Final Report No. 314.
ITEM No 33

THE GERMAN ELECTRICITY SUPPLY SYSTEM

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SUB-COMMITTEE

LONDON - H.M. STATIONERY OFFICE

THE GERMAN ELECTRICITY SUPPLY SYSTEM

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Sponsored by Foreign Office

BIOS Target Numbers
C33/169, C33/185, C33/123,
C33/125, C33/187

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I. OBJECT OF VISIT

The primary object of the visit was to compare and contrast the German high voltage transmission system with the British Grid, with special reference to their performance under war conditions.

A secondary object was to review and supplement where necessary the general description of the German electricity supply system given in the Foreign Office and Ministry of Economic Warfare Report entitled "Germany. Electricity Supply" (Report No. L294/1/Z Part 1 dated *August 1943 and Part 2 dated November 1944).

Specific technical items which had to be investigated included high voltage direct current transmission, and miscellaneous matters relating to electrical distribution on which the Electricity Commissioners called for technical information.

II. SUMMARY

The most important lines in the German high voltage system operate at 220 kV. as compared with 132 kV. on the British Grid.

The German 220 kV. lines cannot by themselves be used to form a complete interconnecting system, but in conjunction with numerous 110 kV. networks a complete grid systemhas been established. The German system, unlike the British Grid, is not operated as a unit, but is divided into two parts which are electrically separate although means are available whereby they can assist one another in emergency. Each of the two main sections of the German supply system has a plant capacity of about 6,000 MW. or approximately 60% of the total plant capacity working in conjunction with the British Grid. The reasons for this sub-division of the German system are alleged to be wholly technical, the most important of these being that power interchanges over the interconnecting 220 kV. lines vary too violently for safe operation under wholly interconnected conditions.

Within the two main sections the degree of interconnection seems to be somewhat less rigid than that of the British Grid, it being common practice to operate sections of 110 kV. networks as radial feeders instead of as ring mains. At lower voltage (60 kV. and below) radial operation of circuits is the prevailing practice. The result of the above method of operation is that security of supply to individual bulk consumers is less than in Great Britain.

*A revised edition of Part I dated June 1945 has been issued.

The possibility of a general failure of supply is, however, reduced.

National control of electricity supply is less fully developed than in Great Britain, but efforts were being made during recent years to unify the system. By the latter stages of the war a fairly effective National Load Despatching centre had been established from which loading instructions were issued to the 14 Power Districts into which Germany was divided for electricity supply administrative purposes. The standard of economic load despatch was low in comparison with that of the British Grid and the organisation and equipment relatively primitive.

The German engineers obtained considerable experience in the use of methods for deliberate load reduction and successfully operated their system at very low frequencies, a system frequency of 45 cycles instead of the normal 50 cycles being quite customary and a frequency as low as 40 cycles having been reached on occasions without general failure of supply.

During the period of the war the national plant capacity was increased by about one-third. Loss of output capacity due to plant being out of service for maintenance or repair was kept at a remarkably low level throughout the war. Nevertheless there was a shortage of generating plant capacity during the winter months which amounted to about 5% - 8% in the winters of 1941/42 - 1943/44 and which reached, after the heavy bombing of the Allies, 25% in the winter of 1944/45.

Engineering features of general interest are the complete elimination of the oil circuit breaker customary in Great Britain and its replacement by the air blast or expansion type.

Transformers of 100 MVA. capacity, with multiple ratios, e.g. 220, 110, 60 and 10 kV. are extensively used.

Transmission line towers are not standardised in Germany to anything approaching the degree established in Great Britain.

Underground cable developments are on the same lines as in Great Britain but are less extensive. The most advanced type we encountered was 110 kV. 3-phase external pressure cable.

Steam power station practice in Germany differs from that in Great Britain mainly in the following respects.

The steam pressures and temperatures are much higher in Germany - the maximum levels encountered being 125 At. and 500° C.

Back pressure turbines are extensively used.

In hydro-electric developments the outstanding feature in Germany is the use of pumped storage for supplying peak loads.

War damage to power plant and transmission lines was extremely heavy in the later stages of the conflict, but the high degree in which supply was restored shortly after cessation of hostilities is a remarkable tribute to the general soundness of the German system and organisation.

In this connection, however, it must be recognised that if the German generating stations had been systematically attacked, the power supply could have been completely cut off.

Regarding contemplated future development the outstanding features we encountered were plans for establishing very high power transmission lines to operate at 400 kV. The purpose of these lines was to bring hydro-electric power from Austria and Norway to Germany.

III. ADMINISTRATIVE AND OPERATIONAL SECTION

1. General

Public electricity supplies in Germany are given by over 5,000 separate undertakings each with its own exclusive area of supply. Most of these undertakings, however, have only a very small area of supply and a relatively small number* of large undertakings are responsible for the greater part of the national public electricity supply. Private generation of electricity by industrial undertakings is on a considerably greater scale than in Great Britain and the total installed capacity and annual production of these private industrial generating stations is little less than that of the stations operating for public supply. Some of the private industrial stations give supplies to the public system as well as to the local industrial plant which they serve.

Before the war no systematic arrangements existed for the inter-connected operation of the generating stations nor was there any organisation for controlling the bulk transfer of electricity on a national scale. It is true that there were many private agreements for the mutual interchange of energy between adjacent undertakings but these arrangements were local or regional and there was no counterpart to the British Central Electricity Board, or "Grid" as it is popularly termed.

The National-Socialist Government recognized the need for such a national organisation and took successive steps for its formation until, by the latter stages of the war, a fairly complete organisation had been established. In particular the total number of separate undertakings had been reduced from a pre-war figure of over 10,000 to about 5,000.

Our investigation into the administration and operation of the German electricity supply system during the war was thus directed, partly to the gradual establishment and the activities of the organisation for the national control of the electricity supply industry and partly to the operation of the power stations and transmission systems owned by the larger electricity supply undertakings.

2. The establishment of National Control over the Electricity Supply Industry

(a) The W.E.V.

When the National-Socialists came into power in 1933 they found an electricity supply industry composed of many thousands of

* It is estimated that the 12 largest undertakings collectively provide about one-third of the total national supply.

separate, or only loosely connected, Undertakings. The sole body which represented the industry collectively was the V.E.W. (Vereinigung der Elektrizitätswerke - Association of Electricity Supply Undertakings). This was an old-established voluntary association and was supported by Undertakings collectively responsible for over 90 per cent of the public electricity supply given in Germany. This Association was concerned with financial, technical and operational problems of the electricity supply industry and also served as a collecting agency for statistics. In addition, it maintained contact with similar associations in other countries and with other branches of industry in Germany, and it represented the electricity supply industry in negotiations with the German Government.

Thus it happened that when the National-Socialists established in 1934 the elaborate organisation under the Ministry of Economic Affairs (Reichwirtschaftsministerium) known as the Estate of Industry and Trade (Organisation der Gewerblichen Wirtschaft) through which they intended to control the whole economic life of Germany, they fitted the V.E.W. into this organisation as the body through which the electricity supply industry should be controlled. The Estate of Industry and Trade was to comprise a number of National Branches (Reichsgruppen) of industry or trade each of which was to be sub-divided into a number of Trade Groups (Wirtschaftsgruppen). One of the National Branches was to be the National Power Branch (Reichsgruppe Energiewirtschaft) and this was to have two Trade Groups, firstly the Electricity Supply Group (Wirtschaftsgruppe Elektrizitätsversorgung - abbreviated to W.E.V.) and secondly, the Gas and Water Group (Wirtschaftsgruppe Gas und Wasser - abbreviated to W.G.W.). The V.E.W. was accordingly reconstituted and renamed the W.E.V., thus becoming the means by which the Government could exert its influence on the electricity supply industry rather than the means by which the industry could influence the Government. The W.E.V. retained the functions of the V.E.W. but had more definite authority and membership was made compulsory. The main functions of the W.E.V. were:-

(i) To exchange technical, economic and commercial experience among the members and to promote standardisation.

(ii) To obtain information and to prepare reports for the National-Socialist Government.

(iii) To approve or disallow applications by members for permission to install new plant for electricity production or supply.

(b) The National Office for Electricity Supply

On the outbreak of war in September 1939, a further step was taken in the establishment of national control over the electricity supply industry. Under an Act for the Assurance of Electricity Supply the Minister of Economic Affairs was empowered to control the allocation of electricity to the various consumers and of load to the various producers. This control he exercised by the establishment of a National Office* for Electricity Supply (Reichsstelle fur die Elektrizitätswirtschaft). The principal duties of this Office were:-

(i) To direct and control in the national interest the output of electricity generating plant, whether publicly or privately owned, and whether normally used for public supply or not.

(ii) To determine the order of priority of electricity consumers and to allocate the available output of the generating plant according to that order.

(iii) To require undertakings to construct such electrical connections as were necessary to enable (ii) to be efficiently performed.

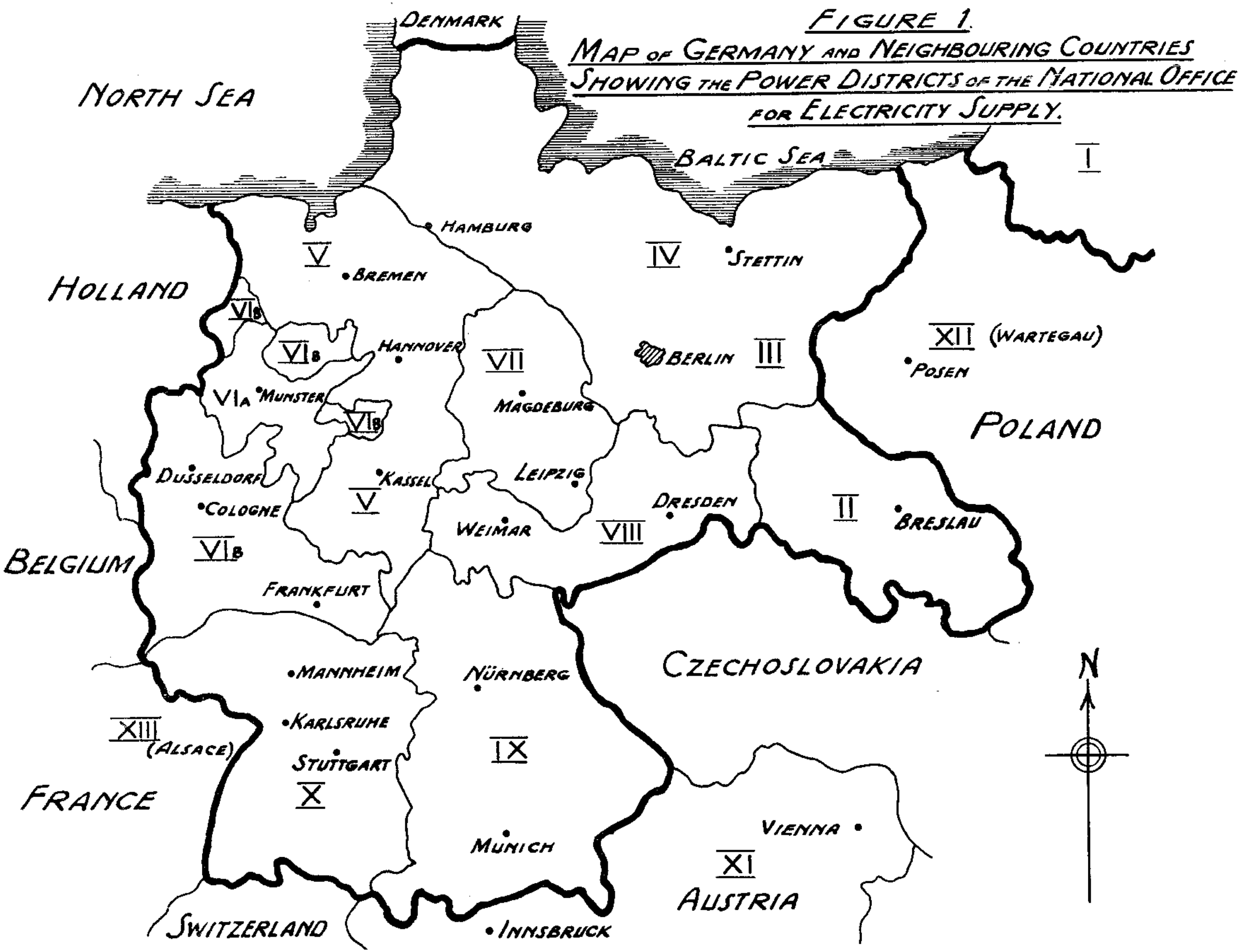
The Head Office of this organisation was established in Berlin and the principal official was known as the National Load Despatcher (Reichlastverteiler). The electrical network controlled by the National Load Despatcher included Austria, Sudetenland, Alsace and the Wartegau of Poland, as well as the whole of Germany. For administrative purposes, this system was divided into 14 Power Districts (Energiebezirke) in each of which there was appointed a District Load Despatcher (Bezirklastverteiler). The approximate geographical boundaries of these Power Districts are shown in Figure 1 on page 8 and it will be seen that there are 11 Districts in Germany (counting VIa and VIb as two Districts) and one each in Alsace, Austria and Poland. These Power Districts were in turn divided into a number of local areas each in charge of a Local Load Despatcher (Ortslastverteiler).

For convenience, the area of each Power District was based on the area supplied by one or two of the major electricity supply undertakings and the load despatcher of the largest of these was appointed Bezirklastverteiler for the District. This sometimes meant that an individual in his capacity as a State

*There were similar National Offices (Reichsstelle) under the Minister of Economic Affairs for the control of other materials used for industrial production. Thus the Minister of Economic Affairs through the appropriate National Office allocated materials to the Electricity Supply Industry. This allocation was done through the W.E.V.

FIGURE 1.

MAP OF GERMANY AND NEIGHBOURING COUNTRIES SHOWING THE POWER DISTRICTS OF THE NATIONAL OFFICE FOR ELECTRICITY SUPPLY.



official had to order actions which were contrary to the interests of the electricity supply undertaking in which he was employed. On the whole, however, the arrangement seems to have been satisfactory.

(c) Other Government organisations concerned with Electricity Supply

Governmental control of the electricity supply industry remained effectively through the two organisations which have been described - the "W.E.V." and the "National Office for Electricity Supply" - although many changes took place at high governmental levels. The principal of these were as follows:-

(i) In 1939 a semi-independent Plenipotentiary for Power Supply (Generalbevollmächtigten für die Energiewirtschaft) was appointed to supervise the National Power Branch of the Estate of Industry and Trade (and hence the W.E.V.).

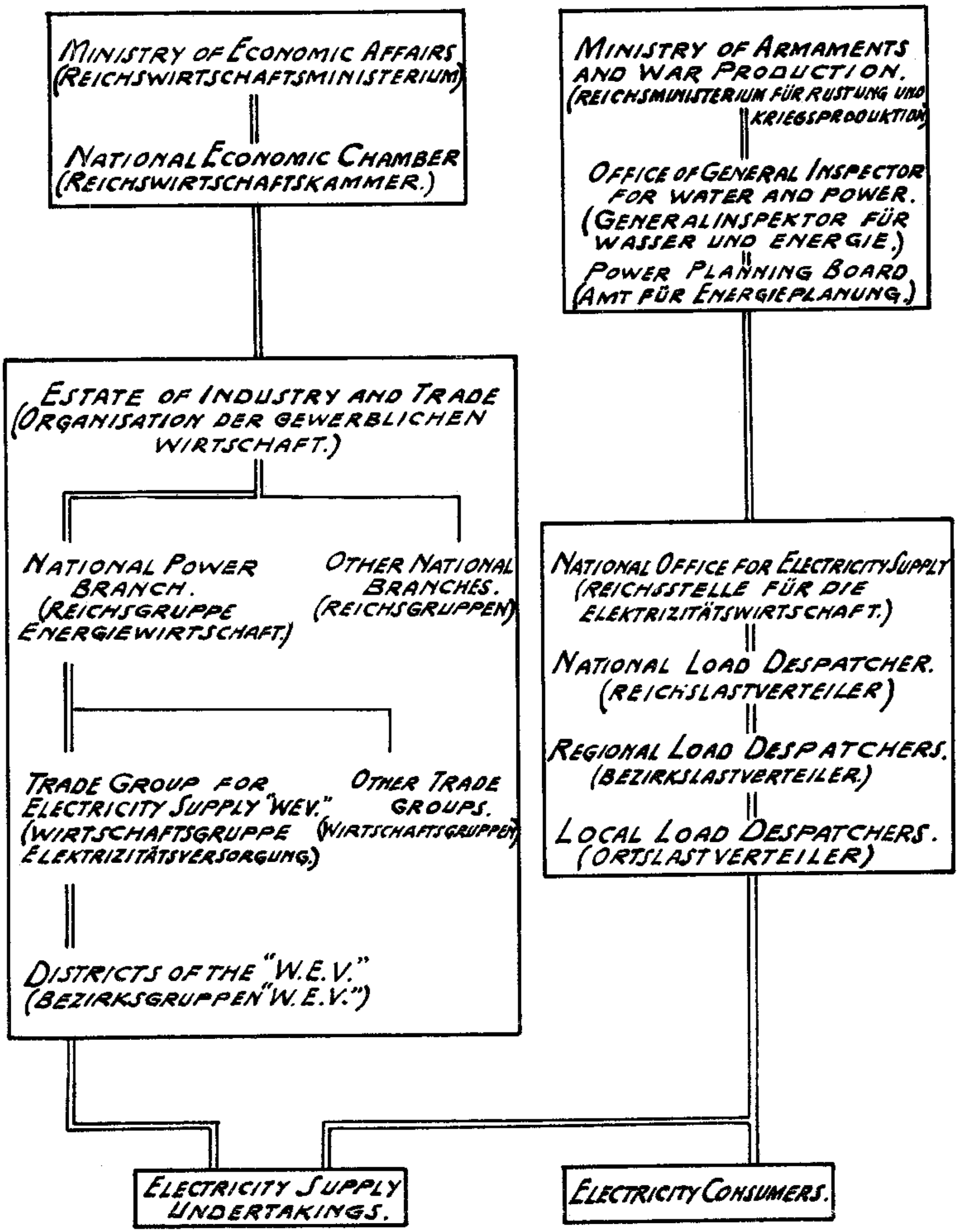
(ii) In 1941 both the National Power Branch of the Estate of Industry and Trade (and hence the W.E.V.) and the National Office for Electricity Supply were subordinated to a General Inspector for Water and Power (Generalinspektor für Wasser und Energie).

(iii) In 1942 the Minister of Armaments and War Production (Reichminister für Rustung und Kriegsproduktion) established a department of his Ministry called the Power Planning Board (Amt für Energieplanung). This Board was concerned with the provision of electricity to new industrial plants.

A diagrammatic illustration of the organisation for the national control of the electricity supply industry in Germany as it existed at the end of the war is given in Figure 2 on page 10.

FIGURE 2

DIAGRAMMATIC REPRESENTATION OF THE ORGANISATION FOR THE NATIONAL CONTROL OF THE GERMAN ELECTRICITY SUPPLY INDUSTRY.



3. Operating Procedure and Experience

The operating headquarters of the National Office for Electricity Supply was the National Load Despatcher's office in Berlin. This office was equipped at first only with telephones and teleprinters (later supplemented by wireless equipment). These were used for communicating with the 14 District Load Despatchers. Towards the end of the war a frequency meter was installed but no other metering was provided. The National Load Despatcher's office was thus an administrative office rather than a control room and was concerned in broad outline with the national plant and load position and with energy transfers between Power Districts rather than with detailed load despatching.

A telephoned report was received each day from each District Load Despatcher giving details for the previous day of the plant capacity available, the peak load supplied, the equivalent electrical energy available from the storage reservoirs of water power stations, the war damage suffered, if any, and the progress made with war damage repairs. An Operation Report was prepared each week by the National Load Despatcher's office and was supplied to Government Departments and to each of the Regional Load Despatchers. A copy of this Report for the week ending 23; 8;42 is given in Appendix A and it will be seen that the subject headings are:-

(a) Load
(b) Seasonal Storage Reservoirs
(c) Capacity not available
(d) Enemy Action
(e) Inter-district energy transfers
(f) Coal supplies
(g) Consumption restrictions.

Based upon the information supplied to him from the Districts the National Load Despatcher issued both long-term and short-term instructions to the District Load Despatchers. The long-term instructions specified the generation and consumption within each District, and the transfer between Districts, of energy (kilowatt-hours) during a given period such as a week or a month. The short-term instructions specified the corresponding figures of power output (kilowatts) at time of peak load.

The 14 Districts had individual maximum loads of from about 300 MW.* up to about 2,000 MW. District I (East Prussia) was not electrically interconnected with the rest of the system and Districts XII (Wartegau of Poland) and XIII (Alsace) were not

* A megawatt (MW.) is 1,000 kilowatts (kW.)

established till the middle of 1944. Attempts were made to operate the remaining 11 Districts in parallel but these were unsuccessful because of the excessive load swings of up to plus and minus 80 MW. which occurred between the Eastern and Western parts of the country. It was accordingly the normal practice to operate the main system in two parts - an Eastern Frequency Block and a Western Frequency Block. Each of these Frequency Blocks had a maximum load of about 5,000 MW.

The inter-district transmission line capacity varied from a maximum of about 500 MW. to a minimum of about 100 MW. These figures were based on a nominal rating of 125 MW. for a 220 kV. circuit and 40 MW. for a 110 kV. circuit. However, in practice, up to 140 MW. was transferred over a 220 kV. circuit and 80 MW. over a 110 kV. circuit.

One of the main functions of the National Load Despatcher was the re-arrangement of inter-district load flows in the event of war damage to the plant in one of the Districts. An example of such a re-arrangement is given in Figure 3 on page 13 which shows the inter-district load flows before and after the loss of Goldenberg power station in District VIB due to air attack. It will be seen that before this incident District VIB was providing an export of 150 MW. while after the incident it received a nett import of 150 MW.

During the war and particularly during the last few months, the system was regularly operated with the frequency and the voltage on the 220 kV. and 110 kV. lines much below normal*. An example typical of these conditions is given in Figure 4 on page 14 which shows the frequency and voltage conditions on the Eastern Frequency Block for a sample day in 1944. It will be seen that the system was operated for long periods with a frequency 10% below normal (i.e. 45 cycles/sec. instead of 50 cycles/sec.) and a voltage 30% below normal (i.e. 77 kV. instead of 110 kV.). Despite these abnormal conditions, the system remained stable. Nor were these conditions the worst which were experienced for on one occasion the system was successfully operated with a system frequency as as low as 40 cycles.

In Great Britain almost the entire production of electrical energy is derived from hard coal. In Germany much use is made of brown coal and water power in addition to hard coal. The relative importance of the different sources of energy is indicated by Figure 5 on page 15; the figures plotted

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* Efforts were, however, made to keep the 60 kV. and lower voltage lines at the correct voltage.

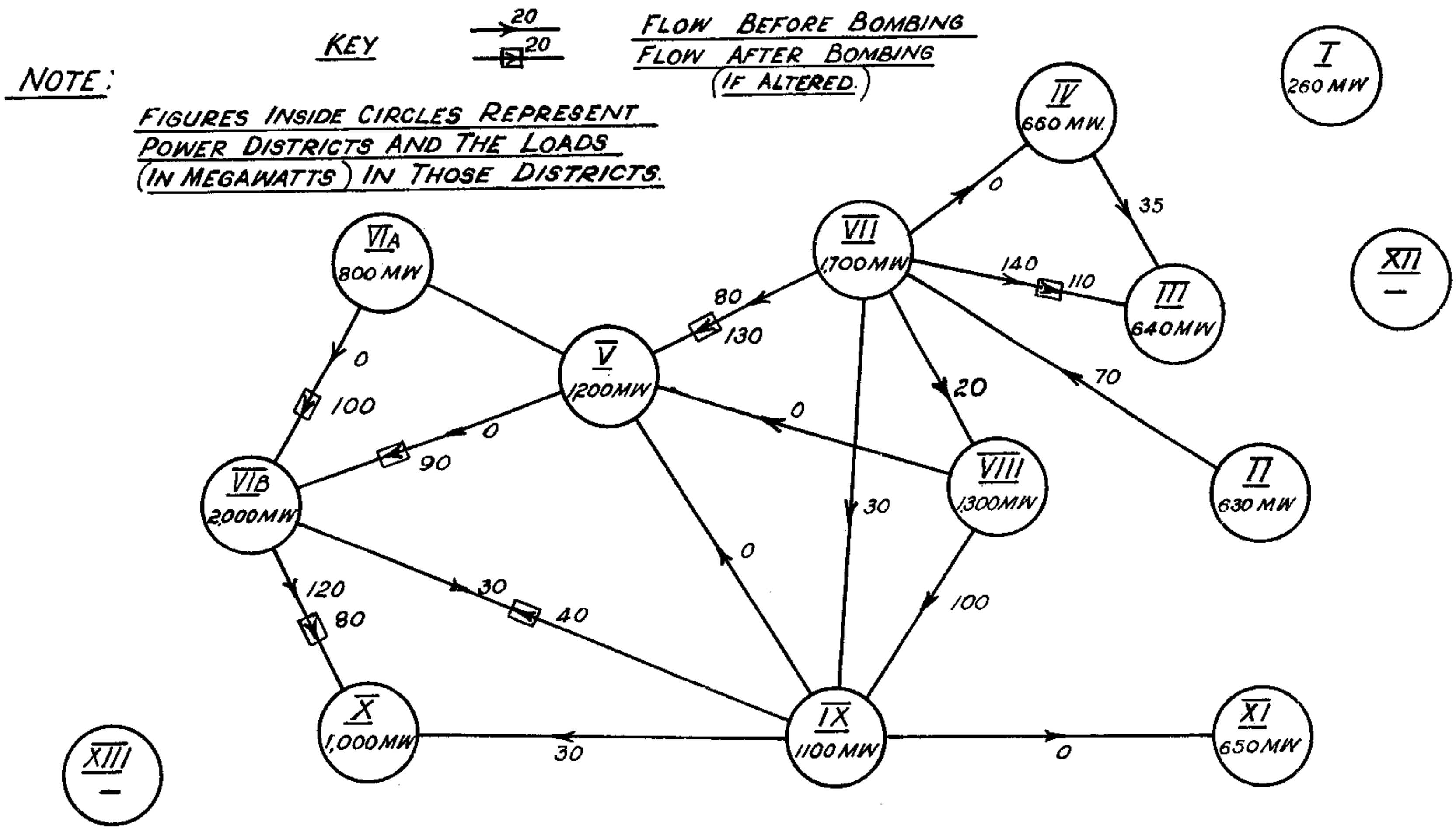


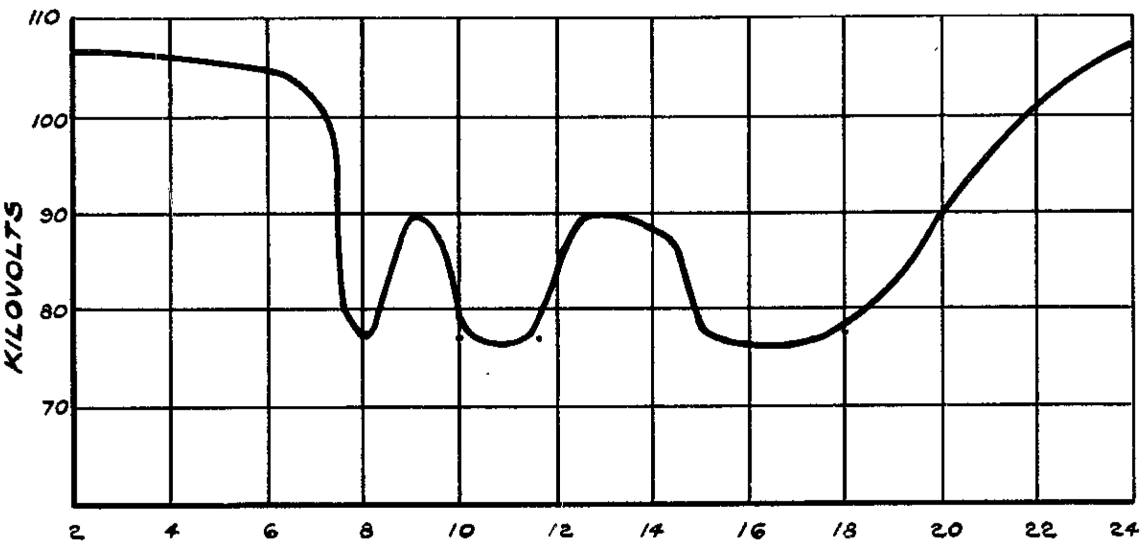
FIGURE 3.

SCHEMATIC DIAGRAM OF CONNECTIONS BETWEEN GERMAN POWER DISTRICTS SHOWING INTER DISTRICT LOAD FLOWS BEFORE AND AFTER THE BOMBING OF GOLDENBURG POWER STATION IN DISTRICT VIB

FIGURE 4.

OPERATING CONDITIONS OF GERMAN EASTERN FREQUENCY BLOCK FOR TYPICAL WORKING DAY IN 1944.

A. RECEIVING VOLTAGE AT BERLIN ON 110 kV. SYSTEM.



B. FREQUENCY.

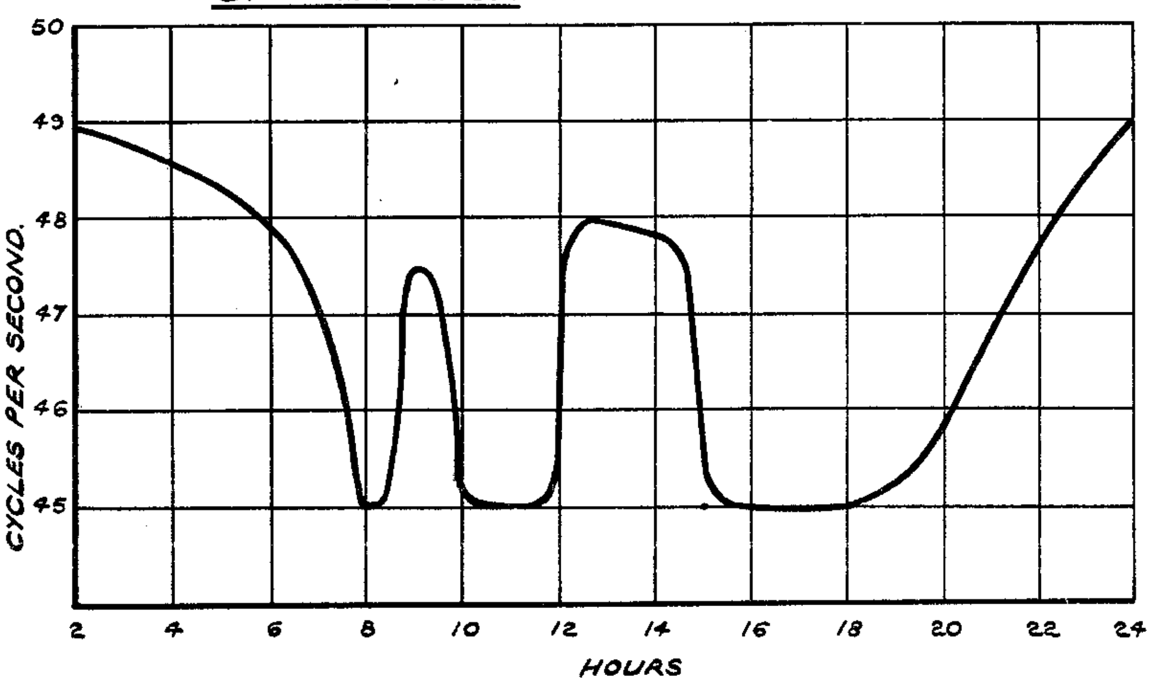
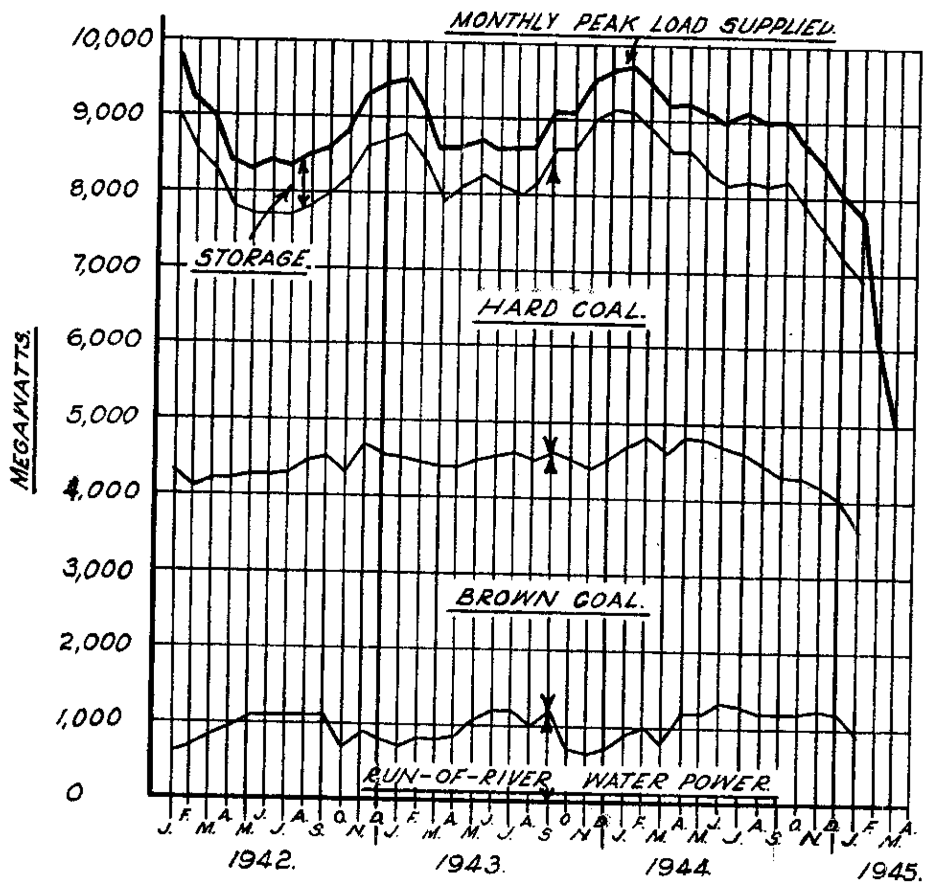


FIGURE 5

SOURCES OF ENERGY USED FOR ELECTRICITY PRODUCTION FOR THE GERMAN PUBLIC SUPPLY SYSTEM. JAN. 1942 — MARCH 1945.

(FOR FIGURES USED SEE APPENDIX D TABLE A)



on Figure 5 are given in Appendix D Table A. It will be seen that the total production at time of monthly peak load may be roughly divided as follows:-

From hard coal	3,800 MW.	= 42%
" brown coal	3,500 MW.	= 39%
" run-of-river water power	1,000 MW.	= 11%
" storage	700 MW.	= 8%

The "storage" stations include steam-accumulator plants, water power stations with large reservoirs and water power stations with pumped-storage. The latter account for the greater part of the output of the "storage" stations and are extensively used in Germany for meeting peak loads and to provide standby for the breakdown of other plant. For such purposes the rapid rate of change of output possible with pumped-storage plants is most valuable and there are 10 large stations of this type in Germany situated at focal points on the network and with a total installed capacity of about 900 MW. A typical daily load curve for the largest of the German electricity supply undertakings is given in Figure 6 on page 17; the figures from which Figure 6 has been prepared are given in Appendix D Table B. This undertaking is one which made great use of pumped-storage stations and it will be seen that the whole of the daily load variations were met from these stations while all other types of plant operated at a substantially constant load. On the day in question one of the pumped-storage stations was actually started-up and shut-down no less than four times within a period of 10 hours.

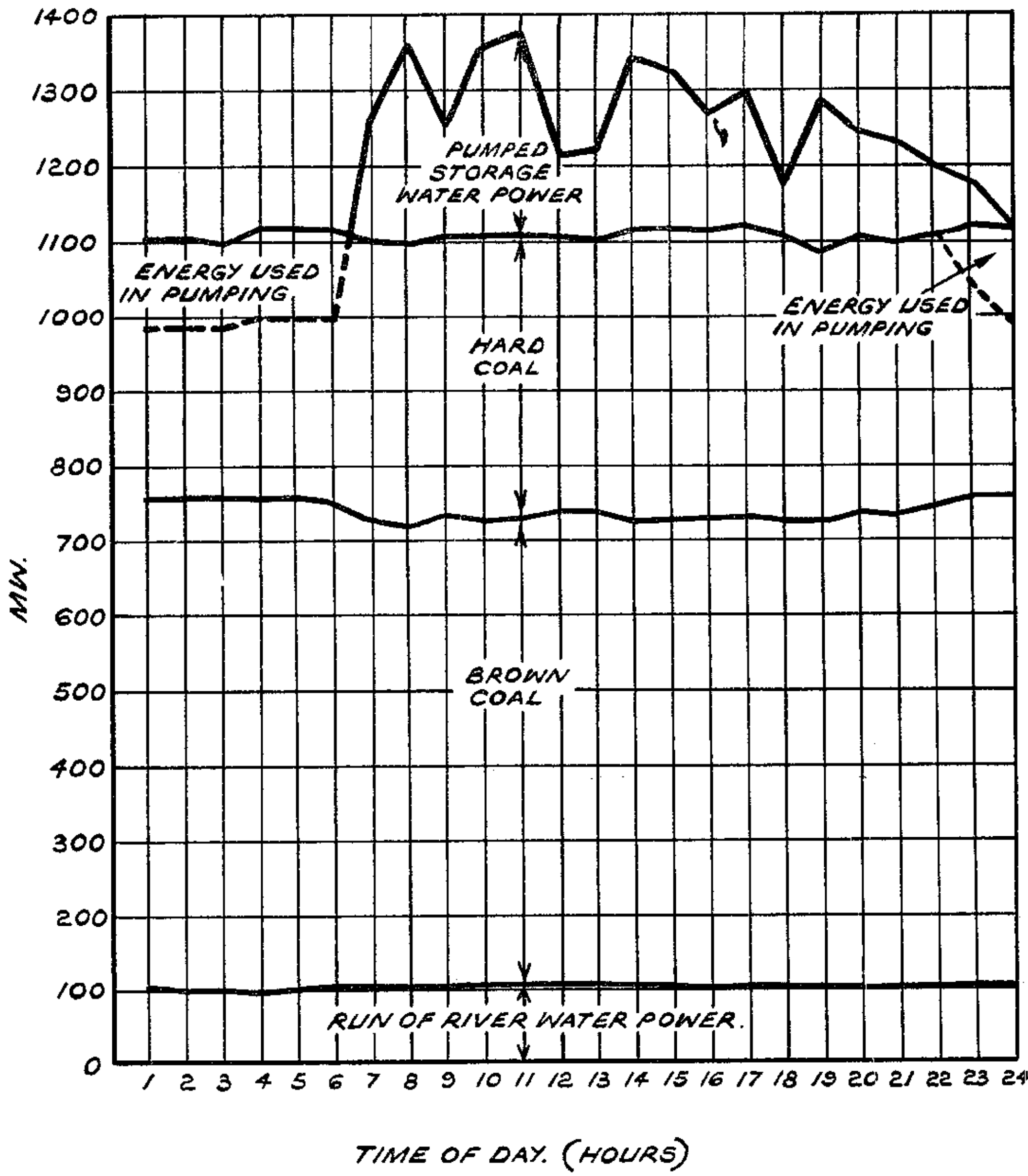
Due to the varied sources of energy used in Germany it was much simpler in that country than in Great Britain to determine the most economical order in which to allocate load to the available generating plant. First all possible use was made of run-of-river water power stations, then of the brown coal fired stations, then of the hard coal fired stations and lastly the peaks were met by the storage stations; this will be clear from Figure 6. The National Load Despatcher only took into account the relative economy of these four main groups of plant when arranging the inter-district transfers. Inside each District the District Load Despatchers took some account of the relative production costs of the various hard coal stations but only simple and approximate methods of determining incremental fuel costs were, in most cases, used.

The Berlin Power & Light Co. (BEWAG) however used a somewhat more elaborate method. This was based on the use of Willans Lines, derived from test results on each set, used in conjunction with the latest available figures regarding the cost and calorific value of fuel. Using these data the order of merit

FIGURE 6

LOAD CURVE FOR THE R.W.E. SYSTEM ON 1/3/44 SHOWING SOURCES OF ENERGY USED.

(FOR FIGURES USED SEE APPENDIX D TABLE B)



of the available generating plant was determined and each station was notified at what total system load each set in that station should be brought into and taken out of service. Thus for instance Set No.4 (of 50 MW. capacity) in Power Station "A" might be the tenth most economical set available and should be operated when the total system load was between 300 MW. and 350 MW. A meter to indicate the total system load was provided in each power station and this meter acted as an automatic load despatching device. Thus when the meter read 300 MW., Set No.4 at Power Station "A" would be synchronised and would be brought up to full load by the time the meter read 350 MW.

4. National Plant and Load Position

(a) Plant Capacity Installed

Figure 7 on page 19 shows the increase during the period 1929 - 1944 in the maximum output capacity of the installed plant serving the German public electricity supply system. It will be seen that the total* capacity at the beginning of the war was about 10,000 MW. During the war about 3,000 MW. of additional output capacity was installed, the average rate of installation thus being about 600 MW. per annum. It will also be seen that the annual rate of installation was fairly uniform throughout the war and never exceeded 900 MW. The figures used in preparing Figure 7 are given in Table 1.

Table 1

Maximum Output Capacity of Installed Generating Plant serving the German Public Electricity Supply System 1929 - 1944

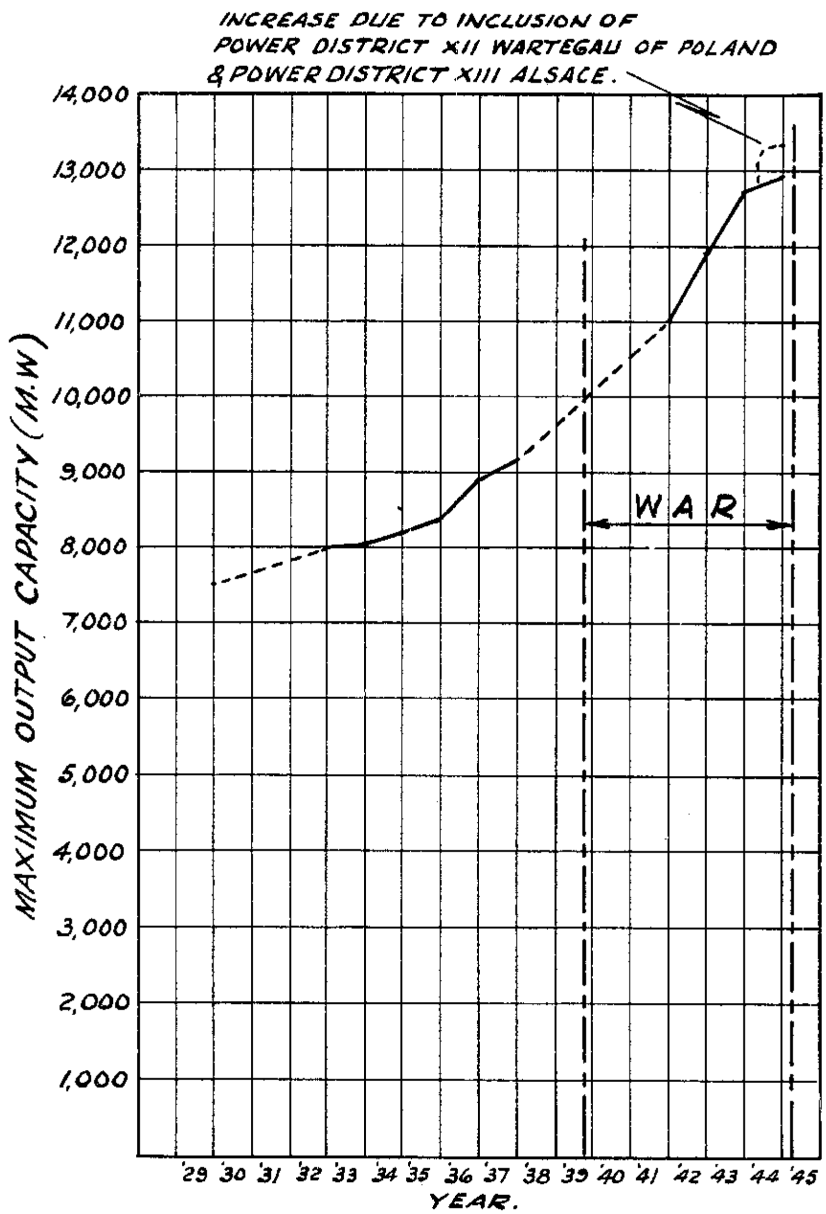
Year		Maximum Output Capacity. MW.
1929		7500
1932		8000
1933		8050
1934		8200
1935		8350
1936		8900
1937		9150
1941	(including Austria & Sudetenland)	11000
1942		11900
1943		12700
1944		12900
1944	(after inclusion of Power Districts XII and XIII)	13300

* The figures given include that part of the capacity of private industrial stations which was used for public supply but not that part used for private industrial supply; the latter amounted to about 7,500 MW. at the beginning of the war and had probably increased to about 10,000 MW. by the end of the war.

FIGURE 7

MAXIMUM OUTPUT CAPACITY OF GENERATING PLANT SERVING THE GERMAN PUBLIC ELECTRICITY SUPPLY SYSTEM. 1929 - 1944.

(ABOUT 600 M.W. OF PLANT IN AUSTRIA & THE SUDETENLAND IS INCLUDED AFTER 1938)



Part of the new plant was installed in existing stations and part in new stations. The following list gives the names and installed capacity of the principal new stations built for public supply during the war:-

Espenhain (near Leipzig)	297 MW.
Watenstedt (near Brunswick)	290 MW.
Karnap (near Essen)	250 MW.
Pommernensdorf (near Stettin)	200 MW.
Lünen (Ruhr area)	180 MW.
Witznau (Black Forest)	176 MW.
Vereinigte Ville and Berrenrath I and II (nearby stations at Knapsack near Cologne)	160 MW.
Hüls (Ruhr area)	150 MW.
Marbach (near Stuttgart)	120 MW.

All the above stations are coal-fired except Witznau which is a hydro pumped-storage station.

The main technical feature of the new coal-fired stations was the use of relatively high steam temperatures and pressures of the order of 1,200 - 1,800 lbs/sq.in. and 900° F. - 950° F. A scheme for the installation of standard stations was also put into effect during the war and construction of about six such stations was started. One of these at Alt Garge, known as Hannover Ost, was almost finished by the end of the war and was to contain 4 sets each consisting of a 20 MW. high pressure turbo-alternator and 50 MW. low pressure turbo-alternator; steam conditions were to be 1,800 lbs/ sq.in. pressure and 930o F. temperature.

(b) Plant Capacity Usable

The plant capacity usable for supplying the German public electricity supply system at any given time was less than the maximum output capacity of the plant installed for this purpose. This was because at any given time some of the plant was not available for service and not all of the plant which was available for service could be effectively used. The reasons why plant was not available may be classified as follows:-

A. Insufficient water flow at hydro stations to provide maximum output.
B. Occupation of generating stations by Allied Forces.
C. Damage to generating plant by bombing.
D. Breakdown.
E. Routine overhaul.

6) Coal Supplies

a) Hard Coal Stations
(with a capacity exceeding 5,000 kW.)

Coal Deliveries	% of Previous Week	% of the same week in the previous Year
212 500 t	94	107
Coal Consumption		
219 200 t	105	124
Increase in Stock	**Decrease in Stock**	
---	6 700 t	

Coal Stock at the end of the week of report

1 264 900 t

Extent to which Stores are full:

54% of the amount scheduled for the 1st October, 1942.

Stocks suffice for:

Less than 1 week in 15 power stations
From 1 to 2 weeks in 19 power stations
More than 2 weeks in 94 power stations
An average of 3.7 weeks in all power stations

b) Brown Coal Power Stations

---

7) Consumption Restrictions

a) Long-term Restrictions

By Circular Instruction No.28/42, steel production was exempted from the general 5% restrictions.

b) Restrictions according to schedule for shedding load

Because of power shortage, the following loads were shed:-

District IV	7 MW.	1 hour	on	4 days
" V	10 MW.	12 hours	on	4 days
" VIb	50 MW.	16 hours	on	3 days
" VII	50 MW.	7 hours	average per day of the week	
" VIII	30 MW.	13 hours	on	4 days
	60 to 90 MW. on one day			
" IX	30 MW.	10 hours	on	4 days

The total shedding amounted at times to as much as 170 MW.

APPENDIX D - TABLES A - E

TABLE A

Sources of Energy used for Electricity Production for the German Public Electricity Supply System
(These figures are plotted in Figure 5 page 15)

Month and Year	Output (MW.) at time of monthly peak load Run-of-river water power	Brown coal fired	Hard coal fired	Storage	Total
1942 Jan.	600	3700	4700	800	9800
Feb.	700	3400	4400	700	9200
March	800	3400	4100	700	9000
April	950	3250	3600	600	8400
May	1050	3200	3450	600	8300
June	1100	3150	3450	700	8400
July	1100	3200	3400	650	8350
Aug.	1100	3350	3350	700	8500
Sept.	1100	3400	3500	600	8600
Oct.	700	3600	3900	600	8800
Nov.	900	3800	3900	700	9300
Dec.	800	3750	4150	750	9450
1943 Jan.	700	3800	4300	700	9500
Feb.	800	3650	3950	750	9150
March	800	3600	3500	700	8600
April	850	3550	3700	500	8600
May	1050	3450	3750	450	8700
June	1200	3350	3550	500	8600
July	1200	3400	3400	600	8600
Aug.	1000	3500	3650	500	8650
Sept.	1200	3400	4000	500	9100
Oct.	700	3800	4100	500	9100
Nov.	600	3800	4600	500	9500
Dec.	700	3800	4650	500	9650
1944 Jan.	900	3800	4400	600	9700
Feb.	1000	3800	4050	650	9500
March	800	3800	4000	600	9200
April	1200	3600	3800	600	9200
May	1200	3600	3500	800	9100
June	1300	3400	3450	850	9000
July	1300	3300	3600	900	9100
Aug.	1200	3250	3700	850	9000
Sept.	1200	3100	3900	800	9000
Oct.	1200	3100	3600	800	8700
Nov.	1250	2950	3300	900	8400
Dec.	1200	2800	3200	850	8050
1945 Jan.	900	2700	3300	850	7750

TABLE B

Typical Daily Load Curve (1: 3:44) for R.W.E. System showing sources of energy used

Hour ended	Run-of-river water power	Brown Coal fired	Hard Coal fired	Pumped-storage water power pump-ing	Pumped-storage water power genera-ting	Total
01	102	655	345	- 118		984
02	100	658	344	- 117		985
03	100	658	341	- 117		982
04	99	657	359	- 117		998
05	100	656	358	- 117		997
06	103	647	362	- 117		995
07	105	622	371		+ 167	1265
08	103	614	375		+ 266	1358
09	105	627	369		+ 149	1250
10	104	621	380		+ 250	1355
11	105	623	378		+ 269	1375
12	106	628	370		+ 106	1210
13	106	633	361		+ 144	1214
14	106	621	383		+ 230	1340
15	105	623	385		+ 212	1325
16	104	624	383		+ 156	1267
17	105	625	387		+ 176	1293
18	103	622	383		+ 69	1177
19	103	621	359		+ 206	1289
20	102	631	369		+ 141	1243
21	102	630	363		+ 135	1230
22	101	644	360		+ 94	1199
23	104	654	359	- 75	+ 55	1097
24	104	654	357	- 118	+ 3	1000

Notes: (1) R.W.E. = Rheinische-Westfalisches Elektrizitätswerk A.G. (Rhine-Westphalian Electricity Co.)

(2) The figures in this Table are plotted in Figure 6 on page 17.

TABLE C (Part I)

Plant Position and Load supplied
for German Public Electricity Supply System
(All figures are in megawatts and refer to conditions
at time of monthly peak load)

Year and Month	Load supplied	Spare plant	Total plant usable Col.2+3	Plant available but not usable	Total plant available Col.4+5	Total plant installed
1	2	3	4	5	6	7
1942 Jan.	9800	-	9800	300	10100	11000
Feb.	9200	-	9200	500	9700	11100
Mar.	9000	-	9000	600	9600	11150
Apr.	8400	200	8600	900	9500	11200
May	8300	150	8450	650	9100	11300
June	8400	100	8500	600	9100	11350
July	8350	150	8500	600	9100	11450
Aug.	8500	100	8600	600	9200	11550
Sept.	8600	-	8600	700	9300	11700
Oct.	8800	-	8800	600	9400	11800
Nov.	9300	-	9300	600	9900	11850
Dec.	9450	-	9450	650	10100	11900
1943 Jan.	9500	-	9500	600	10100	11950
Feb.	9150	150	9300	900	10200	12000
Mar.	8600	450	9050	950	10000	12050
Apr.	8600	200	8800	950	9750	12100
May	8700	100	8800	800	9600	12200
June	8600	200	8800	850	9650	12200
July	8600	200	8800	650	9450	12250
Aug.	8650	-	8650	600	9250	12300
Sept.	9100	-	9100	750	9850	12500
Oct.	9100	-	9100	550	9650	12600
Nov.	9500	-	9500	400	9900	12650
Dec.	9650	-	9650	650	10300	12700
1944 Jan.	9700	-	9700	600	10300	12700
Feb.	9500	200	9700	600	10300	12700
Mar.	9200	100	9300	700	10000	12750
Apr.	9200	150	9350	850	10200	12800
May	9100	300	9400	750	10150	12850
June	9000	350	9350	850	10200	13300
July	9100	200	9300	600	9900	13300
Aug.	9000	200	9200	650	9850	13300
Sept.	9000	-	900	800	9800	13300
Oct.	8700	-	8700	850	9550	13300
Nov.	8400	-	8400	1100	9500	13300
Dec.	8050	-	8050	1000	9050	13300
1945 Jan.	7750	-	7750	1000	8750	13300
Feb.	6050	-	6050	1550	7600	13300
Mar.	5000	-	5000	2000	7000	13300

Note: The figures in this Table are plotted in Fig. 8 on page 22.

TABLE C (Part II)

Analysis of plant capacity not available at time of monthly peak load (Col.7 - Col.6 of Part I)

Year and Month	Plant capacity (MW.) not available due to:- Overhaul	Breakdown	Bomb Damage	Allied Occupation	Water Shortage	Total
1	2	3	4	5	6	7
1942						
Jan.	-	200	-	-	700	900
Feb.	-	700	-	-	700	1400
Mar.	300	600	-	-	650	1250
Apr.	700	550	-	-	450	1000
May	1100	600	-	-	500	1100
June	1300	600	-	-	350	950
July	1400	700	-	-	250	950
Aug.	1350	700	-	-	300	1000
Sept.	1200	700	-	-	500	1200
Oct.	900	550	-	-	950	1500
Nov.	500	700	-	-	750	1450
Dec.	350	550	-	-	900	1450
1943						
Jan.	450	450	-	-	950	1400
Feb.	400	650	-	-	750	1400
Mar.	500	800	100	-	650	1550
Apr.	1050	600	100	-	600	1300
May	1100	600	400	-	500	1500
June	1150	550	350	-	500	1400
July	1250	600	400	-	550	1550
Aug.	1150	650	450	-	800	1900
Sept.	950	800	500	-	400	1700
Oct.	800	900	400	-	900	2200
Nov.	500	800	400	-	1050	2250
Dec.	300	1000	300	-	800	2100
1944						
Jan.	450	1100	350	-	500	1950
Feb.	500	1000	250	-	650	1900
Mar.	600	1100	200	-	850	2150
Apr.	800	950	250	-	600	1800
May	1000	1050	200	-	450	1700
June	1300	800	450	-	550	1800
July	1200	900	300	-	500	2200
Aug.	1150	850	850	-	600	2300
Sept.	1100	850	850	-	700	2400
Oct.	1150	900	900	150	650	2600
Nov.	700	800	1500	150	650	3100
Dec.	600	950	1700	300	700	3650
1945						
Jan.	350	1100	1700	600	800	4200
Feb.	400	1000	2000	1350	950	5300
Mar.	500	1100	2200	1800	700	5800

Note: The figures in this Table are plotted in Fig. 9 on page 23

TABLE D

Load Restrictions imposed on German Public Electricity Supply System 1st Jan. 1942 - 31st Jan. 1945

(Figures given are imposed load restrictions in MW. at time of weekly peak load)

Month	Week No.	1942 MW.	1943 MW.	1944 MW.	1945 MW.
Jan.	1	250	330	600	2430
	2	250	330	600	2480
	3	310	330	500	2490
	4	960	440	310	2500
	5	740	300	200	2500
Feb.	6	350	0	150	
	7	300	0	100	
	8	200	0	100	
	9	150	0	110	
March	10	100	0	200	
	11	0	0	310	
	12	0	0	300	
	13	0	0	200	
	14	0	0	150	
April	15	0	0	70	
April to July	16 to 31	0	0	0	
Aug.	32	80	0	0	
	33	150	60	0	
	34	200	100	0	
	35	200	150	150	
Sept.	36	230	200	250	
	37	280	350	100	
	38	300	400	150	
	39	400	400	150	
	40	300	200	200	
Oct.	41	360	210	200	
	42	400	250	350	
	43	400	300	650	
	44	300	470	1150	
Nov.	45	300	550	1200	
	46	300	700	1450	
	47	400	800	1450	
	48	400	520	1690	
Dec.	49	460	530	1690	
	50	460	550	1700	
	51	400	600	1800	
	52	300	600	1800	

Note; The figures in this Table are plotted in Figure 10 on page 25.

TABLE E

Monthly Totals of Faults on German High Voltage Transmission System January 1942 - February 1943

Cause of Fault	Number of Faults per month													
	1942												1943	
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
BOMBS	6	8	30	52	46	60	56	46	48	20	12	25	77	
BARRAGE BALLOONS														
10-60 kV.			6	4	3	8	6	16	3	8	6	7	38	
110 kV.			5	5	0	4	4	8	5	4	6	9	40	
220 kV.			1	-	-	-	-	-	-	-	2	1	2	
Total			12	9	3	12	10	24	8	12	14	17	80	
ATTACK BALLOONS														
10-60 kV.			60	40	22	58	58	12	12	3	3	24	32	35
110 kV.			19	3	10	10	30	15	8	5	2	26	20	19
220 kV.			2	2	2	3	11	2	7	4	1	7	5	6
Total			81	45	34	71	99	29	27	12	6	57	57	60

Note: The figures in this Table are plotted in Figure 12 on page 33.