production of all these fuels is being developed in the Argentine, and the boiler design is based on the use of these three indigenous fuels, with imported coal to be considered as a possibility. While many essential requirements were specified, including provision in the layout for an extension of 600 MW, Tenderers were given free scope to offer alternative layouts and types of equipment. Adjudication of the Tenders, which all offered different arrangements, was a complicated and lengthy proceeding.

The Partnership's offer was for five 120 MW units with steam conditions at the turbine stop valve of 123 kg/cm^2 and 560°C reheated to 537°C. At the time the Contract was placed there was no operating experience with units of this outside the U.S.A., but a number of units of the same sizes with nearly similar steam conditions were being constructed in Great Britain.

The Buenos Aires site is on reclaimed land. The enquiry was drawn up on the assumption that the main foundations would require piling to a depth of 11 metres, but borings made after the Contract was placed proved that this was not possible. Sir William Halcrow & Partners' solution was to excavate a sub-basement and drive piles to a depth of 16-20 metres from the lower level.

Investigations of the foundation conditions at Buenos Aires following the discovery that the earlier data was inadequate resulted in a delay of several months before construction could commence. Consequently it was not possible to start erection of the main plant until early in 1961 and the first unit is not yet complete.

Fuel The station is designed to make the full output possible using any of shipborne coal, shipborne oil, or piped natural gas as fuel. However, as coal is at present the most expensive fuel the coal handling and pulverising plant, the dust collecting plant, and a large area of land reclamation needed for coal storage are being deferred. Two 21,300 tonne oil storage tanks are being provided and initial commissioning will take place using oil fuel; it is expected that thenatural gas installation will be complete about a year after commissioning the first set when fuel oil will be used only in the event of interruption of the gas supply.

Circulating Water System The design of the circulating water system was outlined in the Specification. Six circulating-water intake pumps of the vertical-shaft axial-flow type with variable pitch impellers raise water from the mouth of the Riachuelo, a tributary of the River Plato, to an un-pressurised double culvert system running the length of the turbine house. Three pumps feed each culvert. The water level in the culverts is automatically controlled by varying the impeller blade angle. Each condenser can be supplied by two horizontal-shaft centrifugal pumps, one drawing from each culvert, and the water is discharged to the circulating-water outfall culvert which enters the River Plate at the opposite side of the peninsula on which the station is built. If one culvert is dry for maintenance or cleaning purposes 60 per cent of the normal full load water flow can be maintained to each condenser from the full culvert. Under this condition the head in the culvert can be raised by 60 cm. and maintained automatically at this higher level to prevent cavitation in the centrifugal pumps. Chlorinating plant is installed at the pump house to control the growth of micro-organisms which have caused trouble at other power stations in the area.

Other Water Supplies Five river water supply pumps situated in the circulating-water intake pump house supply all the other water services required in the power station. The raw water is flocculated and passed through pressure filters to the filtered-water storage tanks from which water is drawn for such uses as auxiliary plant bearing cooling and to maintain supply to the spray-type fire-fighting system for which a supply of clean water is needed. Filtered water is also taken from the tanks for acid treatment, de-gasification and pH adjustment preparatory to passing it through a base-exchange softener to the unit evaporators associated with each turbo-alternator set for use as boiler feed make-up. Degassed water is also chlorinated and used as potable and domestic water and for clean water services within the power station.

Generating Plant The steam generating plant is manufactured by International

Combustion Ltd. Each boiler is of the single-drum natural-circulation "Radiant" type, i.e. the boiler heating surface is made up by arranging the furnace wall tubes in tangent form to receive radiant heat from the furnace. The rating of each unit is 360 tonnes per hour and the guaranteed gross efficiency calculated on the net calorific value of the fuel is 90.8 per cent, burning fuel oil.

The superheater is arranged in four stages the first and second of which are of the horizontal convection type and the third and fourth of the pendent radiant type. The pendent reheater section is arranged between these two groups of primary and secondary superheater surfaces.

Reheat steam temperature control is affected by tilting the burners to adjust the furnace performance, so adjusting the gas temperature entering the reheater. Emergency spray attemperators are fitted at the reheater inlets to operate automatically if the reheat steam temperature exceeds a predetermined upper limit. Main steam temperature control is by spray water attemperators arranged between the primary and secondary superheaters. A gas-recirculating system is also provided to give a supplementary means of steam temperature control.

The soot blowers are air operated the supply to each boiler being tapped from a ring main system maintained at 17.5 kg/cm^2 by a central compressing plant. Two compressors are installed each capable of handling 128 cubic metres of free air per minute and each driven by a 1600 metric horse power electric motor. Four receivers accept air at a pressure of 28.2 kg/cm^2 and maintain the ring-main pressure through pressure-reducing valves. The air consumption of the airheater blowers exceeds the capacity of one of the compressors and the arrangement adopted for maintaining a supply to these blowers was found to be cheaper than to install full-duty compressors.

The turbo-alternator sets are being supplied by the British Thomson-Houston Export Co. Ltd. The turbines are three-cylinder machines; the high-pressure cylinder is of double-casing construction with both casings of ferritic steel, the intermediate-pressure cylinder is a steel casting and the double-flow low-pressure cylinder is fabricated from mild steel. Steam flows in the high-pressure cylinder towards the governor pedestal giving ease of exit to the cold reheat pipes, and making possible the use of a single thrust bearing between the high-pressure and intermediate-pressure turbines and solid couplings throughout. A single steam chest beneath the turbine floor level is used. It is mounted on pin-jointed supports from the foundation block which allow it to move as part of the pipework system. The valve chest contains four single-seated control valves operated hydraulically by the governor and the two emergency stop valves are welded to the ends of the chest.

Each alternator is rated 120 MW, 13.8 kV, 0.8 power factor lagging, is hydrogen cooled at a pressure of 2.1 kg/cm^2 and has a short circuit ratio of 0.52. The stator core and windings are built into a separate inner frame flexibly mounted in an outer frame which is shipped separately. The heaviest part, the inner frame, weighs about 118 tonnes.

The excitation system comprises main and pilot D.C. exciters and a cubicle housing field rheostats, a field circuit breaker and an automatic voltage regulator of the continuously-acting static type employing magnetic amplifiers and motor-driven rotary amplifiers.

Auxiliary Electric Supplies The system adopted for supplying the electrically-driven auxiliaries stems from the idea that the function of an important central generating station is to generate reliably and continuously under all conditions. It was for this reason that Charles H. Merz over 60 years ago pioneered the use of a generator unit transformer directly connected to the generator terminals. The arrangement has become almost universal design practice. All auxiliaries continuously essential for maintenance of generation are fed from the unit transformer; other auxiliaries, less immediately essential, are fed from a common station system.

Control Tower The control tower situated at the North-West corner of the turbine house and joined to it by a foot-bridge is a circular construction the exterior of which is designed to be a principal feature of the entrance to the power station. The shape gives a convenient layout for the control and relay panels which fill an arc of roughly 270° from West through North and East to South leaving an open section clear of equipment affording a good view over the Switchyard in a southerly direction, and good indirect daylighting of the panels. The principal use of the control room is for main switchgear control and to act as a communications centre; the boiler/turbine/alternator controls are placed between the boiler and turbine houses. The basement of the tower contains an air conditioning plant, telecommunications equipment, a first-aid room and an instrument workshop.

Station Output Each alternator is connected to a 13.8/132 kV 145 MVA step-up transformer equipped with off-load tap changing gear.

The entire output will be fed to an existing 132 kV network through four of the six sub-stations being constructed by a division of A.E.I., the group of manufacturers of which B.T.-H. forms part. Transmission to the sub-stations will be at 132 kV over nine feeders each consisting of three single-core oil-filled cables which will form part of the 132 kV cable network. Three feeders will go to the sub-station at Puerto Nuevo 7 km away, three to Dock Sud 3 km away, two to Parque Avallaneda 14 km away and one to Agronomia nearly 17 km away. With further high-voltage cable connections between these and other sub-stations and to the existing power stations an interesting problem in system stability arises particularly at times of light load which has been investigated by the Partnership and the Consultants to establish rules for safe operation of the power station.

The thanks of the Author are due to the B.T.-H.--I.C.L. Partnership for permission to publish the information about the Buenos Aires Central Power Station and to Messrs. A.E. Powell and E. Forth for permission to use the information contained in their paper entitled 'Design, Commissioning and Operation of Blyth 'A' Power Station '.

CENTRAL ELECTRIC BUENOS AIRES - SITE PLAN

A - POWER STATION
B - RESERVE FOR FUTURE EXTENSION
C - BOILER HOUSE
D - TURBINE HOUSE
E - ELECTRICAL ANNEXE
F - 132KV SWITCHGEAR SITE
G - FUTURE 132 KV SWITCHGEAR SITE
H - CONTROL TOWER
J - ADMINISTRATION BUILDING
K - LABORATORY
L - CYCLE SHELTER
M - WELFARE BLOCK
N - CANTEEN
O - GATEHOUSE
P - ACCESS BRIDGE
Q - CAR PARK
R - C.W. INLET CULVERT
S - C.W. OUTLET CULVERT
T - DAILY USE FUEL OIL TANK
U - SOOT BLOWING COMPRESSOR HOUSE
V - CHIMNEY
W - SITE BOUNDARY
X - LINE OF EXISTING SHEET STEEL PILES
Y - LINE OF ORIGINAL RIVER WALL
Z - PRECIPITATOR RESERVE

AA - FUEL OIL STORAGE TANK
BB - FUEL OIL PUMPHOUSE
CC - PENTHOUSE
DD - SWITCHGEAR
EE - NATURAL GAS STORAGE VESSELS
FF - NATURAL GAS REDUCING STATION
GG - AUXILIARY BOILER HOUSE
HH - GAS OIL STORAGE TANK
JJ - GAS OIL FILLING STATION
KK - WORKSHOPS AND STORES
LL - WATER CLARIFICATION PLANT
MM - 200 TON DERRICK
NN - FIRE SERVICE TANK
OO - FIRE SERVICE PUMPHOUSE
PP - CHLORINATING PLANT HOUSE
QQ - C.W. PUMP HOUSE
RR - GARAGE
SS - LOCO SHED

SPANISH TRANSLATION

CENTRAL ELECTRICA BUENOS AIRES - PLAN DE LA OBRA

A - CENTRAL ELECTRICA

B - RESERVADA PARA EXTENSIONES FUTURAS

C - SALA DE CALDERAS

D - SALA DE TURBINAS

E - SALA DE EQUIPOS ELECTRICOS

F - PLAYA DE DISTRIBUCION 132KV

G - PLAYA FUTURA DE DISTRIBUCION 132KV

H - TORRE DE CONTROL

J - EDIFICIO ADMINISTRATIVO

K - LABORATORIO

L - DEPOSITO BICICLETAS

M - SERVICIOS SOCIALES

N - COMEDOR

O - PORTERIA

P - PUENTE DE ACCESO

Q - PLAYA DE ESTACIONAMIENTO AUTOMOVILES

R - CANAL DE ENTRADA DE AGUA DE CIRCULACION

S - CANAL DE SALIDA DE AGUA DE CIRCULACION

T - TANQUE COMBUSTIBLE DE SERVICIO DIARIO

U - SALA DE COMPRESORES PARA SOPLADO DE HOLLIN

V - CHIMENEA

W - LIMITE DEL TERRENO

X - LINEA DE TABLA ESTAJAS EXISTENTES

Y - LINEA DE PAREDON ORIGINAL

Z - RESERVADA PARA PRECIPITADORES

- - - - - - - -

AA - TANQUE ALMACENAMIENTO PETROLEO

BB - SALA DE BOMBAS DE PETROLEO

CC - SALA DE ESCLUSAS

DD - EQUIPO ELECTRICO DE DISTRIBUCION

EE - CILINDROS DE ALMACENAMIENTO PETROLEO

FF - SALA DE REDUCCION DE PRESION DE GAS NATURAL

GG - SALA DE CALDERAS AUXILIAR

HH - TANQUE DE ALMACENAMIENTO DE GASOIL

JJ - LUGAR DE DESCARGA

KK - TALLERES Y ALMACENES

LL - PLANTA DE TRATAMIENTO DE AGUA

MM - GRUA 200 TONELADAS

NN - TANQUE PARA SERVICIO CONTRA INCENDIO

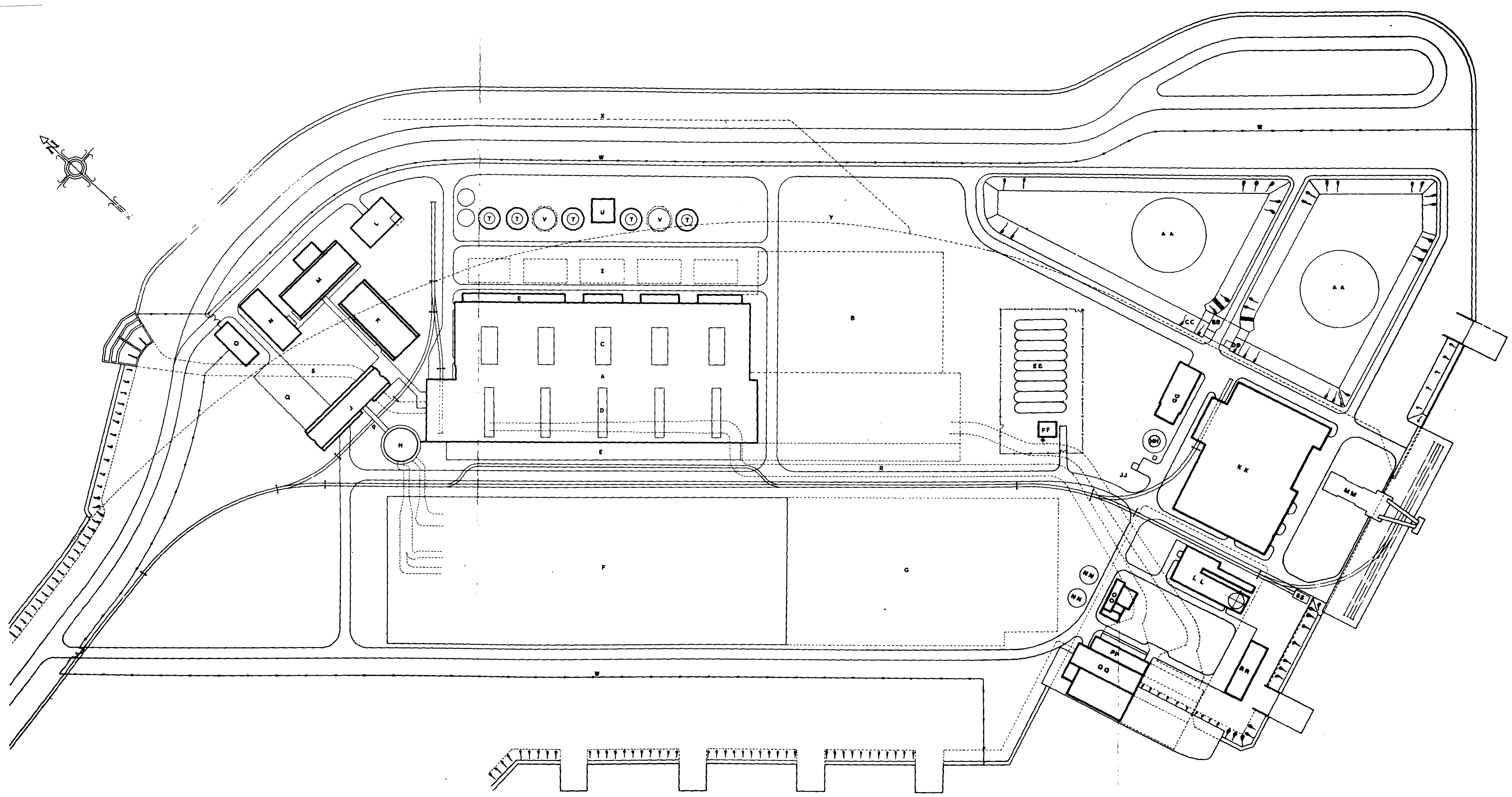
OO - SALA DE BOMBAS CONTRA INCENDIO

PP - PLANTA DE CLORINACION

QQ - SALA DE BOMBAS DE AGUA DE CIRCULACION

RR - GARAGE

SS - DEPOSITO DE LOCOMOTORAS



CENTRAL ELECTRICA BUENOS AIRES.

SITE PLAN.