PAPER No. 381

Wapda Northern Grid System
Need for Peaking Generating Capability
1970-1975

By
A. RAHIMTOOLA*

The basic objective in planning the WAPDA Power System is to develop a generation-transmission expansion pattern that matches the expected load growth in a timely and economical manner. In the past the expansion of the WAPDA System has been accomplished by the installation of high cost steam turbine generator units for base load service and conventional hydroelectric installations for base and peaking service. Continuance of this procedure would mean that as new steam units are installed, the older steam units would operate at low load factors to meet the peak loads as shown in Figs. VII and IX. Since these older steam units are mainly designed for base load, and have high capital costs, operation for peaking purposes would result in a high cost of energy generated and in addition peak loading may also be detrimental to the equipment.

Since the WAPDA System is a mixed system consisting of both thermal and hydroelectric units, planning and programming system expansion to correspond with peak loads economically requires careful planning. The division of hydro and thermal energy generation for the period 1960-1975 is given below:—

WAPDA NORTHERN GRID SYSTEM

Electric Energy Generation (*Kwh* 10^6)

Year	Hydro Energy	Thermal Energy	Total Energy
1960	530	280	810
61	796	264	1060
62	1086	309	1395
63	1269	495	1764
64	1374	779	2153

[*Contd.*

**Superintending Engineer, WAPDA Electricity.*

Year	Hydro Energy	Thermal Energy	Total Energy
65	1370	1114	2484
66	1445	1327	2772
67	2265	811	3076
68	3511	276	3780
69	4354	399	4753
70	4955	680	5635
71	5920	280	6200
72	6327	743	7070
73	6719	1231	7950
74	6921	1789	8710
75	8281	1219	9500

It can be seen from the above table that thermal generation contributed approx. 35% of the total energy for the period 1960-65 whilst hydro generation is expected to contribute approx. 86% of the total energy for the period 1971-75.

In a mixed system, different types of generation are added in such proportions that the more efficient units will have high load factors. This permits maximizing the effect of types having good characteristics and minimizing the effect of those that are unfavourable.

Such an approach to System Planning, which has not been given enough attention in the past, offers considerable savings in capital investment. The guiding principle in System expansion should be to invest funds in highly efficient generating plant that should be operated at high load factors. Peak loads, forced outages and emergencies are very low load factor operations requiring special generating units to meet this demand. In this manner the economics and overall efficiency of the generating system will be substantially improved and, simultaneously, will allow considerable flexibility in operation. The installation and use of special generating equipment for peaking purposes complements and lowers the net cost per KWH of production, thus increasing the annual savings when advanced steam and nuclear plants are installed.

Under the Indus Basin Treaty, WAPDA is installing large efficient hydroelectric units at Mangla and Tarbela. These units when commissioned will generate low cost electric power and will be used mainly for meeting the base loads of the entire system. When sufficient water is available they can also be used for peaking purposes, but this is not possible during the winter and spring months, because the river flows in West Pakistan are very low, and

the output of all hydroelectric stations including Mangla and Tarbela are limited to approx. 50% of full capability.

Up to 1966/67 it was economically feasible to meet power deficits by installing large base load thermal stations such as Multan (260 MW) and Lyallpur (132 MW). Some of the reasons for installing thermal stations were:—

(*a*) They can be commissioned in a relatively short time, as compared to hydro stations.

(*b*) The suppressed connected load on the system was so large that thermal generation would of necessity be operated at high load factors.

(*c*) Cost per installed KW of thermal capacity is substantially cheaper than hydro units with their high investment in civil works.

However, with the commissioning of six large hydro units at Mangla up to 1970 and twelve hydro units at Tarbela commencing from 1975 onwards, the economics of generation in the Northern Grid system will undergo radical change. Installation of more base load steam units to meet this deficit will not be economical due to high investment costs and low load factor operation.

Planning now, more than ever before, must take into account the economics of generating capacity especially suited for peaking and reserve operation under the new conditions. Such capacity must be characterised by the lowest possible investment cost and low operating and maintenance costs with due regard for its adaptability to automation and generally higher energy costs.

There are a number of approaches for providing peaking capacity which have now reached a state of development warranting their consideration in any long-range planning programme. These are :—

1. Steam units designed specifically for peaking service.
2. Pumped storage hydroelectric plants.
3. Diesel engine plants.
4. Conventional and aircraft gas turbine generating plants.

The selection of any of the above plants or combination of types of generation to be developed for a particular system depends on many factors including :

(*a*) Augmentation of hydroelectric capability.

(*b*) Reserve requirements and emergencies.

(*c*) System size and load characteristics, including daily, weekly, monthly and annual load factors, and shapes of the daily and monthly load curves with their seasonal variations.

(*d*) Availability of suitable hydroelectric sites for both conventional and pumping installation.

(*e*) Total energy requirements for any new block of peaking capacity on the system load curve.

(*f*) Interconnections with other systems.

(*g*) The effect of peaking capacity on system transmission requirements.

(*h*) Availability of coal, oil and gas fuel and its cost at various locations on the system.

(*i*) Comparative present costs of energy generation during peak and base periods and probable trends in this cost relationship.

(*j*) Prospects for economic nuclear power plants on the system.

Each of the 4 basic methods of providing peaking capacity are described below :

(*i*) **Steam Units Designed Specifically for Peaking**

Simple and low cost steam units of relatively low efficiency for use primarily for peaks or in emergency are now being built. The elaborate feed water heating arrangements are bypassed thereby giving higher outputs at lower efficiencies. The basic concept is that if the savings in first cost are greater than the resulting higher fuel consumption, then such installations are economical. Up to the present this concept has not reached an advance state of development because the cost differential between them and efficient units is too low.

(*ii*) **Pumped Storage Hydro Plant**

Pumped storage hydro plant is unique among methods of electric generation in being dependent upon other power sources for energy supply. It functions as an energy accumulator which stores low-value off peak energy by using it to pump water from a lower to a higher reservoir from which it can be returned through its turbines to generate power during peak periods when it has capacity as well as energy value. Thus a prerequisite for such development is the availability of low incremental cost energy for the pumping cycle. The source of such energy will almost always be from thermal plants, rarely from hydroelectric installations.

Reduced equipment cost, brought about by the reversible pump turbine unit, permits the pumping and generating operations to

be combined in a single machine. This greatly contributes to the economics of the pump storage installations. Variation in river flows from season to season and from year to year usually prevents a conventional hydroelectric plant from developing its full capability. In situations where off peak pumping power is available economically and in sufficient quantities, it may be feasible to work out an arrangement in connection with new or existing conventional hydro installations which can permit the use of units for pumping or for pumping and generating in such a manner as to substantially increase the firm capability.

(*iii*) Diesel Engine Plants

The use of conventional diesel engines for peaking service on power systems has been used for many years. However, renewed interest in this type of peaking capacity has resulted primarily from the recent development of low cost, packaged, automatically operated, unattended diesel units. Individual diesel units are obtainable in ratings up to 2.5 MW and frequently combined in multiples to provide plants of 10 MW capacity. Packaged units can be transported on railway wagons and trucks to the site and stored outdoors, requiring very little in the way of foundations. The nature of the plant offers wide latitude for site location. Small quantitites of cooling water are required, together with piped-in fuel supply if the unit is to operate on gas.

(*iv*) & (*v*) Conventional and Aircraft Gas Turbine Generating Plant

The gas turbine generating unit is attracting increasing attention as a source of economical peaking capacity. It is low in first cost, relatively quick starting, offers wide choice of site location and is readily automated. For peaking duty such refinements as pre-cooling, inter-cooling and regenerative heating are almost always omitted in the interest of achieving lower capital cost.

Single unit plants of the simple open cycle type are available in ratings up to 20/25 MW. These plants are pre-engineered and prepackaged to minimize field labour. Units in the order of 10 MW are shipped, assembled, but larger ones are erected at site on concrete slab foundations. These units include provision for remote control, and are furnished with self-contained cooling system and weatherproof housing.

The Aircraft type of gas turbine coupled to generators is also becoming increasingly popular. This construction enables outputs ranging from

20—200 MW to be obtained by using multiple jet engines.

One design employs four jet engines in tandem two on either end of the centrally located generator, each jet exhausts to a twostage 3000 r.p.m. power turbine giving a combined output of 70 MW. This unit can come up to full load from cold start in 3-5 minutes. Another design consists of several cylinderical mounted aircraft gas turbines operating as gas generators and exhausting simultaneously into a single stage 1200 r.p.m. power turbine driving a 100 MW generator. Combinations of cylinderical mounted aircraft gas turbines operating in tandem to drive large electric generators are capable of delivering up to 200 MW.

A. Advantages of Gas Turbine for Peaking Power

1. The gas turbine is a compact, complete power plant having a minimum number of station auxiliaries, minimum water requirements and low foundation and building costs.

2. Operating labour costs are low since plant is atomatically controlled and maintenance personnel requirements are much less than conventional steam plants.

3. Gas turbine units can be quickly started, synchronized and loaded within 3 to 10 minutes, automatically or from a remote location. These features can provide significant start-up and stand by savings as compared to alternate steam peaking capacity.

4. High reliability and availability are obtained from these units in peaking service.

5. Gas turbine power plants may be located close to the load for area protection, and to reduce transmission investment and losses, because they need no condensing water. A small amount of cooling water may be required and if gas is used for fuel, provision could be made for piped-in supply. Noise levels have been considerably reduced so that these units can be installed in residential areas.

6. A major advantage in installing gas turbine generating units is the very short time required from the placing of order to commissioning, thereby making this type of generation a flexible planning tool which on occasions may serve to effect 1 to 2 years deferment of a large steam unit.

B. Disadvantages of Gas Turbine

1. Gas turbines are generally operated on high grade liquid fuels or gas which is quite costly. However, since these units should generally be employed for peaking service they would operate at a low load factor so that the direct fuel cost may not be a controlling factor.

2. In the past the small outputs of conventional gas turbines proved a drawback for adding large blocks of generation. However, with the development of Aircraft Gas Turbines which can provide power blocks in the range of 100—200 MW, this problem has been overcome.

3. The capacity of a gas turbine decreases with the increase of ambient temperature. However, since system peaks of the WAPDA System generally occur in the autumn and winter months this does not seriously affect the capacity of these machines.

WAPDA NORTHERN GRID SYSTEM

Annual Load Duration Curves

Figures I through V show the annual load duration curves of the WAPDA Northern Grid System for the period 1971-1975. This period is referred to as pre-Tarbela *i.e.*, after 6 units at Mangla are commissioned and operating and before the first unit of Tarbela is ready in 1975-76. Historical data for the period 1960-65 has been used in preparing these curves, together with knowledge of future loads expected. Sixty typical daily load curves covering the entire twelve month period for the years 1963-65 were plotted, and annual averages obtained. These average curves with their peak component were projected and curves for the period 1971-75 were obtained.

The annual load duration curves show the period of time during the course of the year that the system load will reach or exceed various percentages of annual peak. For instance, in 1974 (Fig. IV), point A on the curve shows that the load will equal or exceed 90% of the annual peak about 2.5% of the time (200 hours in the year), point B indicates load of 65% or greater 50% of the time (4380 hours) and point C indicates the minimum load experienced in the course of the year (generally in April) is about 40%.

Since the load curve shows the period of operation required for various levels of generation during the course of the year, it is very useful in analysing the peaking power requirements of the system. Fig. IV shows the 1974 load duration curve divided into 3 general areas: BASE, the area wherein machines with low operating cost should be operated round the clock at constant load levels : INTERMEDIATE, the area of variable loading requiring frequent machine cycling: PEAK, the area where operation is of such short duration that only the capital costs are significant in determining a selection of new generation.

Fig. XII shows the actual 1964 load duration curve of the WAPDA Northern Grid System. The annual load factor in 1964 was 64%. This curve shows that the peaking capability was 112 MW or 29% and it operates for 1400 hours or 16% of the annual time.

Fig. XI also shows the projected annual load duration curve for 1974 with an annual load factor of 60%. If new base load units are added to the system, older stations like Multan would operate for shorter periods and meet the intermediate peak loads as shown in Fig., VII and IX.

Fig. XI shows a typical daily load curve of the WAPDA Northern Grid System for December 1964 showing Multan Power Station running on base load round the clock, and Unit No. 1 supplying 17% of the total load (Band A). In 1974 if Multan Power Station was to supply 17% of the total load it would operate for only 880 hours in the year or 10% of the annual time (Band B). However, if the WAPDA Grid System was expanded so that 20% of the total load was supplied by special peaking generation, then Multan Power Station would operate for 60% of the annual time. (Band C).

This means that the capital expenditure of the Multan Power Station is being used six times as efficiently if peaking plants are purchased instead of base load units up to 20% of the load. It can also be seen that if the load factor of a system is less than 60%, the economical limit of peaking capacity will also increase. By interspacing the installation of efficient base load units with peaking units, considerable advantages can be taken of installing large base load units at intervals synchronizing with the load growth.

Load Despatch Procedure

The system load which is served by WAPDA constantly varies with time, from hour to hour, day to day, and month to month during the year. In the past the annual peak on the system has been in the month of December, but with the very large tubewell program it is anticipated that the system peak will now occur in the months of September and October. Fortunately the hydro-electric capability during these two months will also be maximum.

The load dispatching routine computes the shape of the daily, monthly and annual load duration curve for the WAPDA Northern Grid System. Hydro energy is fitted under the curve, so that thermal power and energy requirements are a minimum. The generation of hydroelectric energy and power at the reservoir power plants such as Mangla and Warsak, and at the canal power plants such as Rasul, Dargai, Shadiwal, etc., is determined by the reservoir releases and canal flows required to meet surface water demands. The difference between the load energy and the hydroelectric energy is met by scheduling thermal generation.

The WAPDA Power Controller schedules daily operation and loading of generating capacity to match the load curves and the magnitude of the load assigned to the particular machines will determine the economy of daily operation. Approximate energy costs of WAPDA power stations operating to meet

the System Demands are given below:

Name of Station		Cost per Kwh (Paisa)	Load Factor (Percent)
Mangla	..	1.2	65
Warsak	..	2.5	60
Dargai/Malakand	..	1.0	70
Rasul	..	1.8	50
Shadiwal/Nandipur/Chichoki	..	4.0	55
Multan	..	4.5	60
Lyallpur	..	4.5	60
Lahore	..	7.0	45
Old Thermal	..	25.0	12

Generators with the lowest operating cost are operated at full load round the clock. Those with higher costs are operated for shorter periods of time or provide spinning reserve requirements. In this way, the generators available for service are operated to secure maximum overall efficiency with individual load assignments to produce the lowest operating cost.

Figs. VI to IX show the peak day load dispatch curves of the WAPDA Northern Grid System for the months of April and September 1973 and 1974. The month of March represents the period when the system capability is minimum as a result of the reduced reservoir elevation at Mangla. This month, therefore, represents the period when the system deficit will be maximum, and mainly determines the amount of additional generating capability required for the Grid System. The month of September represents the period when the system load is maximum as a result of the large pumping tube-well load. However, during this month, river flows are good and hydroelectric and system capability is very high. The system deficit is therefore only nominal.

Fig. VI—*Peak Day Load Curve—March* 1973: Since hydroelectric generation is at a minimum, thermal generation would operate for longer periods. With no spinning reserves and scheduled maintenance, 102 MW of additional capability is required.

Fig. VII—*Peak Day Load Curve—September* 1973: Since hydro-electric generation is very high, thermal generation is the minimum, and operates for short periods to meet the peak loads. With reserves of 160 MW, the additional generation required is 64 MW.

Fig. VIII—*Peak Day Load Curve—March* 1974: Energy limitations of the Warsak Power Station having 6 units of 40 MW each (240 MW) are clearly

demonstrated. With no reserves, 278 MW of additional capability is required.

Fig. IX—*Peak Day Load Curve—September* 1974: With no reserves 73 MW of additional generation is required.

Using the annual load duration curves, new types of peaking generation have been fitted under this curve to determine the relative pesitions at which they would economically operate in any year. Comparison with generating capacity already available on the system has been done so that an optimum dispatch schedule has been evolved which represents the minimum additions of new capacity which most economically will supplement the existing capacity to meet the system load and maintain the annual reserves.

Fig. X shows the annual load and dispatch curve for 1974. It can be seen that the total peak energy is only 4% of the total energy, but the peak load is 30% of the total system load. The total system load is 1658 MW, and the peak component is 498 MW.The Mangla and Lahore Power Stations would meet the peak load to the extent of 220 MW, leaving a deficit of 278 MW. The load factor of this additional peak capacity is approx. 9%. This new capacity in addition to meeting deficits in the system peaking energy, will also make up energy and capability deficits as a result of :

1. FORCED OUTAGES AND EMERGENCIES.
2. SCHEDULED MAINTENANCE.
3. REDUCED HYDROELECTRIC CAPABILITY DUE TO LOW RIVER FLOWS.

If the peaking component is removed, the load factor of the system in 1974 improves from 60% to 80%. This means that the base load generation would operate for longer periods and be more economical.

An economic comparison of the various types of peaking capacity to meet the system loads during 1973 and 1974, is given in Table I and for 1974 is summarised below. Prices are based on present-day costs:—

Station		Capacity	Load Factor	Cost of (Kwh) (Paisa)
STEAM	..	250 MW	9.5	11.5
HYDRO	..	250 MW	9.5	20.6
DIESEL	..	250 MW	9.5	9.2
GAS TURBINE	..	250 MW	9.5	9.7
AIRCRAFT TURBINE	..	250 MW	9.5	8.8
MULTAN	..	260 MW	9.5	14.1

A vigorous economic solution would consist of evaluating the following basic steps:—

(*a*) Probability mathematics to ensure that each alternative is designed

to a common level of service reliability.

(*b*) Annual capital investment charges for additions to the system generation, transmission or interconnection.

(*c*) Annual production costs of operating the system by simulating system operation throughout the expansion interval.

Then by summing up all annual expenditures and using present worth arithmetic, it is possible to determine the present worth of all revenue requirements of a particular expansion. Comparing those values for different alternatives gives the most economical solution.

From Table I it can be seen that in 1973 for a load duration of 570 hours per year or 6.5% load factor, or 9.5% load factor in 1974 the aircraft gas turbine offers the most economical addition to system generating capacity. The cost of diesel electric generation is also low, but these plants are limited to small blocks of power in the order of 10-20 MW. The cost of energy from the Multan Power Station working at an annual load factor of 9.5% is 14.1 paisa. This is nearly 60% more than the cost of energy from a peaking gas turbine station.

Economic feasibility of aircraft gas turbines for peaking has been determained by cost comparisons with other types of peaking capacity (Table I). The lower efficiency and consequent higher fuel cost of this type of turbine is not the controlling factor. In addition to costs, the aircraft gas turbine has many other benefits for peaking service such as :—

(*a*) Meeting System Emergencies.

(*b*) Augmentation of hydel stations during low water periods.

(*c*) Reduced start-up costs.

(*d*) Increased system flexibility.

(*e*) Decentralized locations with savings in Transmission Lines.

(*f*) Flexibility of fuel.

The continuing development of aircraft gas turbines for higher operating temperatures is expected to reduce both the specific fuel consumption and capital cost per KW. This would further enhance the economies of gas turbines for peaking duty. Continuing development in materials and techniques could also make the aircraft gas trubine suitable for base and semi-base load operation in future.

As the percentage of peaking equipment is increased, the fixed charges decrease and the operating cost increases, as shown in Table II. The sum of these two components produces the bowl-shaped curve and represents total generating costs. For the WAPDA Grid System, an optimum percentage of peaking capacity would range between 15%-25%, based on the projected system annual load duration curves.

The application of aircraft gas turbines would also prove very useful in augmenting and rehabilitating the old thermal and diesel stations at Lyallpur and Sahiwal. The prime movers like steam turbines and diesel engines could be removed and the existing electrical generators coupled to aircraft engines through suitable gearing. This arrangement would enable these old stations to provide cheap and reliable peaking power.

By 1975 the peak load on the WAPDA Northern Grid System is expected to reach approx. 1800 MW. The annual load growth for the period 1970-75 is given below:—

Year	Peak Demand (MW)
1970	1045
1971	1159
1972	1323
1973	1489
1974	1658
1975	1806

It can be seen from the above table, that the system load growth is approx. 150 MW per annum. In order to meet this growth, WAPDA investment in new generation facilities alone will amount to approx. Rs. 150 million per annum as shown in the following table :

Year	Investment* (Million of Rs.)
1970	135
1971	101
1972	134
1973	144
1974	80
1975	141
Total Rs.	735 million

*Harza's Tarbela Study.

Two of the projects covered in the above generation investment prorgam include—

(*a*) Gomal Dam Hydro Project.

(*b*) Gudu Thermal Station.

If peaking gas turbines are installed in place of pumped hydro or base thermal it would result in a very substantial saving in generation investment to WAPDA. In addition, to reducing the cost of the new investment, peaking

generating plant lowers the overall system costs by making greater use of existing base load generation.

For the WAPDA Northern Grid System, it can be seen from the annual load duration curves, that the characteristics of load and existing capacity are such that a combination of high efficiency base load generation and low capital cost peaking capacity will be the optimum type of new generation to add to the system in the future.

In the past the size and timing of new machines was generally based on knowledge of system load growth, and judgment was used to evaluate the economic advantages of the lower unit cost of the larger size units. Improved efficiency available every few years economically justified adding the unit with the lowest heat rate; however, advances in thermal efficiency requires large capital expenditure. In addition a wide choice of generation types at various levels of thermal efficiency at an attractive cost is now available to the Planning Engineers.

A new engineering tool useful in solving the problem of selecting the generating capcity that will ensure the maximum possible overall minimum cost is the high speed digital computer. Of course, the computer does not eliminate the engineer in the solution of this problem, but properly used, the computer makes possible the use of more complete criteria for decision and frees the engineer of the restrictions in perspective which previously resulted from the consideration of only a few variables or the analysis of only a few alternative plans. As a result system engineering and operation can be accomplished with a minimum of approximation, but there will always be need for practical judgment in evaluating the results of an analysis and formulating decisions. Optimum system economy for WAPDA is more nearly attainable today because of advanced study techniques for system analysis and modern computers, which increase the speed and accuracy in developing system design patterns.

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TABLE-I

— ECONOMICS OF NEW PEAKING GENERATION CAPACITY —

1973

TYPE OF PEAKING STATION	INSTALLED CAPACITY (MW)	TOTAL COST (Rs x 10⁶)	COST PER KW (Rs)	LOAD FACTOR	GROSS GENERATION (KWH x 10⁶)	ANNUAL FIXED CHARGES (Rs x 10⁶)	ANNUAL O&M CHARGES (Rs x 10⁶)	ANNUAL FUEL CHARGES (Rs x 10⁶)	STATION HEAT RATE (BTHU/KWH)	TOTAL ANNUAL CHARGES (Rs x 10⁶)	COST PER KWH (PAISAS)	REMARKS
STEAM	100	75.0	750	65	60.0	6.38	0.88	2.30	12500	9.56	15.9	37 MILLION KWH OF ADDITIONAL ENERGY IN 1973 WILL BE USED FOR THE FOLLOWING: (a) PEAKING ENERGY DEFICITS IN THE SYSTEM DURING THE YEAR (b) FORCED OUTAGES AND EMERGENCIES (c) SCHEDULED MAINTENCE
HYDRO	*	200.0	2000	*	58.0	16.00	0.40	—	—	16.40	28.2	
DIESEL		52.5	525		57.5	4.46	0.57	1.86	10500	6.89	11.9	
GAS TURBINE		55.0	550		58.0	4.47	0.53	2.41	13500	7.61	13.1	
AIRCRAFT TURBINE		45.0	450		58.0	3.83	0.53	2.59	14500	6.98	11.9	
@ EHV INTERCONNECTION	—	152.0	—	—	60.0	12.60	inc	—	—	12.60 +	21.0	
—1974—												
STEAM	250	175.0	700	8.5	212	14.80	1.52	8.15	12500	24.47	11.5	202 MILLION KWH OF ADDITIONAL ENERGY IN 1974 WILL BE USED FOR THE FOLLOWING: (a) PEAKING ENERGY DEFICITS IN THE SYSTEM DURING THE YEAR (b) FORCED OUTAGES AND EMERGENCIES (c) SCHEDULED MAINTENCES.
HYDRO	*	500.0	2000		206	40.00	1.00	—	—	41.00	20.6	
DIESEL		131.0	525		204	8.10	1.10	6.59	10500	18.79	9.2	
GAS TURBINE		125.0	500		206	10.60	0.99	8.56	13500	20.14	9.7	
AIRCRAFT TURBINE		100.0	400		206	8.00	0.98	9.19	14600	18.17	8.8	
MULTAN	260	280.0	1075		225	23.80	1.10	6.20	12000	31.70	14.1	

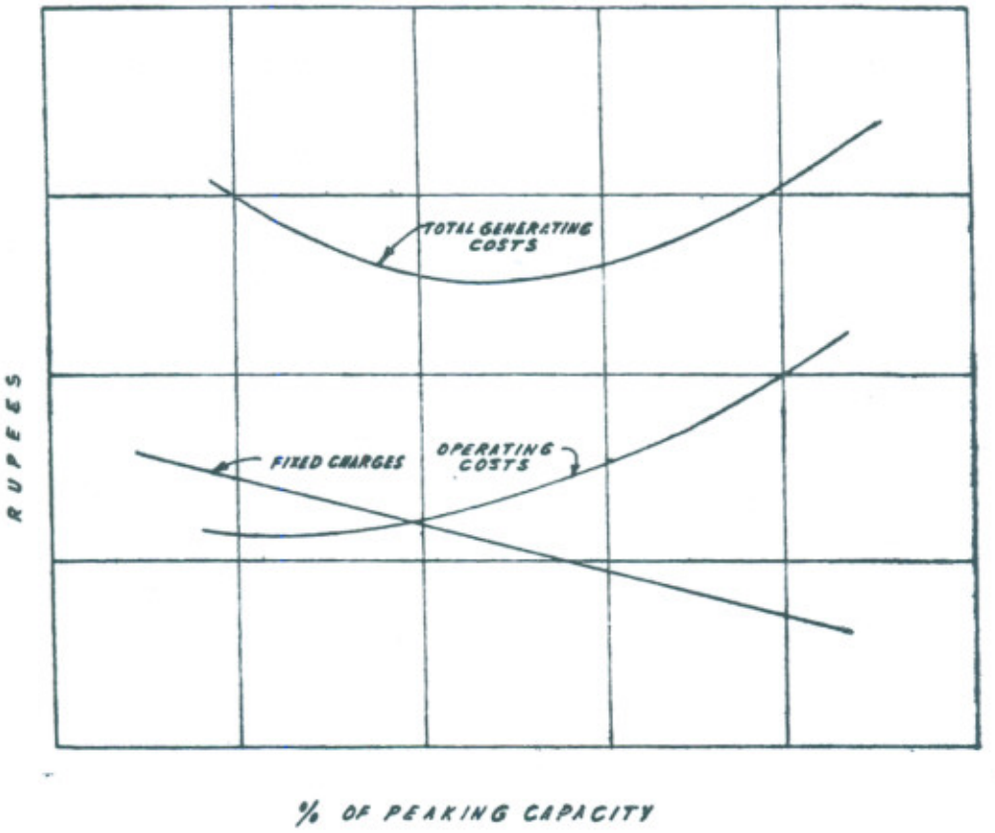
THERMAL FIXED CHARGES AT 8.5%
HYDEL FIXED CHARGES AT 8.0%
COST OF FUEL Rs-3-0 PER MCM (Rs 375)
* CAN ALSO BE USED TO SEND HYDRO ENERGY SOUTH
+ INCLUDES COST OF GENERATION

M. INSAN. TRACED

Table I—Economic Comparison of Peaking Generating Capability.

TABLE-II

— COSTS OF PEAKING GENERATION —



ANNUAL GENERATING COSTS VS PEAKING CAPACITY

"NISER.K. 13²/67"

Table II—Annual Generating Costs Vs. Percentage Peaking Capacity.

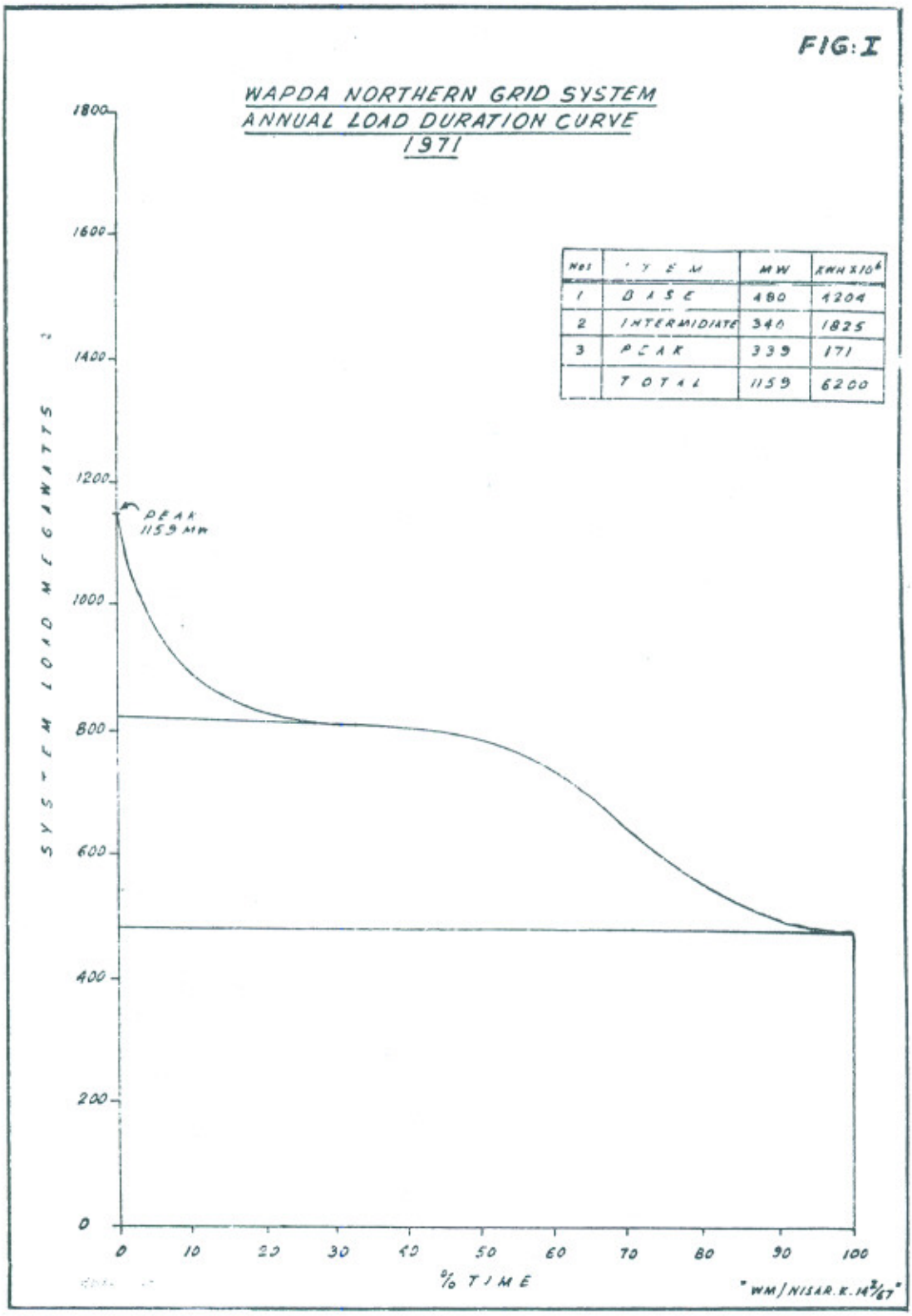


Fig. I—WAPDA Northern Grid System—Annual Load Duration Curve (1971)

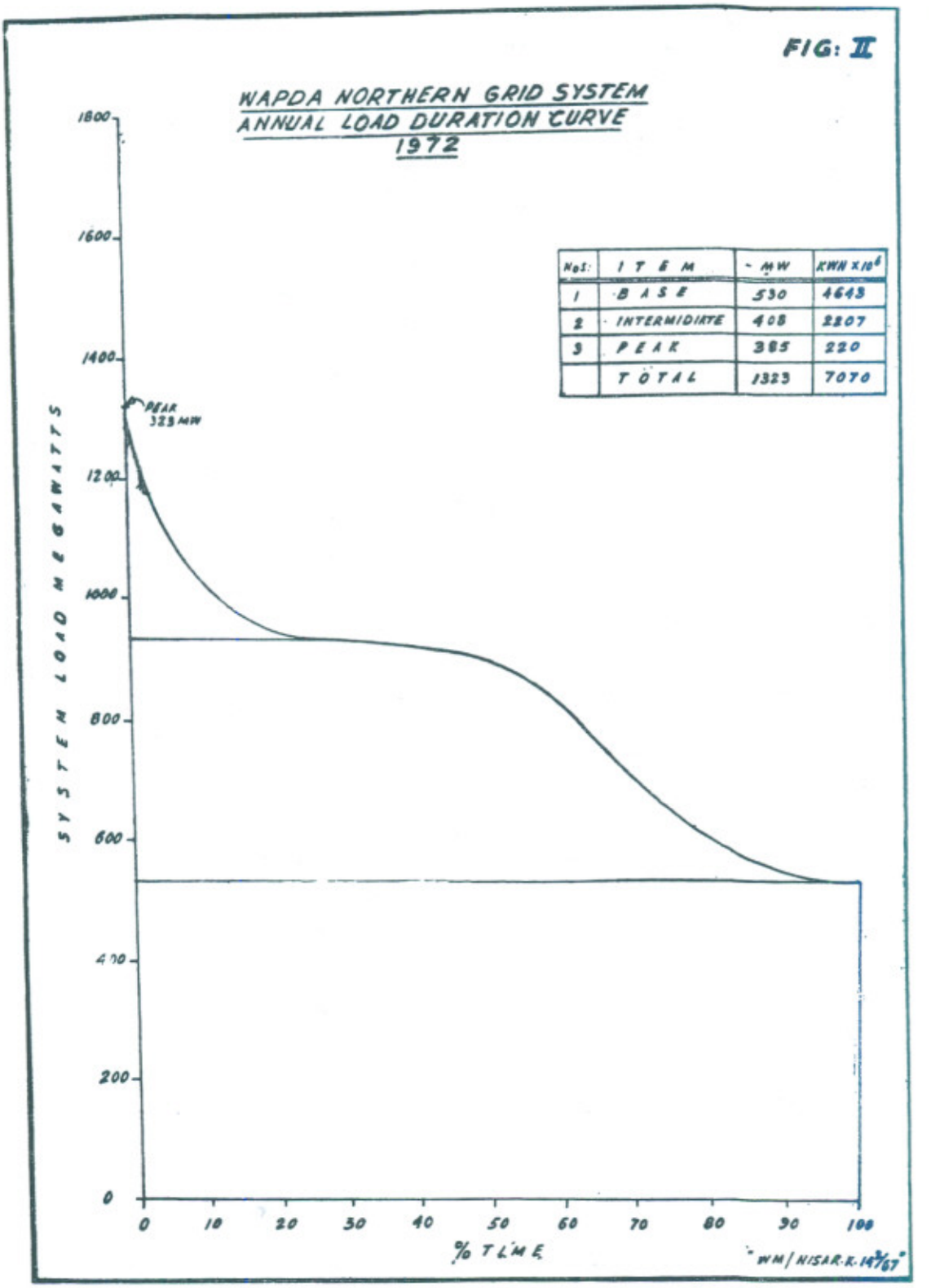
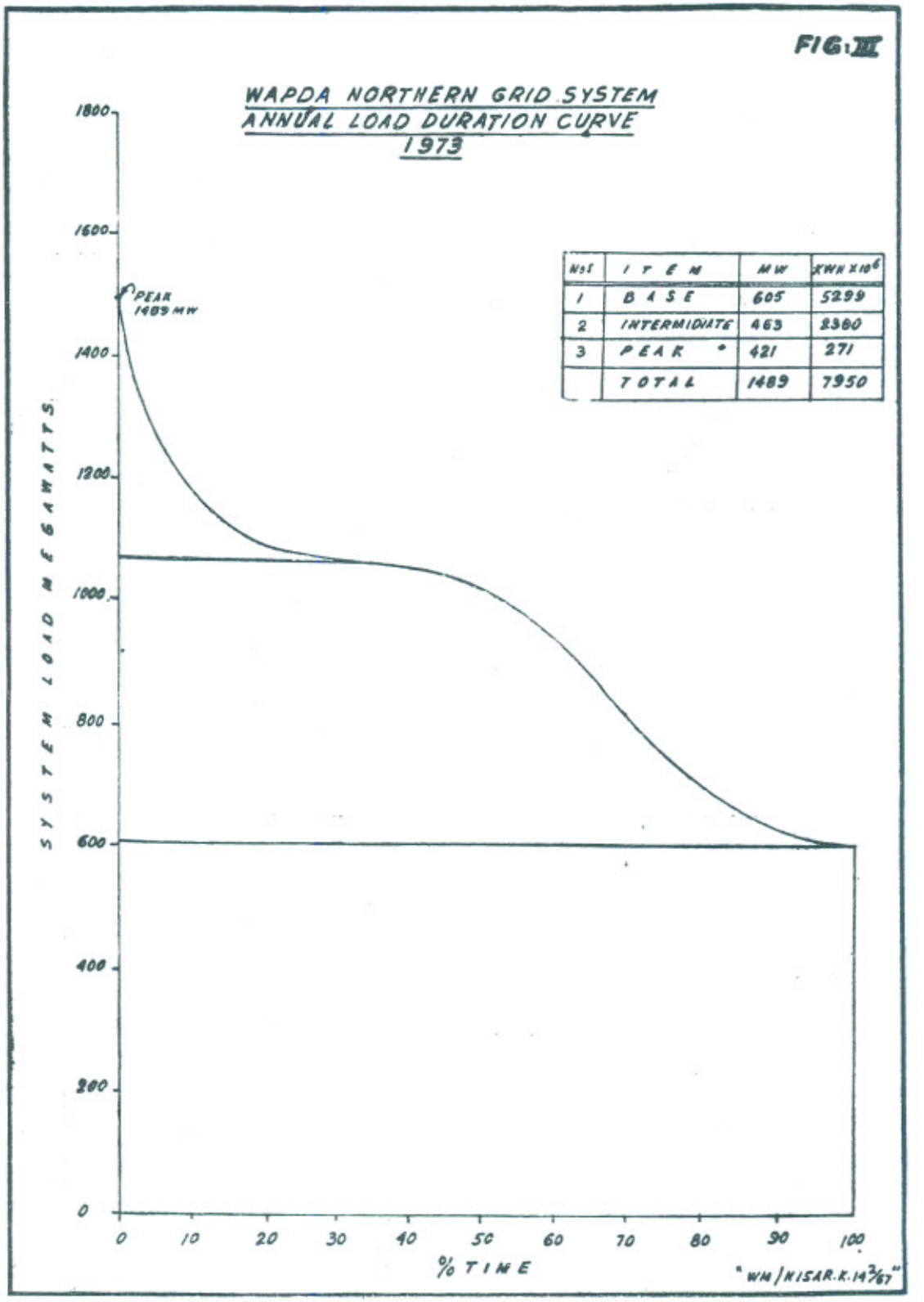


Fig. II—WAPDA Northern Grid System—Annual Load Duration Curve (1972)



NOS	ITEM	MW	KWH X 10^6
1	BASE	605	5299
2	INTERMIDIATE	463	2380
3	PEAK *	421	271
	TOTAL	1489	7950

Fig. III—WAPDA Northern Grid System—Annual Load Duration Curve (1973)

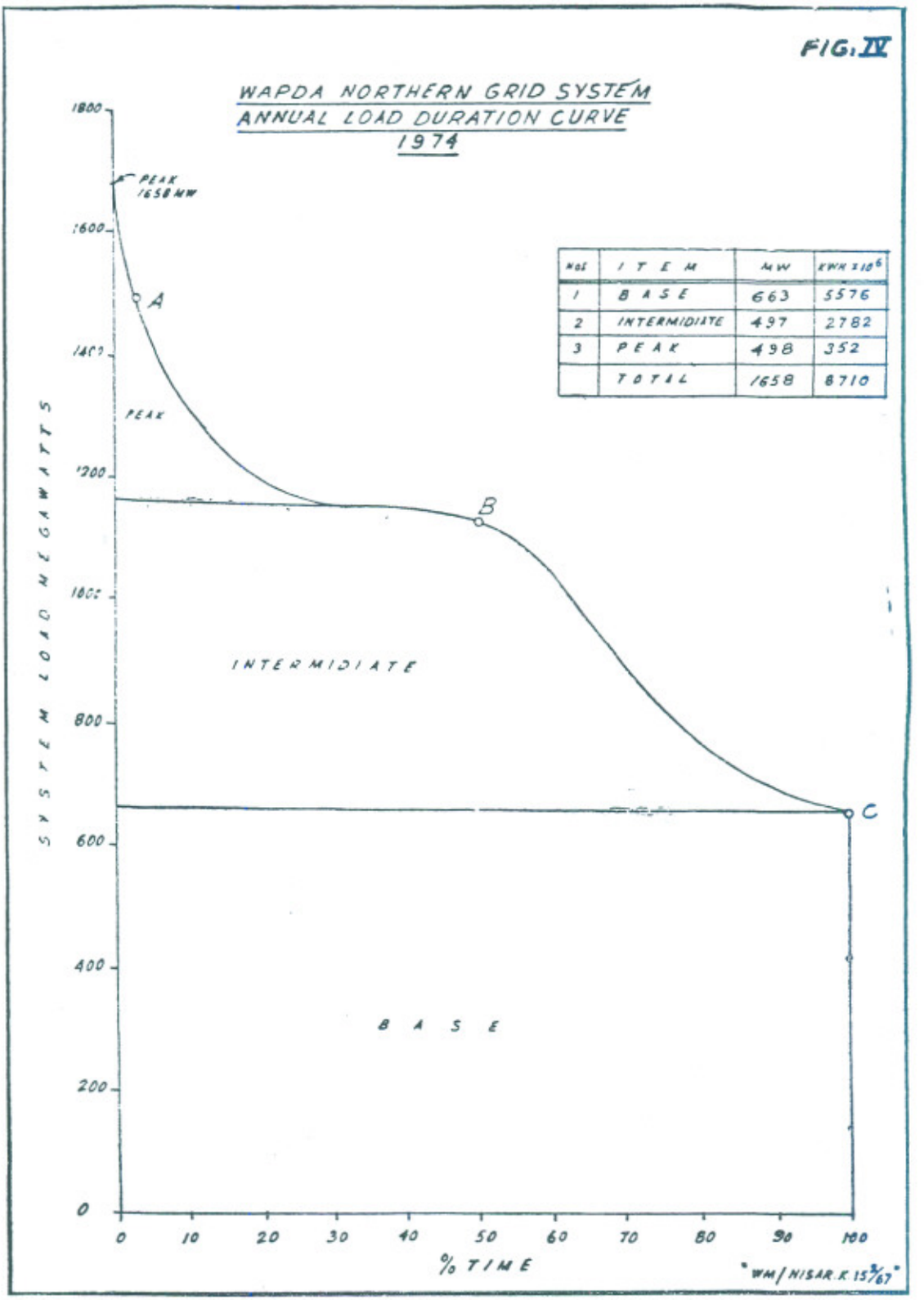
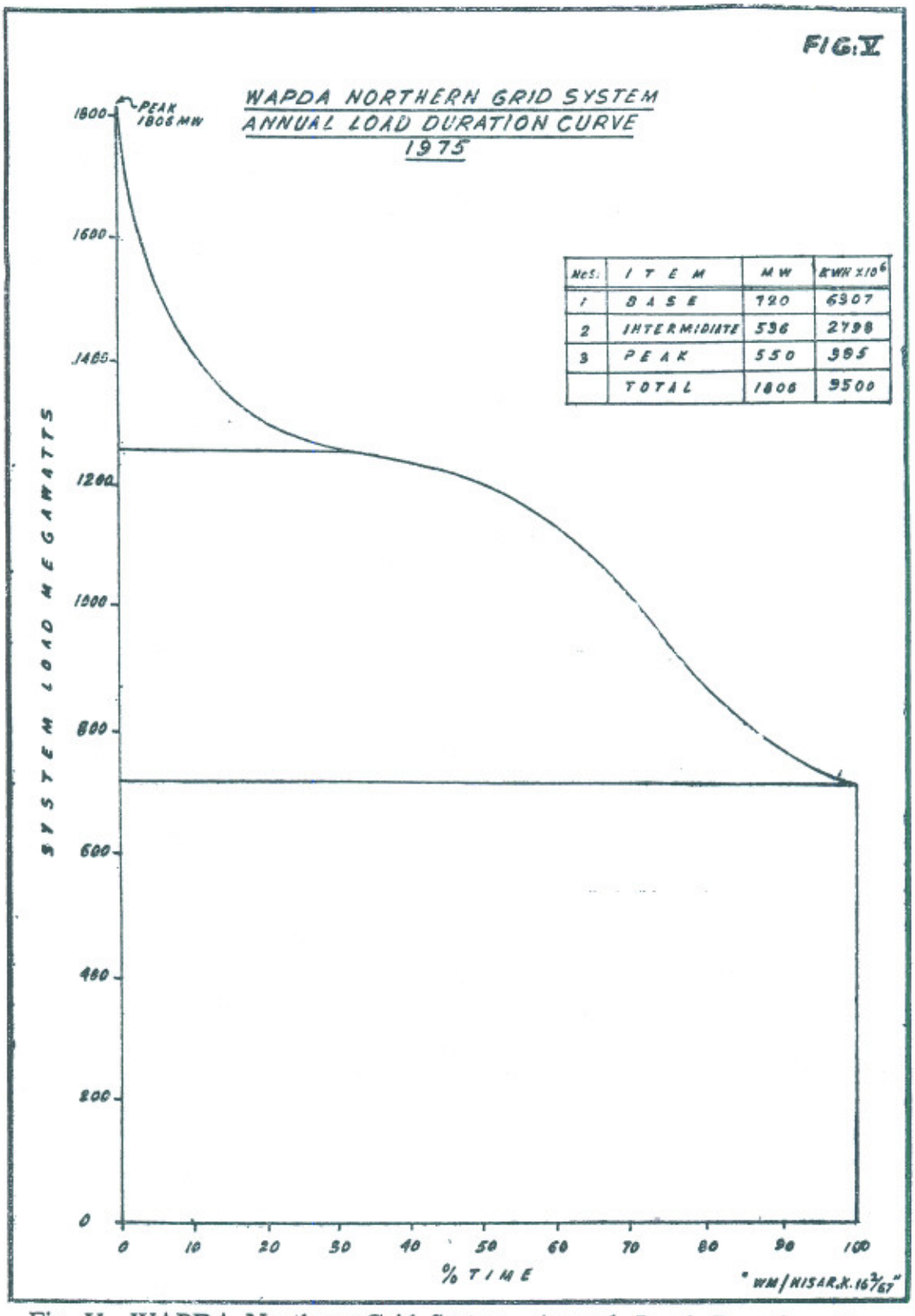


Fig. IV—WAPDA Northern Grid System— Annual Load Duration Curve (1974)



Nos.	ITEM	MW	KWH x 10^6
1	BASE	720	6307
2	INTERMIDIATE	536	2798
3	PEAK	550	395
	TOTAL	1806	9500

Fig. V—WAPDA Northern Grid System—Annual Load Duration Curve (1975)

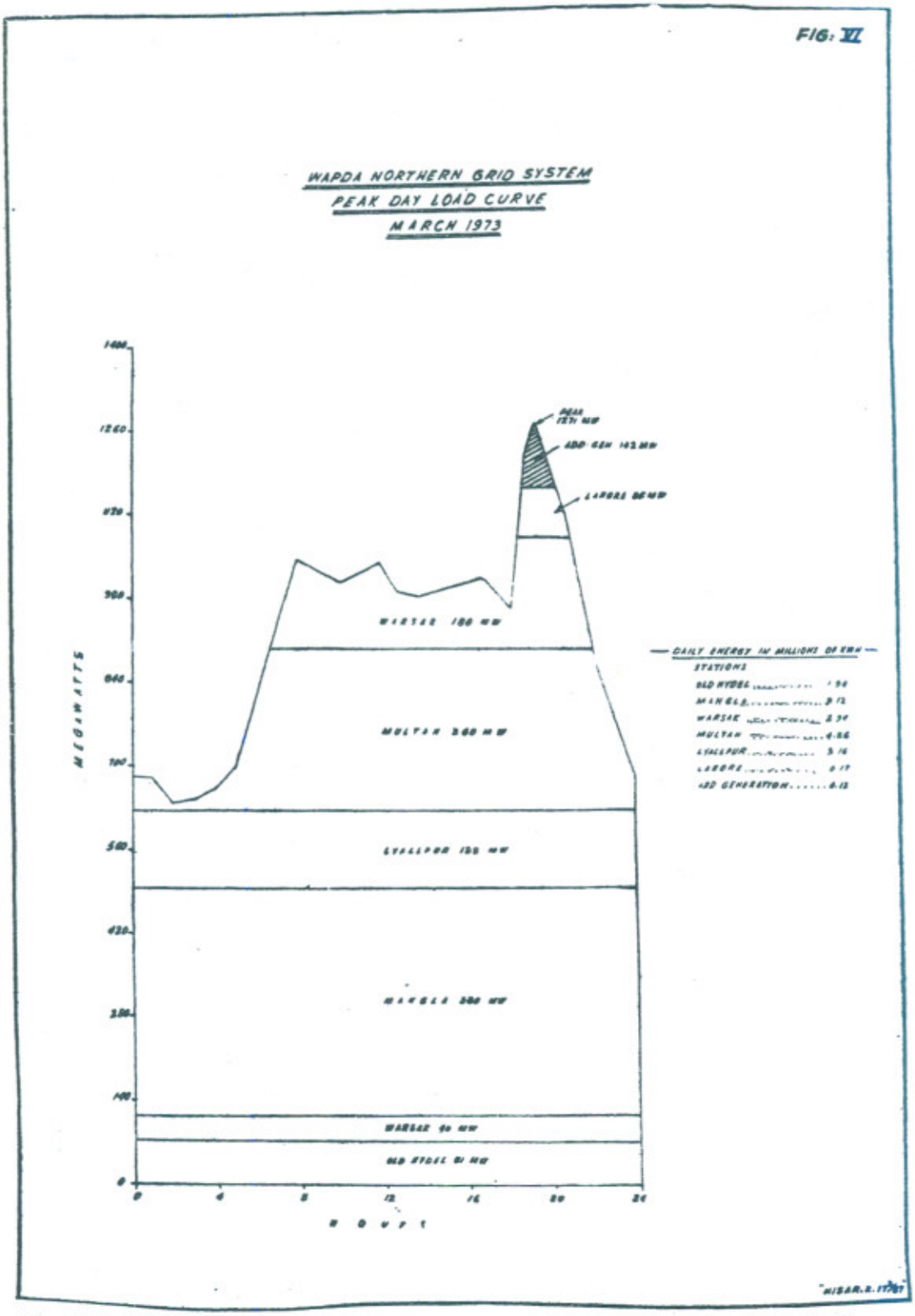


Fig. VI—WAPDA Northern Grid System—Peak Day Load Despatch Curve (Mar. 73)

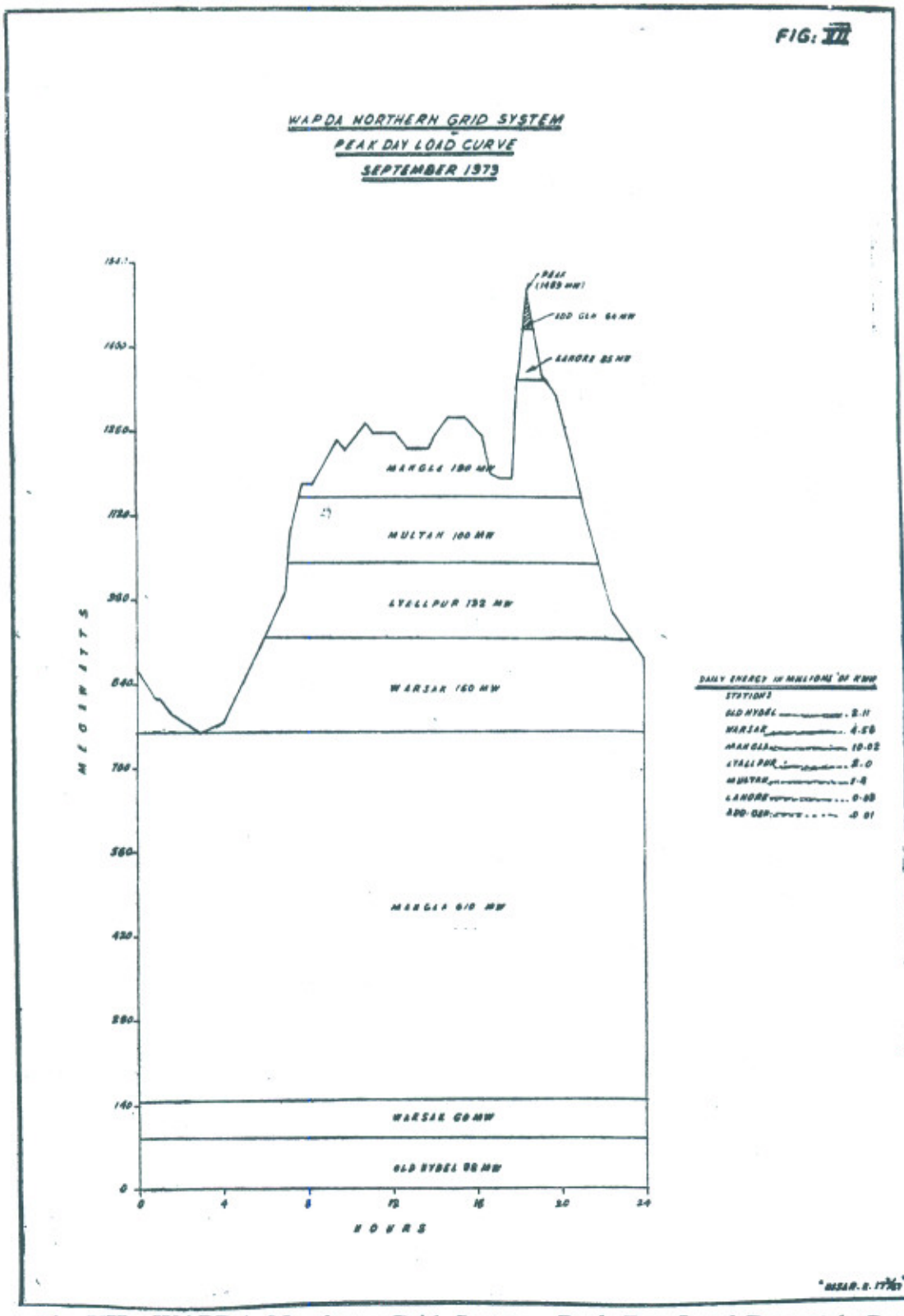


Fig. VII—WAPDA Northern Grid System—Peak Day Load Despatch Curve (Sep. 73)

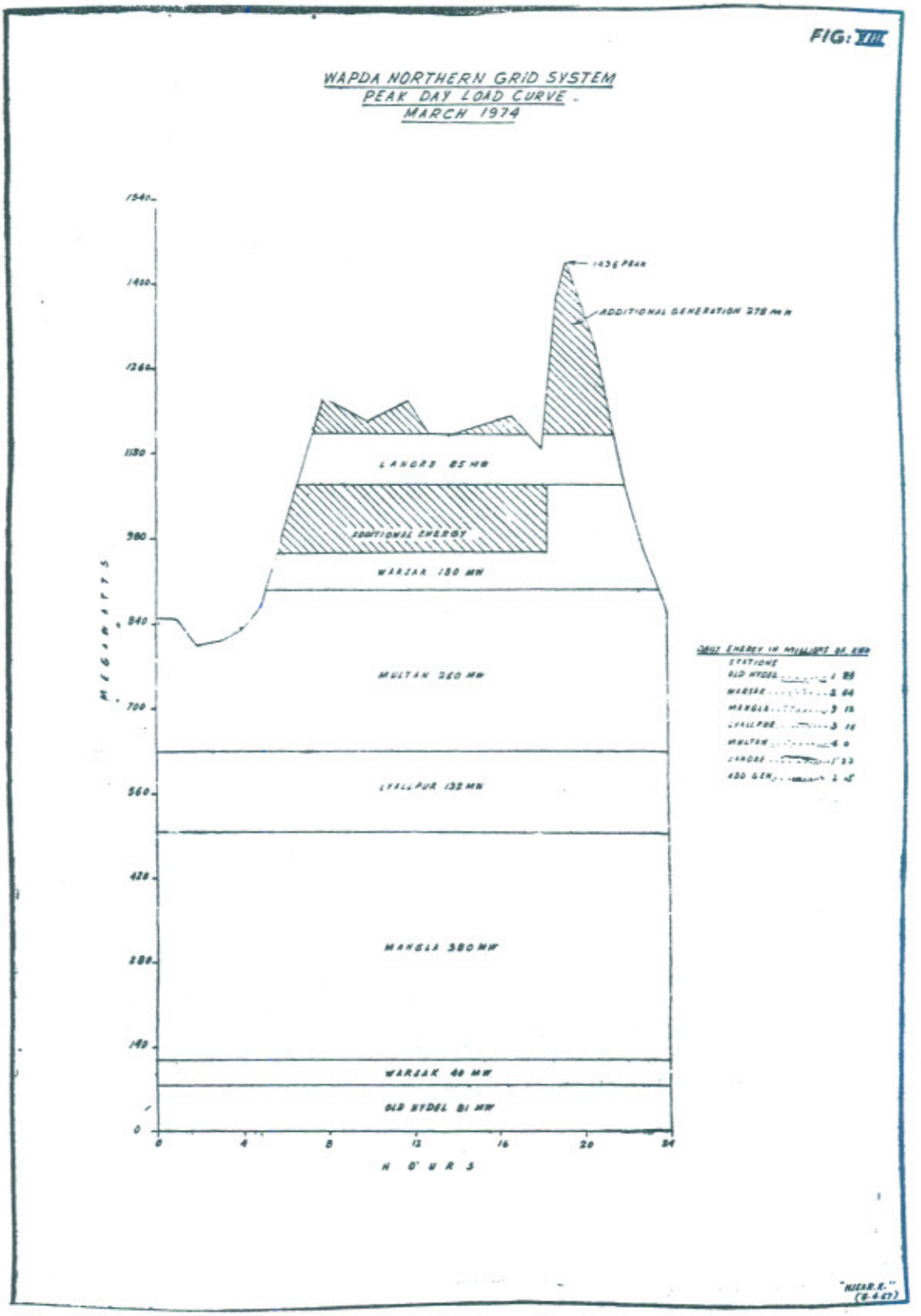


Fig. VIII—WAPDA Northern Grid System—Peak Day Load Despatch Curve (Mar. 74)

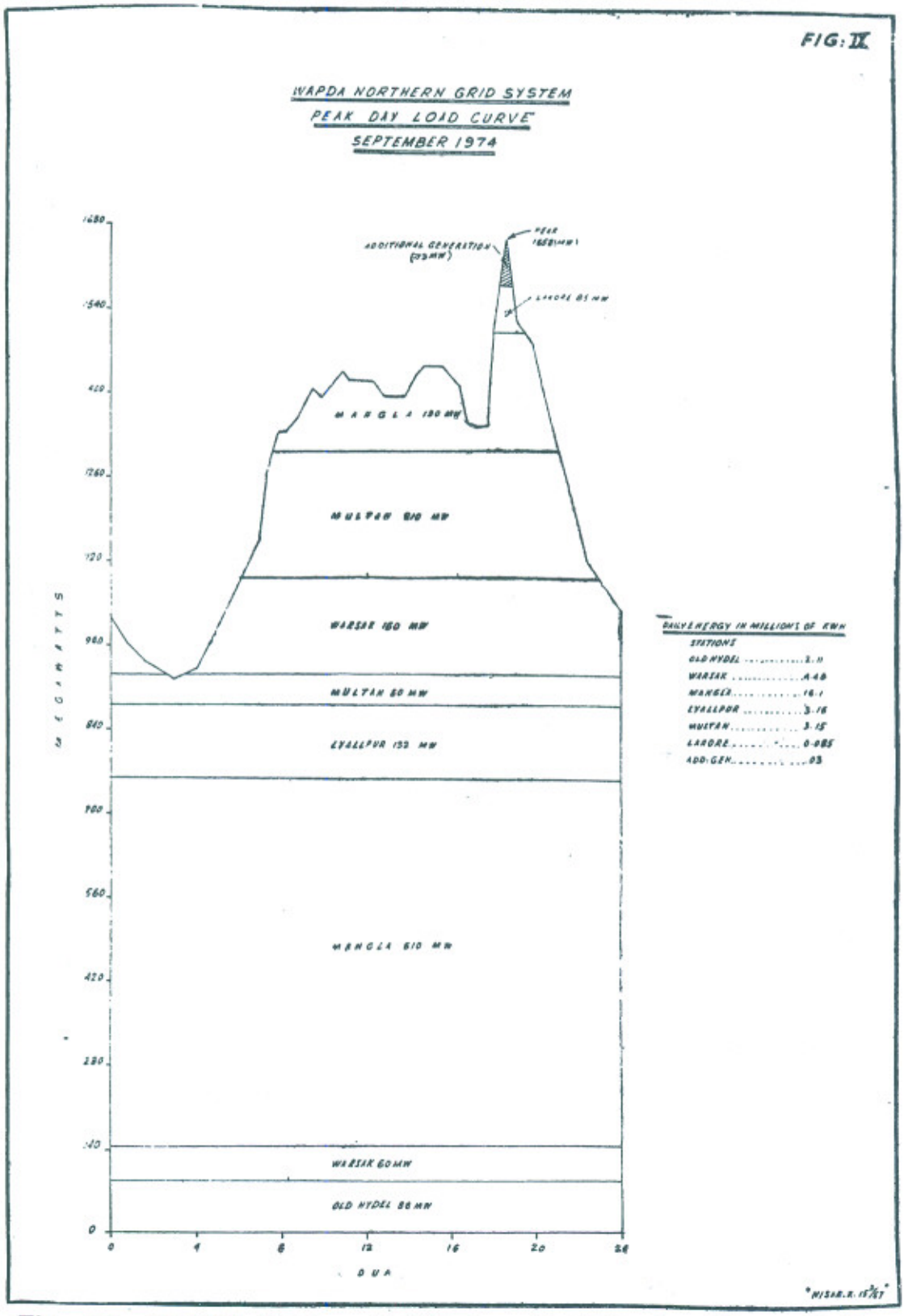


Fig. IX—WAPDA Northern Grid System—Peak Day Load Despatch Curve (Sep. 74)

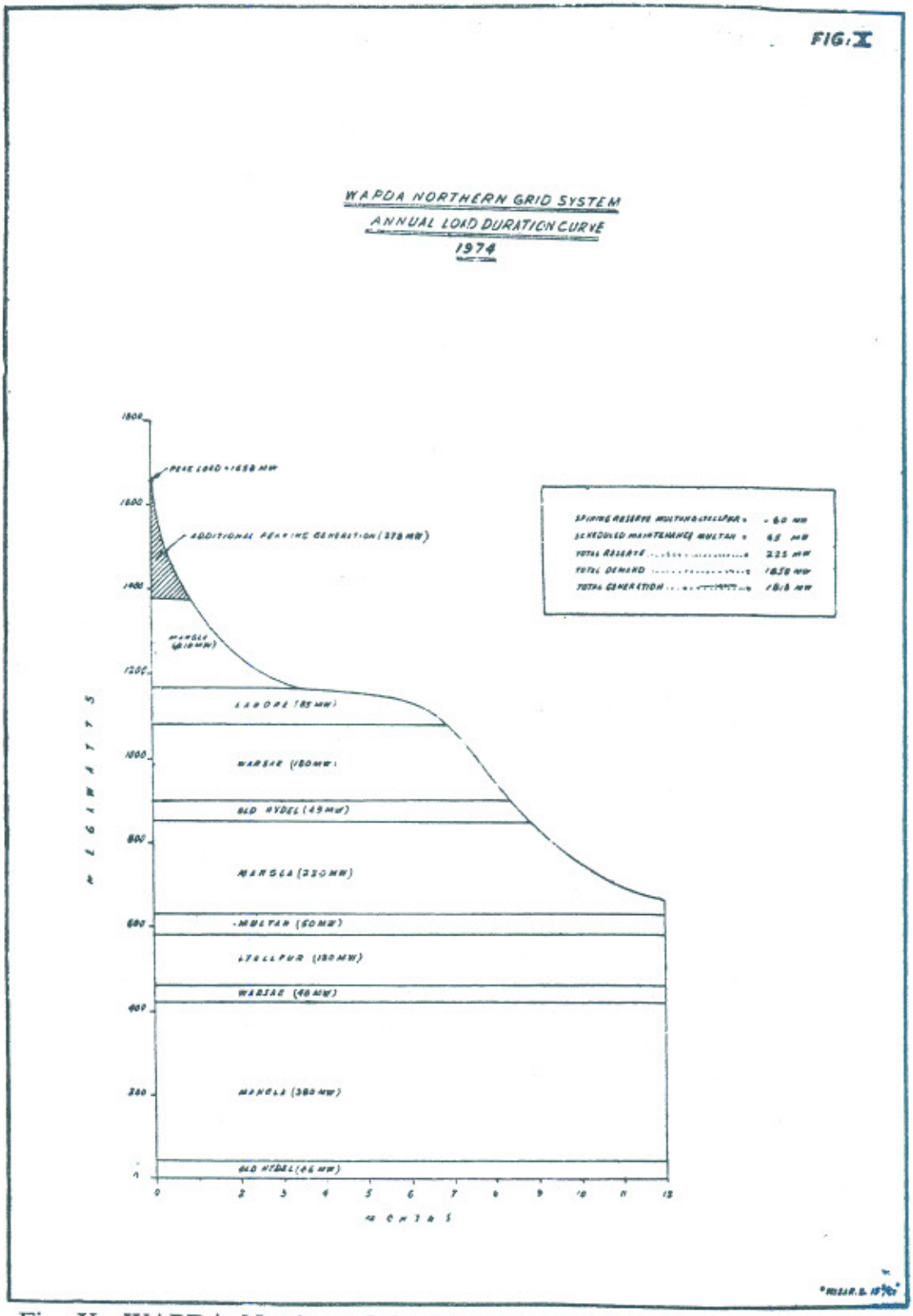


Fig. X—WAPDA Northern Grid System—Annual Load Despatch Curve (1974)

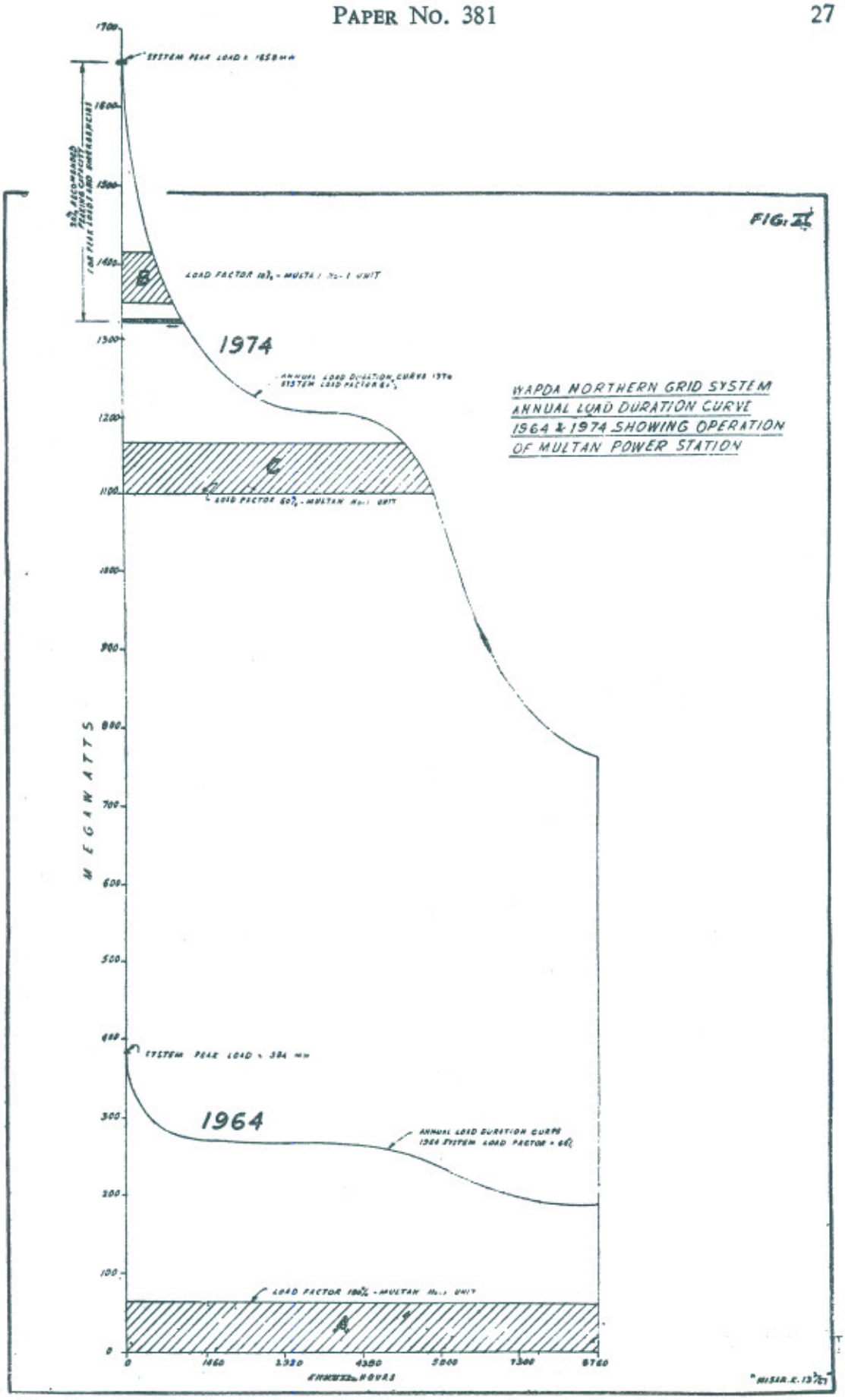


Fig. XI—WAPDA Northern Grid System—Annual Load Duration Curve —1964 and 1974 showing operation of Multan Power Station.

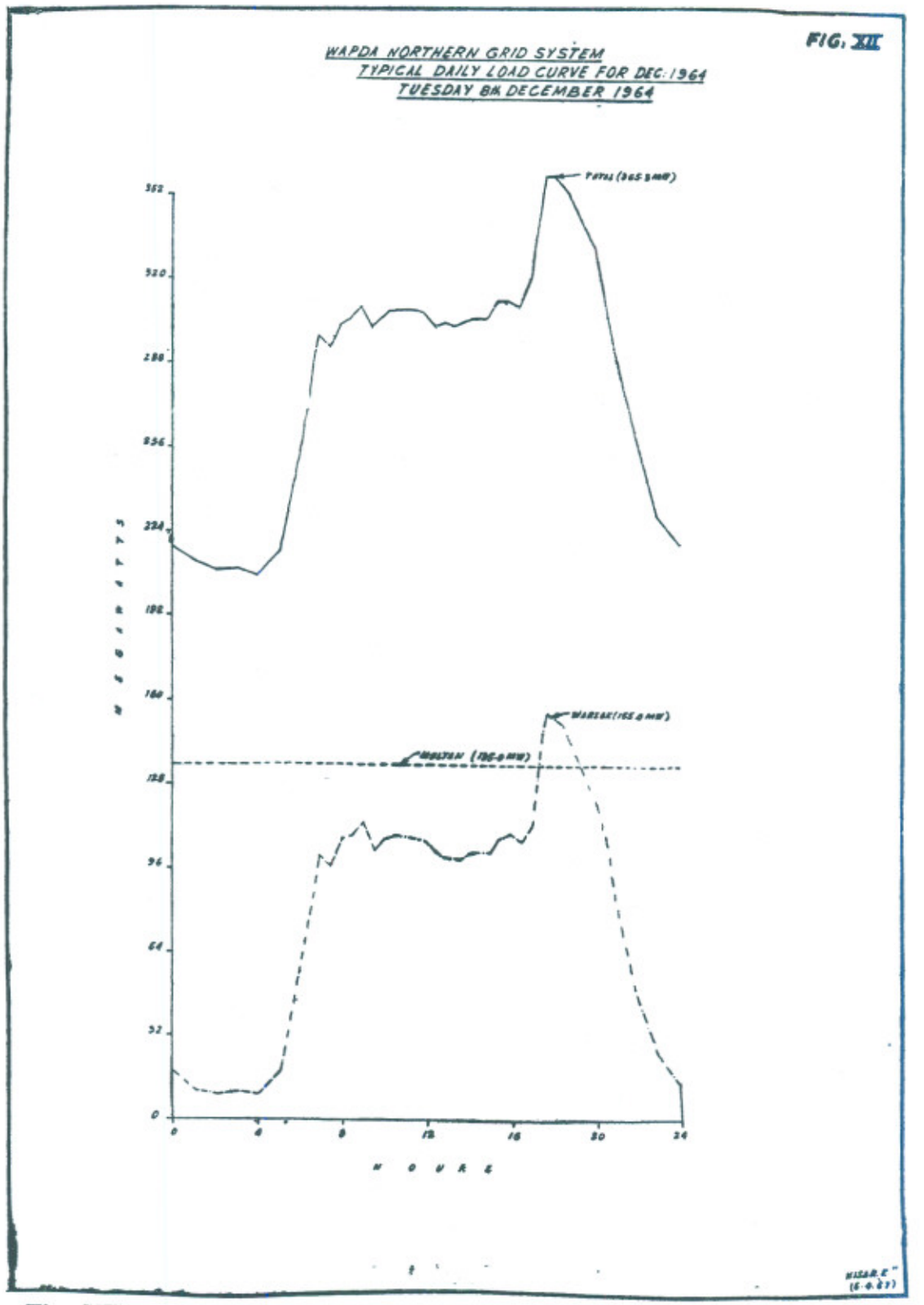


Fig. XII—WAPDA Northern Grid System—Typical Daily Load Despatch Curve. (Dec. 64)