KINGDOM OF THAILAND

# MASTER PLAN STUDY REPORT ON NAM YUAM RIVER BASIN HYDROELECTRIC DEVELOPMENT PROJECT

MARCH 1987

JAPAN INTERNATIONAL CORPORATION AGENCY

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# ON
# NAM YUAM RIVER BASIN
# HYDROELECTRIC DEVELOPMENT
# PROJECT



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# PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government has decided to conduct a Master Plan survey on the Nam Yuam River Basin Hydroelectric Development Project and entrusted the survey to the Japan International Cooperation Agency. JICA sent to Thailand a survey team headed by Mr. Yasuo Takashima, Electric Power Development Co., Ltd., four times from July, 1985 to December, 1986.

The team had discussions with the officials concerned of the Government of Thailand and conducted a field survey in the Nam Yuam basin in Northern Thailand. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

March, 1987

KEISUKE ARITA
President
Japan International Cooperation Agency

Nam Mae Ngao Dam Site

View from upstream
( End of rainy season )

Nam Mae Rit Dam Site

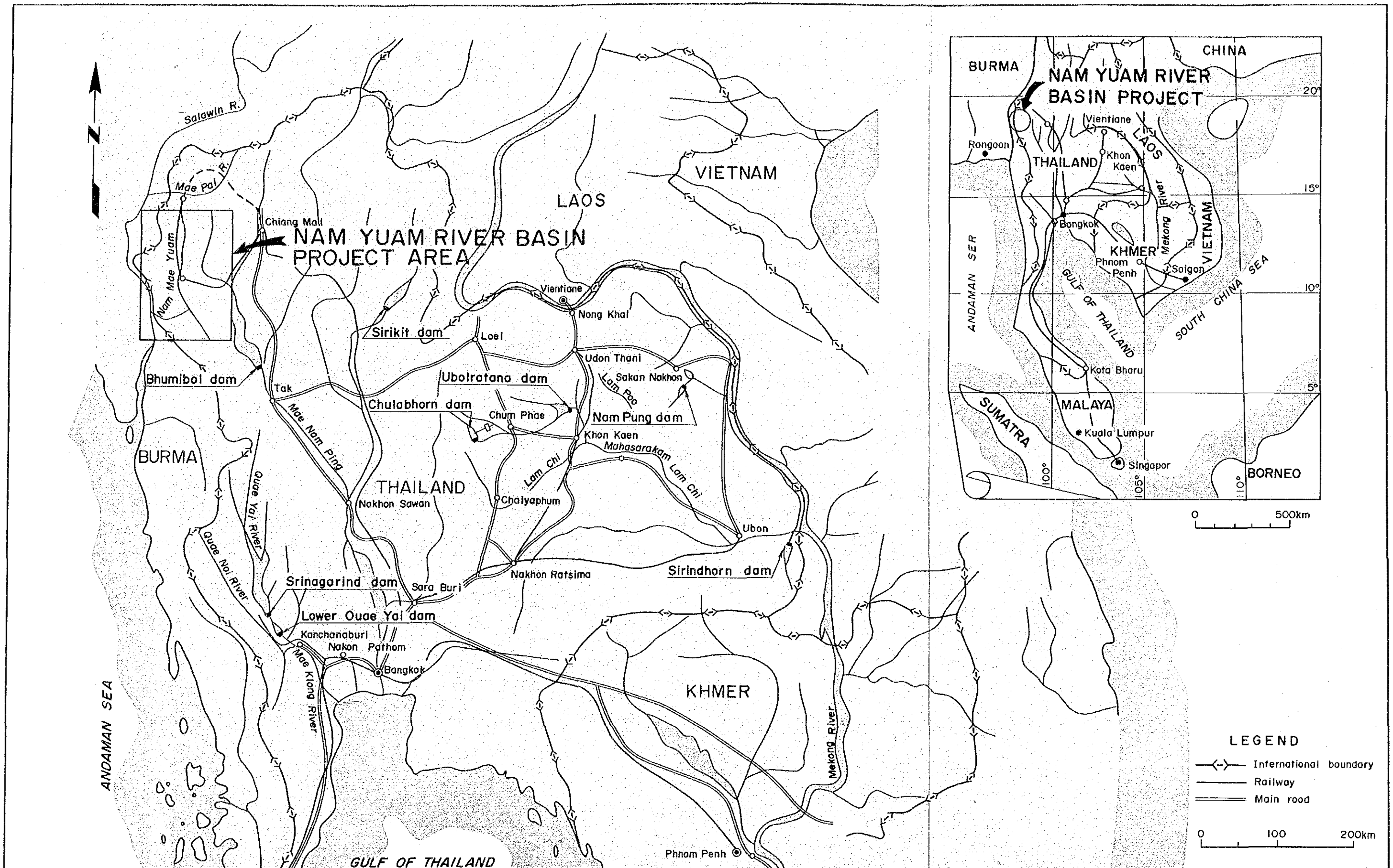
View from down stream
( End of rainy season )

Upper Yuam 1 Dam Site

View from down stream
( End of rainy season )

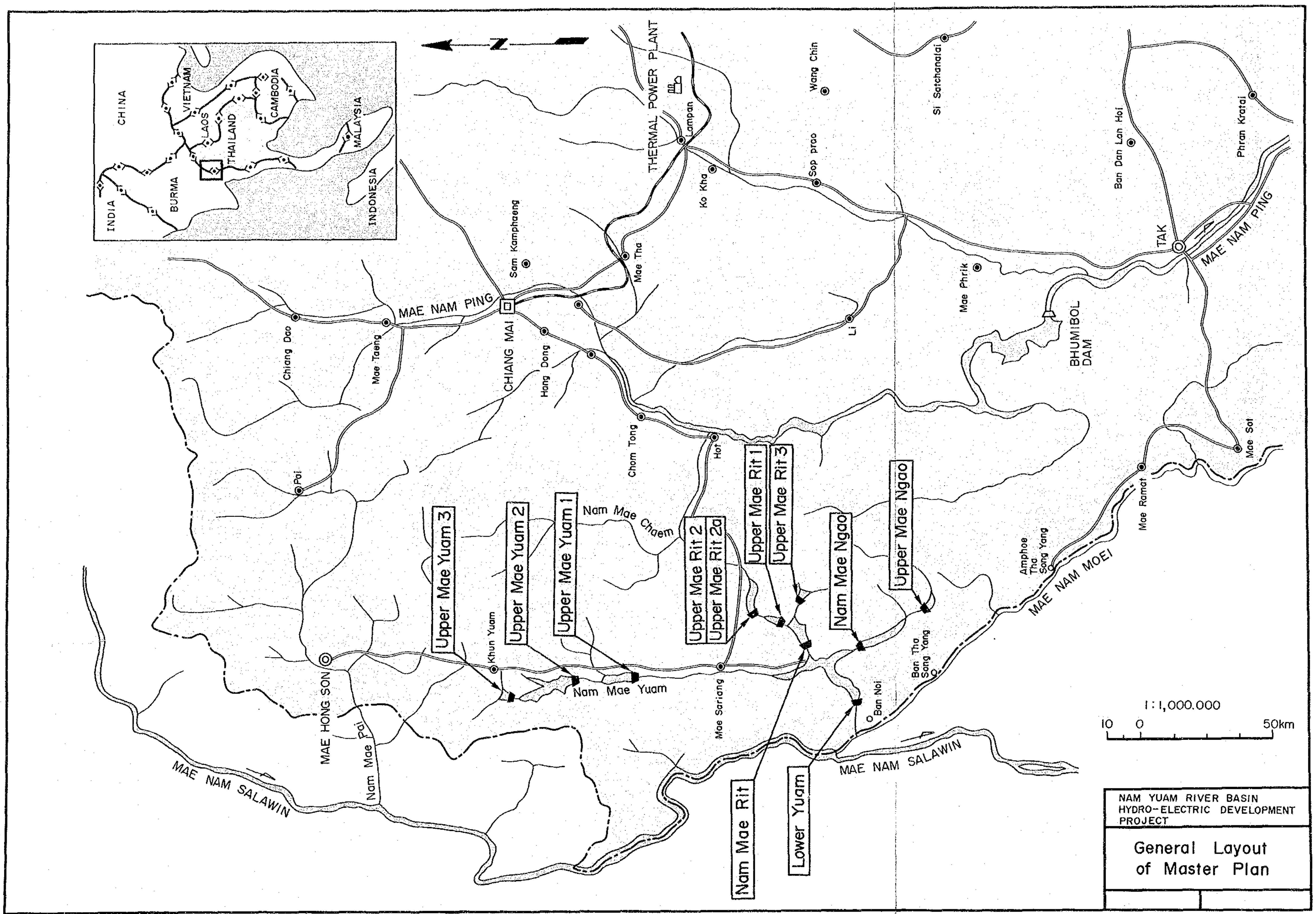
Upper Yuam 2 Dam Site

View from up stream
( End of rainy season )




NAM YUAM RIVER BASIN HYDRO-ELECTRIC DEVELOPMENT PROJECT

KEY AND LOCATION MAP




NAM YUAM RIVER BASIN
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# CONCLUSION AND RECOMMENDATION

# CONCLUSION AND RECOMMENDATION

(1) Conclusion

The total installed capacity of electric power generating plants in Thailand is about 6,500 MW as of 1985. The annual increasing rates of the energy demands for the next 10 years are estimated to be 6% for the whole EGAT system and 10% for the Northern Region where the proposed projects are situated.

According to the load forecast, made by "the Load Forecast Working Group in Thailand", the peak power generation in 2000 will be 10,154 MW and the energy generation in the same year will reach 62,780 GWH in the EGAT whole system.

Further, EGAT forecast that the power and energy demand of Northern Region of Thailand in 1994 will reach 855 MW and 3,700 GWH level respectively. Extrapolating on the basis of these forecasts, the JICA team estimated that the power and energy demands of the region in 2000 would be grown up to 1,220 MW and 5,500 GWH respectively.

The present master plan study is concerned with the study on the hydroelectric power development plan in the Nam Yuam River Basin. (the Yuam River, the Ngao River and the Rit River).

Among nine projects preset by EGAT, four projects; Upper Mae Yuam 1, Nam Mae Rit, Upper Mae Rit 2a and Nam Mae Ngao were firstly ranked higher than others through the first stage study. The ensuing detailed stages of the study have revealed that Nam Mae Ngao No.2 Project was the most promising project from both technical and economical view points.

According to the final result, the installed capacity and the annual energy generation of Nam Mae Ngao No.2 Project are 120 MW and 250 GWH respectively.

This project has many prominent features that the runoff quantity of the Ngao River is plentiful (specific runoff 50 lit/sec/$km^2$ of this river is a rare value observable in rivers in Thailand), that the peak power supply capacity can be obtained without construction of a downstream equalization pondage, that the access road to the project site is already completed and that there are no significant environmental nor submergence problems forseen in the project area. These considerations lead to the conclusion that the construction of this project can be started immediately after the usual steps will be taken properly.

Therefore, it is an urgent need to proceed into the feasibility study with a provision that the high water level, tail water level, maximum turbine discharge, installed capacity, etc. should be re-examined in more detail.

Since the remaining three projects have less economic feasibility judging from the present study result, it is expected that these projects will be implemented in future when the economic circumstances will be improved.

(2) Recommendation

It is concluded that the feasibility study should be started as early as possible. In order to conform with this conclusion, the following works are recommended to be performed continuously.

1) Detailed survey of the Nam Mae Ngao Project area, in particular, levelling survey between Nam Mae Ngao Project and Lower Yuam Project.

2) Hydrological observation and/or data collection

   (a) for gaging stations at Ban Mae Ngao, Ban Mae Suat and Ban Wang Khan (EGAT)

   (b) for gaging stations at Ban Tha Rua and Sop Han (NEA)

   (c) for irrigation water-take and spilled water over the weir of the Mae Sariang irrigation facility (RID)

3) Geological test boring

   The location and quantities of the bore holes are shown on Fig. 3-5 and Table 3-2.

# CHAPTER 1. INTRODUCTION

## CHAPTER 1 INTRODUCTION

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# CHAPTER 1. INTRODUCTION

## 1.1 Outline of the Project Area

The Yuam river is a tributary of the Moei river which forms the boundary between Thailand and Burma. After merging the Yuam river, the Moei river joins with the Salawin river which rises from Tibet, flows down through Burma and finally drains into the Andaman Sea.

The Yuam river basin, therefore, is located in the northwestern corner of Thailand, and ranges over approximately 60 km in the east and west and 160 km in the north and south directions, having the catchment area of slightly more than 6,000 square kilometers.

Mountains of 1,000 m high class lie in a row in the north and south direction of the Yuam river basin, forming the topographic feature of a long basin. The center town is Mae Sariang (about 20,000 of population) belonging to the district of Changwat Mae Hong Son. The Yuam river originates at the northern end of the basin, flows south and merges the Rit river at the point of about 35 km south to Mae Sariang. After merging the Rit river, the Yuam river flows down south more 5 km to a confluence point of the Ngao river which is also a tributary but running up from the opposite direction, south to north. The Yuam river then turns the flows to west almost in right angle and joins with the Moei river near Hoei Varieu, a downstream hamlet of the Lower Yuam project site.

The national highway No. 108 connecting Changwat Chiang Mai and Amphoe Mae Sariang runs the east foot of Mt. Doi Inthanon (2,595 m high), which is the highest in Thailand, passes Amphoe Chom Thong, goes over the plateau in the east side of the Yuam river basin along the Chaem river, a tributary of the Ping river. The total distance between Changwat Chiang Mai and Amphoe Mae Sariang is approximately 200 km.

The midstream area of the basin is well developed in various irrigation facilities. Particularly, intake facilities have been constructed by the Royal Irrigation Department (RID) across the main river at the point about 13 km upstream of Amphoe Mae Sariang and a main irrigation canal, which has the capacity of about 3 $m^3$/sec, runs down on the right-bank tableland.

## 1.2 Background of the Project

Thailand's economic growth rate in 1970's marked at 7.4%, following Hong Kong, South Korea, Taiwan, Singapore, etc., being prominent in the Asian developing nations. Particularly, the growth of its industrial sector was significant, doubling the share in the whole economy compared with that in 1960's.

The installed capacity of electric power generating facilities of EGAT is 6,460 MW and the generated energy is 23,357 GWh in 1985. Composition of power source consists of 1,814 MW in hydro plant (28.1%) and 4,646 MW in thermal plant (71.9%).

Electricity demand increasing rates in the future, according to estimation by the "Load Forecast Working Group for Power Tariff Sub-committee", will reduce gradually from the estimated annual rate of 14% in 1983, to 6.5% in 1991, and afterwards it will continue almost constantly at the annual rate of 6%.

The electricity demand in 1991 is estimated to be 6,199 MW of power and 37,349 GWh of energy being about double of 3,204 MW and 19,066 GWh of those in 1983. Even after 1991, an annual increase of demand is considered to be 400 MW to 500 MW and 2,400 GWh to 3,200 GWh respectively.

The oil fired power generation shares large portion of the current electricity generation.

It is, therefore, significant for economic stability of the country to develop oil substitutive projects by utilizing indigeneous energy sources such as natural gas, lignite, hydropower etc., suppressing the increase of oil importation as much as possible under the government policy.

The main hydroelectric power resources development in Thailand has been carried out in large-scale projects such as Bhumibol (420 MW) on the Ping river, Sirikit (375 MW) on the Nam river, Srinagarind (360 MW) on the Quae Yai river and Khao Laem (300 MW) on the Quae Noi river. At present Chiew Larn (240 MW) is almost completed, and moreover Nam Chon (580 MW) which is planned in the upstream of

Srinagarind Dam is awaiting for the commencement of construction. As a result of these developments, it may be that the remaining possible large-scale hydroelectric power resources are limited mainly in the basin of the international rivers such as the Mae Khong river and the Salawin river, existing along the boundary. However, the Mae Khong river projects include internationally-complicated factors, so that it is very hard to imagine that the development will be realized in the near future. Under such circumstances, keen attention has been focussed recently to the Salawin river basin especially to the Yuam river basin, a tributary of the Salawin river and the investigation works necessary for the development has been carried out in these years.

Standing on the abovementioned background, the Master Plan has been projected by EGAT to formulate the Yuam river basin hyroelectric development as a whole thereby taking into consideration of the Lower Yuam project which has already been studied by NEA under the cooperation of JICA.

## 1.3 Outline of the Project

The study on the development plan was proceeded in two stages and an additional stage.

At the first stage, 9 sites for the master plan study were selected and the first field investigation and desk study on the basis of topographical maps of 1:50,000 were carried out. As the result of the first stage study, the 4 sites, Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a and Upper Mae Yuam 1, were found to be of high priority from economical point of view.

The second stage included the second field investigation for the 4 sites and the detailed study. Nam Mae Ngao site turned out to be of the highest priority.

The outline of the 9 sites is presented as follows.

| Project Name | Dam Height (m) | HWL (m) | Total Storage (MCM) | Installed Capacity (MW) | Annual Energy Production (GWh) |
|---|---|---|---|---|---|
| Upper Mae Yuam 1 | 62 | 325 | 421.4 | 18.5 | 54.5 |
| Upper Mae Yuam 2 | 65 | 380 | 178 | 11.4 | 37.0 |
| Upper Mae Yuam 3 | 62 | 477 | 67.6 | 4.1 | 13.0 |
| Nam Mae Rit | 87 | 270 | 85.7 | 24.0 | 61.5 |
| Upper Mae Rit 1 | 66 | 407 | 19.4 | 10.3 | 42.5 |
| Upper Mae Rit 2 | | | | | |
| Original | 63 | 585 | 13.5 | 6.1 | 28.0 |
| Alternative A | 38 | 560 | 3.2 | 11.2 | 43.6 |
| Upper Mae Rit 3 | 64 | 490 | 15.8 | 10.4 | 42.7 |
| Nam Mae Ngao | 114 | 260 | 661.2 | 116.9 | 245.2 |
| Upper Mae Ngao | 80 | 340 | 43.2 | 9.1 | 33.2 |

## 1.4 Contents of the Investigation Works

The investigation works consisted of the three sectors; the engineering sector to judge the technical feasibility, the economic sector to evaluate the project economy and the irrigation sector to define the effects on the existing agriculture in the project area.

The following items were the subjects to be investigated for the Master Plan Study.

(1) Civil engineering investigations (topography, geology, hydrology and meteorology, site survey of main structures and construction materials, cost for similar projects, etc.)

(2) Electric power investigations (electric power demand, power system planning, transmission line, etc.)

(3) Irrigation investigation (irrigation facilities, irrigated agriculture, etc.)

(4) Other investigations (environment, transportation facilities, etc.)

(5) Data collection (including population, GDP, price index, tariff rates, etc.)

The Field Investigation Works of JICA Survey Team have been carried out four times for the above five items.

The outline of the individual field works were as follows.

(a) First Field Investigation Work

First Field Investigation works were carried out from July 8, 1985 to August 6, 1985.

During the field survey, JICA Survey Team held discussion with EGAT's engineers concerned for the implementation plan of the field investigations and the studies, based on "the Inception Report" submitted by JICA Survey Team.

The results of the discussion are concluded in "the Minutes of Meeting on Discussion of First Reconnaissance (July 1985)".

Further, the reconnaissance survey for the project sites including the three main projects; Nam Mae Ngao, Nam Mae Rit and Upper Mae Yuam 1, was carried out by EGAT engineers and the Team.

The participants of the both parties are listed in the participants list 1.

(b) Second Field Investigation Work

Second Field Investigation Works were carried out from October 28, 1985 to December 26, 1985 (one geologist stayed in the field up to January 10, 1986).

During JICA Survey Team staying in Thailand, the team presented "the Interim Report" including the Supplementary Report dated November 1985, and held discussion on the report.

The results of the discussion were concluded in "the Second Minutes of Meeting for the Master Plan on the Nam Yuam River

Basin Hydroelectric Development Project, December 1985".

Following items were the remarkable points in the second field investigation works.

1) The projects to be studied on the second stage were selected as follows;

   Nam Mae Ngao
   Upper Mae Rit 2a
   Nam Mae Rit
   Upper Mae Yuam 1     (See the attached Table 5-14-2)

2) The locations, work quantities and specifications of the drilling and material investigation at the projects site have been decided.

   Some of the investigation works were being executed at the site.

3) The boring accessaries supplied by JICA were handed over to EGAT as shown in the list.

Addition to the above, EGAT engineers and the team conducted the site survey including the Lower Yuam Site studied already by JICA as the related project to the Master Plan.

The participants of the second field investigation works are listed in the participants list 2.

(c) Third Field Investigation Work

The third field investigation works were carried out by JICA Survey Team from 26th of June to 8th of July, 1986.

During the team staying in Thailand, the team presented and held discussion on the second stage study results and carried out the field survey works for the selected and related projects (Lower Yuam project) with EGAT's engineers.

The study results were generally accepted by EGAT and concluded in the third minutes of meeting. The details of the conclusion are described in "the third minutes of meeting, July 1986". The participants in the field are listed in the participant list 3.

Meanwhile, in the field investigation works, topographical mapping, drilling work with permeability test for geological survey and laboratory test of soil material for the selected sites were performed by EGAT.

As for the environmental impact coming up from the implementation of these projects, the study has been performed and reported by EGAT to the Master Plan Study.

Therefore, it should be noted that the environmental study described in the Chapter 11 "Environmental Problem" are the summary of the study for which the permission by EGAT to compile in this report has been given and which the team has considered to be appropriate.

(d) Fourth Field Investigation Work

Fourth field investigation works were carried out by JICA survey team from 6th of December to 20th of December 1986. During the team staying in Thailand, the team presented and held discussion on the final draft of the mater plan study. The study results were fundamentally accepted by EGAT and concluded in "the fourth minutes of meeting, 19th of December, 1986. The participants are listed in the participant list 4.

## 1.5 Acknowledgement

The team wishes to express his sincere appreciation and thanks to EGAT and many other Thai officials concerned for their faithful and warm cooperation in conducting this study.

Participants List 1 (First investigation)

EGAT

| | Name | | Position |
|---|---|---|---|
| 1. | Mr. Sommart | Boonpiraks | Director, Project Planning and Investigation Department |
| 2. | Mr. Payak | Ratnarathorn | Chief, Water Resources Planning and Development Division |
| 3. | Mr. Prasit | Srisaichua | Assistant Chief, Water Resources Planning and Development Division (Team Leader) |
| 4. | Mr. Niwat | Patanasemakul | Head, Water Resources Development Section (Civil Engineer) |
| 5. | Mr. Peerawat | Pumthong | Engineer Class 1 (Water Resources Engineer) |
| 6. | Mr. Peradeth | Nidhinandana | Geologist Class 2 (Coordinator) |
| 7. | Mr. Chutha | Promchinavongs | Engineer Class 1 (Hydrologist) |
| 8. | Mr. Piyachat | Nithipaibool | Engineer Class 1 (Soil Engineer) |
| 9. | Mr. Punpong | Vivattananon | Geologist Class 1 (Geologist) |
| 10. | Mr. Amphon | Sutthibutra | Chief, Survey Division |
| 11. | Mr. Somchai | Kokkemhaeng | Head, Material Testing Section |
| 12. | Mr Junichi | Tani | Expert of JICA |

JICA Survey Team

| | | | |
|---|---|---|---|
| 1. | Mr. Yasuo | Takashima | Leader |
| 2. | Mr. Tetsuo | Nishigori | Assistant Leader |
| 3. | Mr. Yoshihiro | Nakazawa | Civil Engineer (Planning) |
| 4. | Mr. Senzo | Hakoshima | Civil Engineer (Cost Estimation) |
| 5. | Mr. Junya | Takimoto | Hydrologist |
| 6. | Mr. Kazuhisa | Takeda | Geologist |
| 7. | Mr. Makoto | Tanaka | Economist |

Participants List 2 (Second field investigation)

EGAT

| | | | |
|---|---|---|---|
| 1. | Mr. Sommart | Boonpiraks | Director, Hydro-Power Engineering Department |
| 2. | Mr. Wuthi | Poonudom | Assistant Director, Hydro-Power Engineering Department |
| 3. | Mr. Payak | Ratnarathorn | Chief, Water Resources Planning and Development Division |
| 4. | Mr. Prasit | Srisaichua | Assistant Chief, - ditto - |
| 5. | Mr. Niwat | Patanasemakul | Head, Water Resources Development Section |
| 6. | Mr. Songpan | Panvanich | Engineer |
| 7. | Mr. Peerawat | Pumthong | Engineer |
| 8. | Mr. Chamnan | Tanakorn | Assistant Chief, Survey Division |
| 9. | Mrs. Supawan | Klaipongpan | Head, Geology Section |
| 10. | Mr. Punpong | Vivatlananon | Geologist |
| 11. | Mr. Nopporn | Prapaitrakul | Head, Dam and Foundation Section |
| 12. | Mr. Nipon | Pienpucta | Head, Powerhouse and Structure Section |
| 13. | Mr. Manop | Manowatana | Head, Site Engineer |
| 14. | Mr. Chutha | Promchinavongs | Engineer |
| 15. | Mrs. Siriluck | Srivichit | Scientist |
| 16. | Dr. Virawan | Sombutsiri | Assistant Head, Environmental Evaluation Section |
| 17. | Mr. Prakob | Dhienhirunya | Assistant Chief, Power System Planning Division |
| 18. | Mr. Thawat | Pinta | Assistant Head, Transmission System Planning Section |
| 19. | Mr. Wiboon | Pongtepupathun | Engineer |
| 20. | Miss Sarinthip | | Engineer |
| 21. | Mr. Junichi | Tani | JICA expert |

JICA

| | | | |
|---|---|---|---|
| 1. | Mr. Yasuo | Takashima | Leader, JICA Survey Team |
| 2. | Mr. Tetsuo | Nishigori | Assistant Leader |
| 3. | Mr. Akiyoshi | Noda | Irrigation Engineer |
| 4. | Mr. Yoshihiro | Nakazawa | Civil Engineer |
| 5. | Mr. Koichi | Tanaka | Civil Engineer |
| 6. | Mr. Hiromichi | Somukawa | Geologist |
| 7. | Mr. Seiji | Oda | System Engineer |

Participants List 3 (Third field investigation)

EGAT

| | | | |
|---|---|---|---|
| 1. | Mr. Sommart | Boonpiraks | Director, Hydro-Power Engineering Department |
| 2. | Mr. Wuthi | Poonudom | Assistant Director, Hydro-Power Engineering Department |
| 3. | Mr. Payak | Ratnarathorn | Chief, Water Resources Planning and Development Division |
| 4. | Mr. Prasit | Srisaichua | Assistant Chief, Water Resources Planning and Development Division |
| 5. | Mr. Niwat | Patanasemakul | Head, Water Resources Development Section |
| 6. | Mr. Chokchai | Watcharasansap | Assistant Head, Water Resources Development section |
| 7. | Mr. Peerawat | Pumthong | Engineer |
| 8. | Mr. Peeradej | Nidhinandana | Geologist |
| 9. | Mr. Piew | chitrakorn | Geologist |
| 10. | Mr. Punpong | Vivatlananon | Geologist |
| 11. | Mr. Manop | Manowatana | Head, Site Engineer |
| 12. | Mr. Kitti | Naparaksvong | Chief, Meteorological and Hydrological Division |
| 13. | Mr. Chutha | Promchinavongs | Hydrologist |
| 14. | Mr. Junichi | Tani | JICA Expert |

JICA

| | | |
|---|---|---|
| 1. Mr. Yasuo | Takashima | Leader, JICA Survey Team |
| 2. Mr. Tetsuo | Nishigori | Assistant Leader |
| 3. Mr. Haruo | Suzuki | JICA Official |
| 4. Mr. Kiyoshi | Ishikawa | Geologist |

Participants List 4 (Fourth field investigation)

EGAT

| | | |
|---|---|---|
| 1. Mr. Swarng | Champa | Assistant General Manager-Hydro Power Development |
| 2. Mr. Sommart | Boonpiraks | Director, Hydro-Power Engineering Department |
| 3. Mr. Wuthi | Poonudom | Assistant Director, Hydro-Power Engineering Department |
| 4. Mr. Payak | Ratnarathorn | Chief, Water Resources Planning and Development Division |
| 5. Mr. Prasit | Srisaichua | Assistant Chief, Water Resources Planning and Development Division |
| 6. Mr. Niwat | Patanasemakul | Head, Water Resources Development Section |
| 7. Mr. Peerawat | Pumthong | Engineer Class 2 |
| 8. Mr. Peradeth | Nidhinandana | Geologist Class 2 |
| 9. Mr. Chamnan | Tanakorn | Assistant Chief, Survey Division |
| 10. Mr. Thongjier | Thong-Aun | Head, Applied Hydrology and Research Section |
| 11. Mrs. Supwawan | Klaipongpan | Assistant Chief, Geology and Soil Engineering Division |
| 12. Mr. Piew | Chitrakarn | Geologist |
| 13. Mr. Somchai | Kokkemhaeng | Head, Material Testing Section |
| 14. Mr. Piyachat | Nithipaibool | Engineer Class 1 |
| 15. Mr. Saman | Pongprapapan | Engineer Class 5 |

| | | | |
|---|---|---|---|
| 16. | Dr. Virawan | Sombutsiri | Assistant Head, Environmental Evaluation Section |
| 17. | Mrs. Siriluck | Srivichit | Scientist Class 1 |
| 18. | Miss Sopa | Wongratanakornkrai | Engineer Class 1 |
| 19. | Mrs. Kanya | Sunthrarak | Publication Relation Officer |
| 20. | Mr. Junichi | Tani | JICA Expert |

JICA

| | | | |
|---|---|---|---|
| 1. | Mr. Yasuo | Takashima | Leader, JICA Team |
| 2. | Mr. Tetsuo | Nishigori | Assistant Leader |
| 3. | Mr. Yoshihiro | Nakazawa | Civil Engineer |
| 4. | Mr. Koichi | Anada | JICA Official |

## Boring Accessories

| Description | Quantity |
|---|---|
| 1. Triple Core Barrel, 3 m (NMLC Size)<br>Set O.D. of Bit 75.3 mm<br>Set I.D. of Bit 51.9 mm<br>Set Reaming Shell O.C. of Bit 75.7 mm | 3 sets |
| 2. Triple Core Barrel, 1.5 m (NMLC Size)<br>The same as the above | 3 sets |
| 3. Diamond Core Bit, 20 cts.<br>Size 1/25 - 1/40 Hard Matrix<br>Grade AAA<br>Semi round Crown Design | 36 pieces |
| 4. Reaming Shell, 10 cts.<br>Size 1/15 - 1/20<br>Grade AA<br>Ring set type | 9 pieces |
| 5. Diamond Casing Shoe Bit, 16 cts.<br>Size 1/15 - 1/20<br>NW. Grade AA, Hard Matrix | 9 pieces |
| 6. Metal Casing Shoe Bit<br>NW. Tungsten | 18 pieces |
| 7. Water Swivel<br>Roller bearing type with drillrod adaptor NW, Heavy Duty | 3 pieces |
| 8. Core Spring (Locating Washer)<br>Spare part | 24 pieces |
| 9. Core Lifter Case<br>Spare part | 24 pieces |
| 10. NW. Casing 3 m | 20 pieces |
| 11. NW. Casing 1.5 m | 20 pieces |
| 12. NW. Rod 3 m | 50 pieces |
| 13. NW. Rod 1.5 m | 10 pieces |

# CHAPTER 2. LOAD FORECAST

# CHAPTER 2 LOAD FORECAST

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# CHAPTER 2. LOAD FORECAST

## 2.1 Load Forecast Review for Whole EGAT System

Electric power demand in the EGAT system has been increased at a surprising rate during the past 15 years. A peak power generation at 743 MW in 1970 has grown up to 3878 MW (5.2 times) in 1985 and an annual energy generation increased from 4095 GWh to 23357 GWh (5.7 times) during the same period. (see Table 2-1)

The average annual growth rate of the peak power and energy generation are therefore 11.6% and 12.3% respectively. Considering the fact that during this period the oil crises hit the world twice and the economic activities in many other countries in the world had been stagnated quite a long time, these growth rates are very dominant and reflect the viability of Thailand's economy.

Based on these actual growth records, the load forecast for the next 16 years (1986 - 2001) has been made by the Load Forecast Working Group in Thailand. (Table 2-1) According to this forecast the peak power generation in 2001 will be 10154 MW (i.e. 2.6 times that of 1985) and energy generation in the same year will reach 62780 GWh (i.e. 2.7 times that of 1985). The average growth rates correspond to 6.2% and 6.4% respectively. Although decreased a little, these growth rates imply that the economic activities in this country for the next 16 years will still go up as vigorously as it has been.

The annual load factor of the whole EGAT system was 62.47% in 1970. It rose up to 70.69% in 1979 and after that stays within a 67% - 71% band width. (see Table 2-1 & Fig. 2-1)

These show that a pattern of power consumption in this country, especially in the greater Bangkok area is approaching to that of a developed country.

However as the country as a whole, a potential power demand seems still great. The load factor for the next 16 years will not be improved so much. This is reflected in the load forecast that the factor will remain at around 67 - 71% level increasing slightly from 68.75% in 1985 to 70.58% in 2001. (see Table 2-1 & Fig. 2-1)

## 2.2 Load Forecast Review for Whole PEA's Service Area

PEA (Provincial Electricity Authority) supplies electric power to the whole country except Greater Bangkok area. The growth rate of PEA is much more than that of EGAT whole system. A power demand of 318 MW in 1973 was boosted to 1684 MW in 1984. (Table 2-2) This is in fact 5.1 times that of 1973 or an average 16.0% annual growth rate during these 11 years. The annual load factors also come up from 54.81% in 1973 to 55.25% in 1984.

In the past, many non-electrified rural areas were existed in Thailand, and only for very limitted areas were supplied power by isolated diesel power plants.

From the mid 70's, EGAT and PEA poured an especial effort to expand the power supply capabilities and to eliminate the non-electrified areas. As the results, almost 80% of the non-electrified villages had then been energized up to 1984.

The expansion program also included those areas which are nearer and surrounding the main demand centers as well as powering up the demand centers themselves.

All of these efforts have resulted in the miraculous growth rate as above described.

Standing on these achievements, the working group forecasts power demands for next 10 years (1985 - 1994) as shown in Table 2-2. The power and energy demand in 1994 will be 4123 MW and 21876 GWh or 2.4 times and 2.7 times those of 1984 respectively. The corresponding average growth rates are 9.3% and 10.3% annually. (See Fig. 2-1) Annual load factors will also go up from 55.25% in 1984 to 60.57% in 1994 which is a faster improvement than that of the whole EGAT system.

## 2.3 Load Forecast for Northern Region

According to the PEA's classification, Northern Region consists of 3 sub-regions, i.e. Northern Region I, Northern Region II and Northern Region III.

This area is almost the same region which is classified as Region 4 according to the EGAT definition, consisting of 16 provinces in the north and the northern part of the central areas.

The main load centers in the Northern Region are Chiang Mai, Nakhon Sawan, Chiang Rai, Phitsanulok, Phrae, etc. of which the biggest one is Chiang Mai, the second largest city in Thailand.
Since the Nam Yuam hydro power projects situate within this region, it is of especial necessity to study the power demand in the region. Actual records and forecast values by EGAT are shown in Table 2-3 and Fig. 2-2.

According to these information, power and energy demands in the Northern Region have soared up from 68.66 MW and 282.92 GWh in 1972 to 335.62 MW and 1350.04 GWh in 1984 or 4.9 times and 4.8 times respectively. These correspond to an average annual growth rates of 14.1% and 13.9% respectively which are almost comparable with PEA's whole service area as described in the foregoing section.

The annual load factor was fluctuated from 47.03% in 1972 to 45.93% in 1984. (Table 2-3 and Fig. 2-1)

Note that the absolute values themselves of these factors are still pretty lower than those of PEA's whole service area.

As for the forecast, the power and energy demands will grown up to the levels of 855 MW and 3700 GWh in 1994 respectively or the expected average annual growth rates of 9.8% and 10.6% for the following 10 years. (1984 - 1994).

At the same time, annual load factor will be raised from 45.93% in 1984 to 49.41% in 1994.
But the growth rates for both power and energy will gradually slow down to around 7% in 1994 and the annual load factor approaches 50%.

So far as we have reviewed, the forecast up to 1994 have been confirmed to be reasonable.

Now therefore basing upon these forecasts, we will extend them further by the simple extrapolation method which will be highly supported by judgement.

We will consider two scenarios, scenario 1 and scenario 2, differing one another in terms of the annual growth rates of energy demands as follows:

(i) Scenario 1

from 1995 to 1999, 7%

from 2000 to 2004, 6%

from 2005 to 2010, 5%

from 2011 to 2020, 4%

(ii) Scenario 2

from 1995 to 1999, 6%

from 2000 to 2004, 5%

from 2005 to 2010, 4%

from 2011 to 2020, 3%

The results of forecasts are shown in Table 2-4 and Table 2-5 and are plotted on Fig. 2-2.

Next step to be taken is to forecast the annual load factors. As we have already seen in the previous sections, it is a definite tendency that the annual load factors are improved if a system grows up and also the charactor of the demand become matured. (i.e. the pattern of power consumption approaches towards that of a developed country).

On Fig. 2-3, the recorded annual load factors and those estimated by the Working Group (taken from Table 2-2 and Table 2-3) are plotted.

A regression line,

$$Y = b_0 + b_1X \quad \cdots\cdots\cdots \quad (1)$$

Where

Y: annual load factor (%)

X: fiscal year

$b_0$, $b_1$ : parameters

was assumed and the values of $b_0$ and $b_1$,

$$b_0 = -531.638 \text{ and } b_1 = 0.291544$$

were obtained by using the least square method. (see Table 2-6) The correlation coefficient obtained was 0.902.

Now by employing this regression line, the future values of annual load factors of Northern Region are estimated by substituting the annual energy demands in Table 2-4 and Table 2-5 into X.

The results are shown on the same tables and plotted on Fig. 2-2 too. According to this estimation, the annual load factors of the Northern Region will be 50% in 1995, 51.5% in 2000, 52.9% in 2005 and 54.4% in 2010, and 57.3% in 2020 in case of scenario 1.

The estimation of peak demand in the Northern Region is now possible by using the formula

$$\text{Peak demand} = \frac{\text{Annual energy demand}}{\text{Annual load factor x 8760}} \quad \text{..............} \quad (2)$$

Substituting the already obtained values of annual energy demands and annual load factors (in Table 2-4 and Table 2-5) into (2), Peak demands in the Northern Region were calculated as shown in Table 2-4 and Table 2-5 and plotted on Fig. 2-2.

According to these results, the power demands of the Northern Region will be 904 MW in 1995, 1221 MW in 2000, 1573 MW in 2005, 1935 MW in 2010 and 2719 MW in 2020 in case of scenario 1.

## 2.4 Main Power Supply Area of Nam Yuam Hydroelectric Projects

The proposed installed capacities of Nam Yuam hydropower plants, Nam Mae Ngao, Nam Mae Rit, Upper Mae Yuam, etc. will range from about 10 MW to 120 MW as will be studied in later chapters.

It is tentatively assumed that the first target year is 2000 and that at least two of the Nam Yuam hydroelectric projects will have been operated.

As we have studied in the previous sections, power demands in 2000 will be 9680 MW in the whole EGAT system and 1,220.5 MW in the Northern Region. (See Table 2-1 & Table 2-4)

Thus the proposed installed capacities of the Nam Yuam hydroelectric projects are very small if compared to the power demand of the whole EGAT system and even if they are compared with that of the Northern Region, they are only a fraction of it.

The Yuam river basin situates in the north-western part of Thailand, remotes about 700 km from Bangkok.

The electric power generated by the Nam Yuam hydroelectric projects will be transmitted to the Lamphun Substation over a 230 KV transmission line. The distance from the Yuam river basin to Lamphun is about 200 km and from Lamphun to Bangkok is about 500 km.

Since the Chiang Mai area is the biggest demand center in the Northern Region, it is most probable that the energy generated by the Nam Yuam hydroelectric projects will be absorbed in this region.

This supposition is also the most economical way with regard to the power flow because otherwise the power shall be transmmitted to the Bangkok area over 700 Km long transmission line.

The power demand in the greater Bangkok area will be supplied mainly by Bhumibol (535 MW), Sirikid (375 MW), Srinagrarind (360 MW) and Khao Laem (300 MW), all are situated nearer to the metropolitan area than the Nam Yuam hydroelectric projects. Thus in the following study, the Northern Region is set as the power supply area of the Nam Yuam hydroelectric projects.

Table 2–1 EGAT Total Generation Requirement

| Fiscal Year | Peak Generation | | Energy Generation | | Load Factor % |
|---|---|---|---|---|---|
| | MW | % Increase | GWh | % Increase | |
| | | | ACTUAL | | |
| 1970 | 743.35 | 0.00 | 4,095.32 | 0.00 | 62.47 |
| 1971 | 872.70 | 16.62 | 4,792.88 | 17.03 | 62.69 |
| 1972 | 1,023.80 | 17.89 | 5,711.16 | 19.16 | 63.37 |
| 1973 | 1,199.30 | 16.57 | 6,872.84 | 20.34 | 65.42 |
| 1974 | 1,256.30 | 4.75 | 7,258.62 | 5.61 | 65.96 |
| 1975 | 1,406.60 | 11.96 | 8,211.57 | 13.13 | 66.64 |
| 1976 | 1,652.10 | 17.45 | 9,414.48 | 14.65 | 65.05 |
| 1977 | 1,873.40 | 13.40 | 10,950.62 | 16.32 | 66.73 |
| 1978 | 2,100.60 | 12.13 | 12,371.67 | 12.98 | 67.23 |
| 1979 | 2,255.00 | 7.35 | 13,964.56 | 12.88 | 70.69 |
| 1980 | 2,417.40 | 7.20 | 14,753.73 | 5.65 | 69.67 |
| 1981 | 2,588.70 | 7.09 | 15,959.97 | 8.18 | 70.38 |
| 1982 | 2,838.00 | 9.63 | 16,881.95 | 5.78 | 67.91 |
| 1983 | 3,204.30 | 12.91 | 19,066.30 | 12.94 | 67.92 |
| 1984 | 3,547.30 | 10.70 | 21,066.44 | 10.49 | 67.79 |
| 1985 | 3,878.40 | 9.33 | 23,356.74 | 10.87 | 68.75 |
| | | | FORECAST | | |
| 1986 | 4,346.00 | 12.06 | 25,747.00 | 10.23 | 67.63 |
| 1987 | 4,764.00 | 9.62 | 28,261.00 | 9.76 | 67.72 |
| 1988 | 5,162.00 | 8.35 | 30,620.00 | 8.35 | 67.71 |
| 1989 | 5,500.00 | 6.55 | 32,975.00 | 7.69 | 68.44 |
| 1990 | 5,858.00 | 6.51 | 35,203.00 | 6.76 | 68.60 |
| 1991 | 6,199.00 | 5.82 | 37,349.00 | 6.10 | 68.78 |
| 1992 | 6,539.00 | 5.48 | 39,518.00 | 5.81 | 68.99 |
| 1993 | 6,881.00 | 5.23 | 41,728.00 | 5.59 | 69.23 |
| 1994 | 7,226.00 | 5.01 | 43,967.00 | 5.37 | 69.46 |
| 1995 | 7,594.00 | 5.09 | 46,306.00 | 5.32 | 69.61 |
| 1996 | 7,977.00 | 5.04 | 48,751.00 | 5.28 | 69.77 |
| 1997 | 8,376.00 | 5.00 | 51,308.00 | 5.25 | 69.93 |
| 1998 | 8,792.00 | 4.97 | 53,983.00 | 5.21 | 70.09 |
| 1999 | 9,227.00 | 4.95 | 56,782.00 | 5.18 | 70.25 |
| 2000 | 9,680.00 | 4.91 | 59,712.00 | 5.16 | 70.42 |
| 2001 | 10,154.00 | 4.90 | 62,780.00 | 5.14 | 70.58 |

Remark: Working Group Load Forecast
September, 1985

Table 2-2 PEA's Demand

| Fiscal Year | Peak Demand | | Energy Received from EGAT | | Annual Load Factor % |
|---|---|---|---|---|---|
| | MW | % Increase | GWh | % Increase | |
| | | | ACTUAL | | |
| 1973 | 328.00 | 15.78 | 1,574.80 | 27.47 | 54.81 |
| 1974 | 385.00 | 17.38 | 1,797.10 | 14.12 | 53.29 |
| 1975 | 455.50 | 18.31 | 2,124.60 | 18.22 | 53.25 |
| 1976 | 575.50 | 26.34 | 2,655.30 | 24.98 | 52.53 |
| 1977 | 681.80 | 18.47 | 3,314.70 | 24.83 | 55.50 |
| 1978 | 790.00 | 15.87 | 3,916.10 | 18.14 | 56.59 |
| 1979 | 889.30 | 12.57 | 4,542.20 | 15.99 | 58.31 |
| 1980 | 973.90 | 9.51 | 4,966.10 | 9.33 | 58.05 |
| 1981 | 1,115.36 | 14.53 | 5,569.22 | 12.14 | 57.00 |
| 1982 | 1,261.75 | 13.12 | 6,189.70 | 11.14 | 56.00 |
| 1983 | 1,493.38 | 18.36 | 7,287.34 | 17.73 | 55.71 |
| 1984 | 1,684.10 | 12.77 | 8,173.90 | 12.17 | 55.25 |
| | | | FORECAST | | |
| 1985 | 1,980.80 | 17.62 | 9,643.60 | 17.98 | 55.58 |
| 1986 | 2,228.50 | 12.51 | 11,037.10 | 14.45 | 56.54 |
| 1987 | 2,531.00 | 13.57 | 12,658.70 | 14.69 | 57.09 |
| 1988 | 2,811.30 | 11.07 | 14,115.70 | 11.51 | 57.16 |
| 1989 | 3,028.40 | 7.72 | 15,556.20 | 10.20 | 58.64 |
| 1990 | 3,265.50 | 7.83 | 16,874.50 | 8.47 | 58.99 |
| 1991 | 3,482.40 | 6.64 | 18,102.60 | 7.28 | 59.34 |
| 1992 | 3,695.00 | 6.10 | 19,337.60 | 6.82 | 59.58 |
| 1993 | 3,909.00 | 5.79 | 20,597.90 | 6.52 | 60.15 |
| 1994 | 4,123.00 | 5.47 | 21,876.00 | 6.20 | 60.57 |

Remark: FY.1977-1982 demand including Siam Metal Enterprises' demand.

Table 2–3 Region 4 Generation Requirement (EGAT)

| Fiscal Year | Peak Generation | | Energy Generation | | Load Factor |
|---|---|---|---|---|---|
| | MW | % Increase | GWh | % Increase | % |
| | | | Actual | | |
| 1972 | 68.66 | 0 | 282.92 | 0 | 47.03 |
| 73 | 74.96 | 9.18 | 333.59 | 17.9 | 50.8 |
| 74 | 82.44 | 9.98 | 358.62 | 7.5 | 49.66 |
| 75 | 94.13 | 14.18 | 397.92 | 10.96 | 48.26 |
| 76 | 121.77 | 29.36 | 481.54 | 21.01 | 45.14 |
| 77 | 155.56 | 27.75 | 616.71 | 28.07 | 45.26 |
| 78 | 176.56 | 13.5 | 719.20 | 16.62 | 46.5 |
| 79 | 185.19 | 4.89 | 735.76 | 2.30 | 45.35 |
| 1980 | 199.03 | 7.47 | 799.05 | 8.60 | 45.83 |
| 81 | 231.34 | 16.23 | 894.85 | 11.99 | 44.16 |
| 82 | 256.33 | 10.80 | 997.57 | 11.48 | 44.43 |
| 83 | 292.06 | 13.94 | 1,178.85 | 18.17 | 46.08 |
| 84 | 335.62 | 14.91 | 1,350.04 | 14.52 | 45.93 |
| | | | Forecast | | |
| 1985 | 416.51 | 24.1 | 1,713 | 26.89 | 46.96 |
| 86 | 466.56 | 12.02 | 1,930 | 12.67 | 47.24 |
| 87 | 514.47 | 10.27 | 2,172 | 12.54 | 48.21 |
| 88 | 557.30 | 8.33 | 2,363 | 8.79 | 48.41 |
| 89 | 601.91 | 8.0 | 2,565 | 8.55 | 48.64 |
| 90 | 647.61 | 7.59 | 2,772 | 8.07 | 48.86 |
| 91 | 696.95 | 7.62 | 2,998 | 8.15 | 49.1 |
| 92 | 747.06 | 7.19 | 3,230 | 7.74 | 49.35 |
| 93 | 799.53 | 7.02 | 3,474 | 7.55 | 49.6 |
| 94 | 854.74 | 6.91 | 3,700 | 6.51 | 49.41 |

Table 2–4 Load Forecast (1995–2020), Northern Region Scenario 1

| Year | Energy demand GWH | Energy demand Increase % | Annual load factor % | Peak demand MW | Peak demand Increase % |
|---|---|---|---|---|---|
| 1994 | 3,700 | | 49.41 | 854.74 | |
| 1995 | 3,959 | 7.0 | 49.99 | 904.06 | 5.8 |
| 96 | 4,236 | 7.0 | 50.28 | 961.74 | 6.4 |
| 97 | 4,533 | 7.0 | 50.58 | 1,023.06 | 6.4 |
| 98 | 4,850 | 7.0 | 50.87 | 1,088.37 | 6.4 |
| 99 | 5,189 | 7.0 | 51.16 | 1,157.84 | 6.4 |
| 2000 | 5,501 | 6.0 | 51.45 | 1,220.54 | 5.4 |
| 01 | 5,831 | 6.0 | 51.74 | 1,286.51 | 5.4 |
| 02 | 6,181 | 6.0 | 52.03 | 1,356.13 | 5.4 |
| 03 | 6,552 | 6.0 | 52.32 | 1,429.56 | 5.4 |
| 04 | 6,945 | 6.0 | 52.62 | 1,506.67 | 5.4 |
| 05 | 7,292 | 5.0 | 52.91 | 1,573.28 | 4.4 |
| 06 | 7,656 | 5.0 | 53.20 | 1,642.81 | 4.4 |
| 07 | 8,039 | 5.0 | 53.49 | 1,715.64 | 4.4 |
| 08 | 8,441 | 5.0 | 53.78 | 1,791.72 | 4.4 |
| 09 | 8,863 | 5.0 | 54.07 | 1,871.20 | 4.4 |
| 2010 | 9,213 | 4.0 | 54.37 | 1,935.41 | 3.4 |
| 11 | 9,587 | 4.0 | 54.66 | 2,002.21 | 3.5 |
| 12 | 9,970 | 4.0 | 54.95 | 2,071.21 | 3.4 |
| 13 | 10,369 | 4.0 | 55.24 | 2,142.79 | 3.5 |
| 14 | 10,784 | 4.0 | 55.53 | 2,216.91 | 3.5 |
| 15 | 11,215 | 4.0 | 55.82 | 2,293.53 | 3.5 |
| 16 | 11,664 | 4.0 | 56.11 | 2,373.03 | 3.5 |
| 17 | 12,130 | 4.0 | 56.41 | 2,454.71 | 3.4 |
| 18 | 12,615 | 4.0 | 56.70 | 2,539.80 | 3.5 |
| 19 | 13,120 | 4.0 | 56.99 | 2,628.03 | 3.5 |
| 2020 | 13,645 | 4.0 | 57.28 | 2,719.36 | 3.5 |

Note: Annual load factor is estimated by the model

$$LF = -531.638 + 0.291544 \cdot Year$$

see. Table 2-6

Table 2-5 Load Forecast (1995-2020), Northern Region Scenario 2

| Year | Energy demand | | Annual load factor % | Peak demand | |
|---|---|---|---|---|---|
| | GWH | Increase % | | MW | Increase % |
| 1994 | 3,700 | | 49.41 | 854.74 | |
| 1995 | 3,922 | 6.0 | 49.99 | 895.61 | 4.8 |
| 96 | 4,157 | 6.0 | 50.28 | 943.80 | 5.4 |
| 97 | 4,407 | 6.0 | 50.58 | 994.63 | 5.4 |
| 98 | 4,671 | 6.0 | 50.87 | 1,048.20 | 5.4 |
| 99 | 4,951 | 6.0 | 51.16 | 1,104.74 | 5.4 |
| 2000 | 5,199 | 5.0 | 51.45 | 1,153.53 | 4.4 |
| 01 | 5,459 | 5.0 | 51.74 | 1,204.43 | 4.4 |
| 02 | 5,732 | 5.0 | 52.03 | 1,257.62 | 4.4 |
| 03 | 6,018 | 5.0 | 52.32 | 1,313.05 | 4.4 |
| 04 | 6,319 | 5.0 | 52.62 | 1,370.86 | 4.4 |
| 05 | 6,572 | 4.0 | 52.91 | 1,417.93 | 3.4 |
| 06 | 6,835 | 4.0 | 53.20 | 1,466.64 | 3.4 |
| 07 | 7,108 | 4.0 | 53.49 | 1,516.95 | 3.4 |
| 08 | 7,393 | 4.0 | 53.78 | 1,569.26 | 3.4 |
| 09 | 7,689 | 4.0 | 54.07 | 1,623.34 | 3.4 |
| 2010 | 7,919 | 3.0 | 54.37 | 1,662.67 | 2.4 |
| 11 | 8,157 | 3.0 | 54.66 | 1,703.56 | 2.5 |
| 12 | 8,401 | 3.0 | 54.95 | 1,745.26 | 2.4 |
| 13 | 8,654 | 3.0 | 55.24 | 1,788.38 | 2.5 |
| 14 | 8,913 | 3.0 | 55.53 | 1,832.28 | 2.5 |
| 15 | 9,181 | 3.0 | 55.82 | 1,877.57 | 2.5 |
| 16 | 9,456 | 3.0 | 56.11 | 1,923.81 | 2.5 |
| 17 | 9,740 | 3.0 | 56.41 | 1,971.06 | 2.5 |
| 18 | 10,032 | 3.0 | 56.70 | 2,019.76 | 2.5 |
| 19 | 10,333 | 3.0 | 56.99 | 2,069.78 | 2.5 |
| 2020 | 10,643 | 3.0 | 57.28 | 2,121.08 | 2.5 |

Note: Annual load factor is estimated by the model

$$LF = -531.638 + 0.291544 \cdot Year$$

see. Table 2-6

Table 2–6 Regression of Annual Load Factors of Northern Region on Years

| Year X | L.F. Y |
|---|---|
| **Actual** | |
| 1976 | 45.14 |
| 77 | 45.26 |
| 78 | 46.50 |
| 79 | 45.35 |
| 80 | 45.83 |
| 81 | 44.16 |
| 82 | 44.43 |
| 83 | 46.08 |
| 84 | 45.93 |
| **Forecast** | |
| 1985 | 46.96 |
| 86 | 47.24 |
| 87 | 48.21 |
| 88 | 48.41 |
| 89 | 48.64 |
| 90 | 48.86 |
| 91 | 49.10 |
| 92 | 49.35 |
| 93 | 49.60 |
| 94 | 49.41 |

Regression

Model:
Y= b0+b1×X

Coeffs of Normal
Equations:

A11 = 19
A12= 37715
B1 = 894.46
A21 = 37715
A22= 74864845
B2 = 1775669.28

Solution

b0 = -531.63769
b1 = .29154383

Error

Err1 = .0005615
Err2= 1.1146

Correlation
Coefficient

R2=
.813725704214
Corr. Coeff.=
.902067461027

Obtained regression model:

$$LF = -531.638 + 0.291544 \cdot Year$$

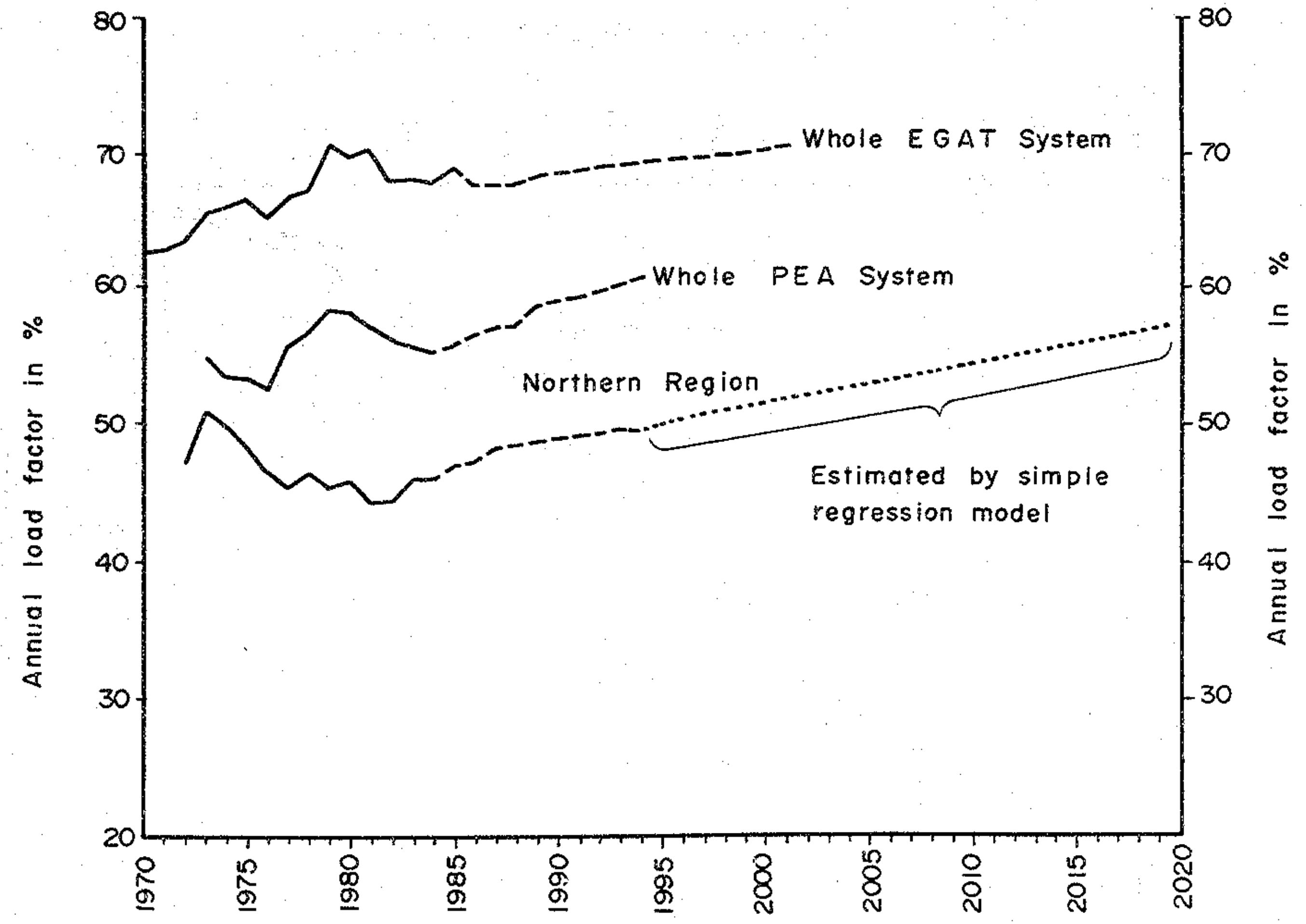



Fig. 2–1 Annual Load Factor

Source: E G A T: POWER DEVELOPMENT PLAN (1986-2001), Nov. 1985, Table 3-2, P.9, and
LOAD FORECAST WORKING GROUP: LOAD FORECAST, Sep. 1985, Table 2-4, P.8.

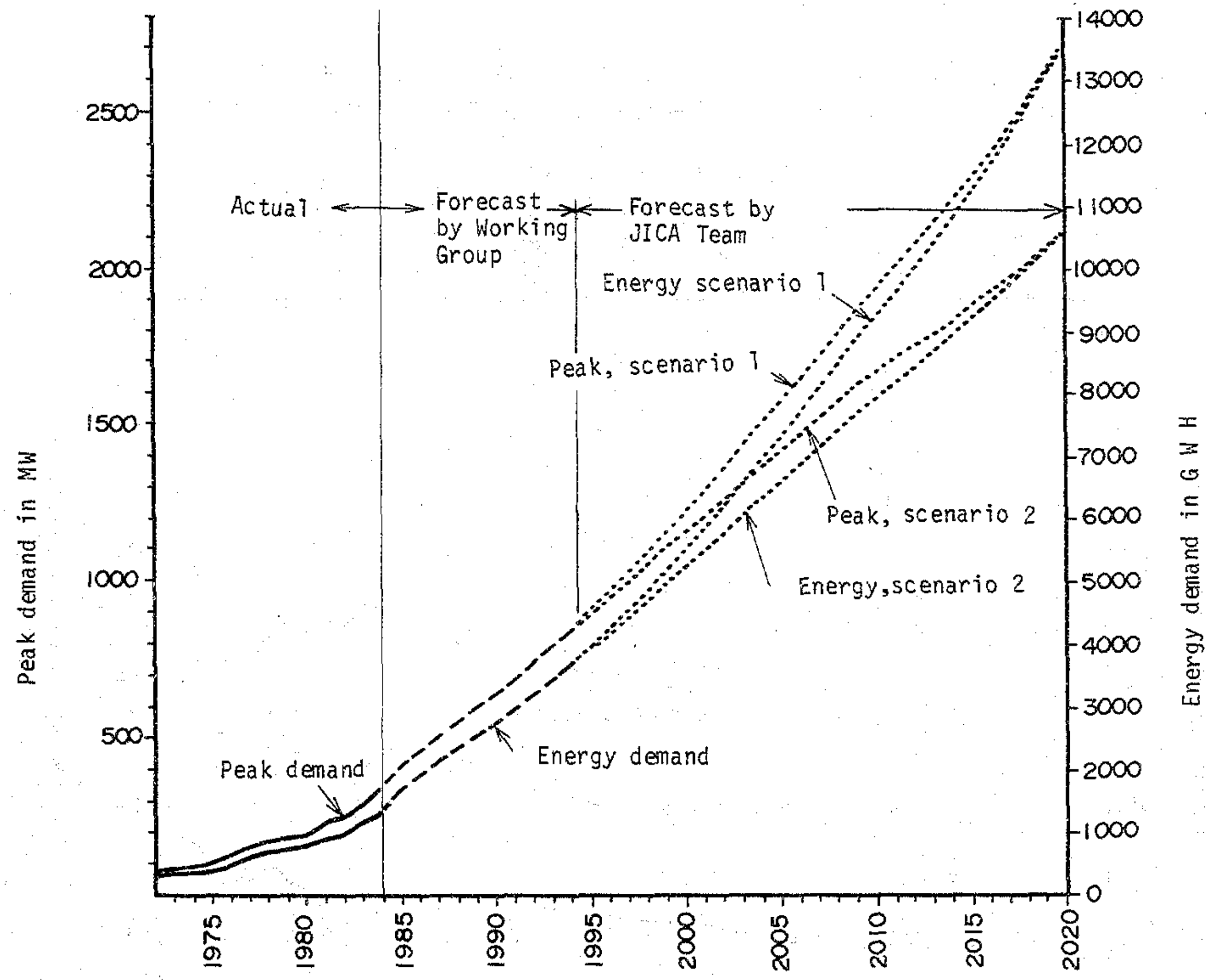



Fig. 2–2 Load Forecast, Northern Region

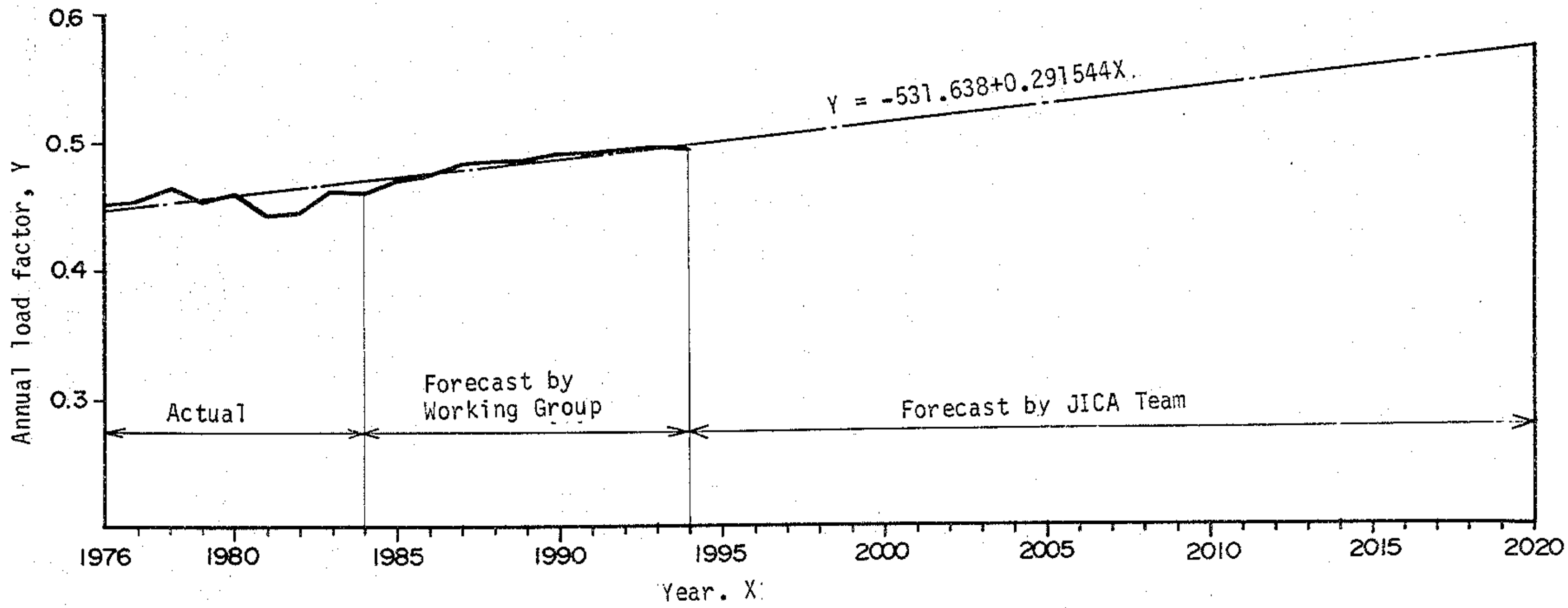



Fig. 2–3 Annual Load Factors, Actual and Estimated for Northern Region

## 2.5 Daily Load Factors

The annual load factors and daily load factors of the whole EGAT system recorded from 1970 to 1985 are shown on Table 2-7 together with the peak demands and annual energy generations.

The annual load factors of Northern Region (EGAT-R4) are summarized on Table 2-8 and daily load factors of Northern Region (EGAT-R4) on Table 2-9. Four kinds of load factors, i.e. annual load factors and daily load factors of whole EGAT, annual load factors of Northern Region (EGAT-R4) and daily load factors of Northern Region (EGAT-R4) as above tabulated are plotted on the same graph as shown on Fig. 2-4.

Daily load curves and daily load duration curves of the peak demand days of the whole EGAT system from 1975 to 1985 are plotted on Fig. 2-5 through Fig. 2-15 and those of Northern Region (EGAT-R4) from 1979 through 1985 are shown on Fig. 2-16 through Fig. 2-21. Also, all the daily load curves of the Northern Region are superposed on the same graph as shown on Fig. 2-22.

It is interesting to see from this graph that the peak demands increased very rapidly year by year and the deviations between the maximum and minimum demands within the same days were also increased conspicuously.

This tendency of the Northern Region is rather exceptional because, in general, as a system grow or become matured, a value of load factor goes up, but the contrary tendency has occurred in this region.

One of the reasons for this situation is that EGAT and PEA have accelerated power expansion programs these years. As the results, not only formerly non-electrified areas but also already electrified areas have been strengthened or expansioned and the latent demands sharply come true.

As can be seen from Fig. 2-22, the rates of demand increases in the early morning and in the evening peak hours are greater than those in the off-peak hours.

However, since the accelerated program is expected to complete by 1986, the shapes of the load curves and load duration curves after 1987 will gradually be improved toward the matured ones.

As for the whole EGAT system, as we have seen on Fig. 2-4, the annual load factors and daily load factors are approximately paralleled with each other. Also, the annual load factors of the Northern Region is paralleled with that of the whole EGAT system.

From these findings, it will be admissible to assume that the daily load factors of the Northern Region will be paralleled with the annual load factors of this region in future.

Basing upon this assumption, the values of the daily load factors of the region are estimated as follows:

i) the values in 1986 are 61.88% which is the same level as 1985 (i.e. assumed to remain at the same level as 1985 due to the effects of the accelerated electrification projects.)

ii) the values after 1987 go up parallel with those of the annual load factors of Northern Region.

The estimated results are shown on Table 2-10 which says that the daily load factors will be 67.3% in 1995, 68.8% in 2000, 70.2% in 2005, 71.7% in 2010, 73.1% in 2015 and 74.6% in 2020 respectively.

Table 2-7 Relation between Annual and Daily Load Factors EGAT Whole System (1970-1985)

| | * Annual LF % | Daily LF (Peak Day) % | Date of Peak Day | Annual Energy Generation GWH | Peak Demand MW |
|---|---|---|---|---|---|
| 1970 | 62.5 | 75.0 | Sep. 24, 70 | 4,095.32 | 748.35 |
| 1971 | 62.7 | 70.5 | Sep. 29, 71 | 4,792.88 | 872.70 |
| 1972 | 63.4 | 74.4 | Sep. 14, 72 | 5,711.16 | 1,028.80 |
| 1973 | 65.4 | 75.9 | Sep. 6, 73 | 6,872.84 | 1,199.30 |
| 1974 | 66.0 | 77.7 | Sep. 6, 74 | 7,258.62 | 1,256.30 |
| 1975 | 66.0 | 75.4 | Sep. 24, 75 | 8,211.57 | 1,406.60 |
| 1976 | 61.1 | 76.0 | Sep. 21, 76 | 9,414.48 | 1,652.10 |
| 1977 | 66.7 | 78.2 | Jun. 9, 77 | 10,950.62 | 1,873.40 |
| 1978 | 67.2 | 74.4 | Sep. 8, 78 | 12,371.67 | 2,100.60 |
| 1979 | 70.7 | 76.2 | Aug. 23, 79 | 13,964.55 | 2,255.0 |
| 1980 | 69.7 | 79.8 | Mar. 28, 80 | 14,753.73 | 2,417.4 |
| 1981 | 70.3 | 78.0 | Sep. 29, 81 | 15,959.97 | 2,588.7 |
| 1982 | 67.9 | 75.2 | Sep. 20, 82 | 16,881.94 | 2,838.0 |
| 1983 | 67.9 | 80.4 | May 18, 83 | 19,066.30 | 3,204.3 |
| 1984 | 67.8 | 78.75 | Mar. 28, 84 | 21,066.44 | 3,547.3 |
| 1985 | 68.8 | 79.0 | Mar. 29, 85 | 23,356.74 | 3,878.4 |

* Source: EGAT Power Development Plan (1985 - 2001)
Nov. 1985, Table 3-2, P. 9

Table 2-8 Annual Power Demand and Annual Load Factors of Northern Region (EGAT-R4)

| Fiscal year | Peak demand MW | Annual energy demand GWH | Annual load factor % | |
|---|---|---|---|---|
| | (Actual) | | | |
| 1972 | 68.66 | 282.92 | 47.03 | |
| 73 | 74.96 | 333.59 | 50.8 | |
| 74 | 82.44 | 358.62 | 49.66 | |
| 75 | 94.13 | 397.92 | 48.26 | |
| 76 | 121.77 | 481.54 | 45.14 | |
| 77 | 155.56 | 616.71 | 45.26 | |
| 78 | 176.56 | 719.20 | 46.5 | |
| 79 | 185.19 | 735.76 | 45.35 | |
| 80 | 199.03 | 799.05 | 45.83 | |
| 81 | 231.34 | 894.85 | 44.16 | |
| 82 | 256.33 | 997.57 | 44.43 | |
| 83 | 292.06 | 1,178.85 | 46.08 | |
| 84 | 335.62 | 1,350.04 | 45.93 | from Table 2-3 (1972–94) |
| | (Forecast) | | | |
| 85 | 416.51 | 1,713 | 46.96 | |
| 86 | 466.56 | 1,930 | 47.24 | |
| 87 | 514.47 | 2,172 | 48.21 | |
| 88 | 557.30 | 2,363 | 48.41 | |
| 89 | 601.91 | 2,565 | 48.64 | |
| 90 | 647.61 | 2,772 | 48.86 | |
| 91 | 696.95 | 2,998 | 49.1 | |
| 92 | 747.06 | 3,230 | 49.35 | |
| 93 | 799.53 | 3,474 | 49.6 | |
| 94 | 854.74 | 3,700 | 49.41 | |
| 95 | 904.06 | 3,959 | 49.99 | |
| 96 | 961.74 | 4,236 | 50.28 | |
| 97 | 1,023.06 | 4,533 | 50.58 | |
| 98 | 1,088.37 | 4,850 | 50.87 | |
| 99 | 1,157.84 | 5,189 | 51.16 | |
| 2000 | 1,220.54 | 5,501 | 51.45 | Forecast "scenario 1" from Table 2-4 (1995–2004) |
| 01 | 1,286.51 | 5,831 | 51.74 | |
| 02 | 1,356.13 | 6,181 | 52.03 | |
| 03 | 1,429.56 | 6,552 | 52.32 | |
| 04 | 1,506.67 | 6,945 | 52.62 | |

(Continued to next page)

Table 2–8 (Continued)

| Fiscal year | Peak demand MW | Annual energy demand GWH | Annual load factor % | |
|---|---|---|---|---|
| 2005 | 1,573.28 | 7,292 | 52.91 | |
| 06 | 1,642.81 | 7,656 | 53.20 | |
| 07 | 1,715.64 | 8,039 | 53.49 | |
| 08 | 1,791.72 | 8,441 | 53.78 | |
| 09 | 1,871.20 | 8,863 | 54.07 | |
| 10 | 1,935.41 | 9,218 | 54.37 | |
| 11 | 2,002.21 | 9,587 | 54.66 | |
| 12 | 2,071.21 | 9,970 | 54.95 | |
| 13 | 2,142.79 | 10,369 | 55.24 | |
| 14 | 2,216.91 | 10,784 | 55.53 | |
| 15 | 2,293.53 | 11,215 | 55.82 | |
| 16 | 2,373.03 | 11,664 | 56.11 | |
| 17 | 2,454.71 | 12,130 | 56.41 | |
| 18 | 2,539.80 | 12,615 | 56.70 | |
| 19 | 2,628.03 | 13,120 | 56.99 | |
| 2020 | 2,719.36 | 13,645 | 57.28 | |

Table 2-9 Demand of Northern Region (EGAT-R4) Coincident to Peak Load and Daily Load Factors

| Fiscal year | Peak demand MW | Energy supplied in peak day MWH | Daily L.F. % | Date of peak day | Substations for which date are not available |
|---|---|---|---|---|---|
| 1975 | 17.49 | 289 | 68.7 | 24 Sep. 1975 | LP1, TA1, PL1, CM1, CM2, MR, LN1, TE, ST |
| 76 | 24.55 | 396 | 67.3 | 21 Sep. 1976 | LP1, TA1, PL1, CM1, CM2, MR, LN1, TE, ST |
| 77 | 37.54 | 548 | 60.8 | 26 Sep. 1977 | PR, PY, LP1, PL1, CM1, CM2, MR, LN1, TE, ST |
| 78 | 56.15 | 808 | 60.0 | 6 Sep. 1978 | PR, PY, PL1, CM1, CM2, MR, LN1, TE, ST |
| 79 | 72.56 | 1,114.1 | 63.98 | 20 Apr. 1979 | PR, PY, LP1, PL1, CM1, LN1, ST |
| 80 | 96.89 | 1,590.7 | 68.41 | 13 Aug. 1980 | PY, LP1, PL1, TK2, TE, ST |
| 81 | NA | | | | |
| 82 | 187.13 | 2,806.2 | 62.48 | 12 May 1982 | PL1, CM1, TK2, LN1, TE |
| 83 | 223.62 | 3,242.7 | 60.42 | 6 Jul. 1983 | (UT), TK2, LN1, TE, ST |
| 84 | 266.60 | 3,621.9 | 56.61 | 17 Sep. 1984 | TK2, TE, ST |
| 85 | 367.80 | 5,462.2 | 61.88 | 29 Mar. 1985 | TK2, SK |

Source: "Demand of substation coincident to peak load in Northern Region (EGAT-R4)" which is one of the answers for JICA team's questionare to EGAT.

Note : Above data are missing several substations, in the region. Especially those from 1975 to 1978 are missing Chiang Mai 2 substation which is a major substation in Northern Region. Hence the Peak demands in this table do not coincide with those shown in Table 2-3.

Table 2-10 Daily Load Factors of Northern Region

| Fiscal year | Annual load factor[1) ] LFyear | Daily load factor[2)] LFday | LFday-LFyear | Fiscal year | Annual load factor LFyear | Daily load factor Lyday | LFday-LFyear |
|---|---|---|---|---|---|---|---|
| | % | % | % | | % | % | % |
| 1975 | 48.26 | 68.7 | 20.44 | 1985 | 46.96 | 61.88 | 14.92 |
| 76 | 45.14 | 67.3 | 22.16 | 86 | 47.24 | 61.88 | |
| 77 | 45.26 | 60.8 | 15.54 | 87 | 48.21 | 65.53 | |
| 78 | 46.5 | 60.0 | 13.50 | 88 | 48.41 | 65.73 | |
| 79 | 45.35 | 63.98 | 18.63 | 89 | 48.64 | 65.96 | |
| 80 | 45.83 | 68.41 | 22.58 | 90 | 48.86 | 66.18 | |
| 81 | 44.16 | NA | - | 91 | 49.10 | 66.42 | |
| 82 | 44.43 | 62.48 | 18.05 | 92 | 49.35 | 66.67 | |
| 83 | 46.08 | 60.42 | 14.34 | 93 | 49.60 | 66.92 | |
| 84 | 45.93 | 56.61 | 10.68 | 94 | 49.41 | 66.73 | |
| | | Total= | 155.92 | 95 | 49.99 | 67.31 | |
| | | Mean = | 17.32 | 96 | 50.28 | 67.60 | |
| | | | | 97 | 50.58 | 67.90 | |
| | | | | 98 | 50.87 | 68.19 | |
| | | | | 99 | 51.16 | 68.48 | |
| | | | | 2000 | 51.45 | 68.77 | |
| | | | | 01 | 51.74 | 69.06 | 17.32 (86–2020) |
| | | | | 02 | 52.03 | 69.35 | |
| | | | | 03 | 52.32 | 69.64 | |
| | | | | 04 | 52.62 | 69.94 | |
| | | | | 05 | 52.91 | 70.23 | |
| | | | | 06 | 53.20 | 70.52 | |
| | | | | 07 | 53.49 | 70.81 | |
| | | | | 08 | 53.78 | 71.10 | |
| | | | | 09 | 54.07 | 71.39 | |
| | | | | 10 | 54.37 | 71.69 | |
| | | | | 11 | 54.66 | 71.98 | |
| | | | | 12 | 54.95 | 72.27 | |
| | | | | 13 | 52.24 | 69.56 | |
| | | | | 14 | 55.53 | 72.85 | |
| | | | | 15 | 55.82 | 73.14 | |
| | | | | 16 | 56.11 | 73.43 | |
| | | | | 17 | 56.41 | 73.73 | |
| | | | | 18 | 56.70 | 74.02 | |
| | | | | 19 | 56.99 | 74.31 | |
| | | | | 2020 | 57.28 | 74.60 | |

1) Northern Region (EGAT-R4) from Table 8

2) Northern Region (EGAT-R4) from Table 9

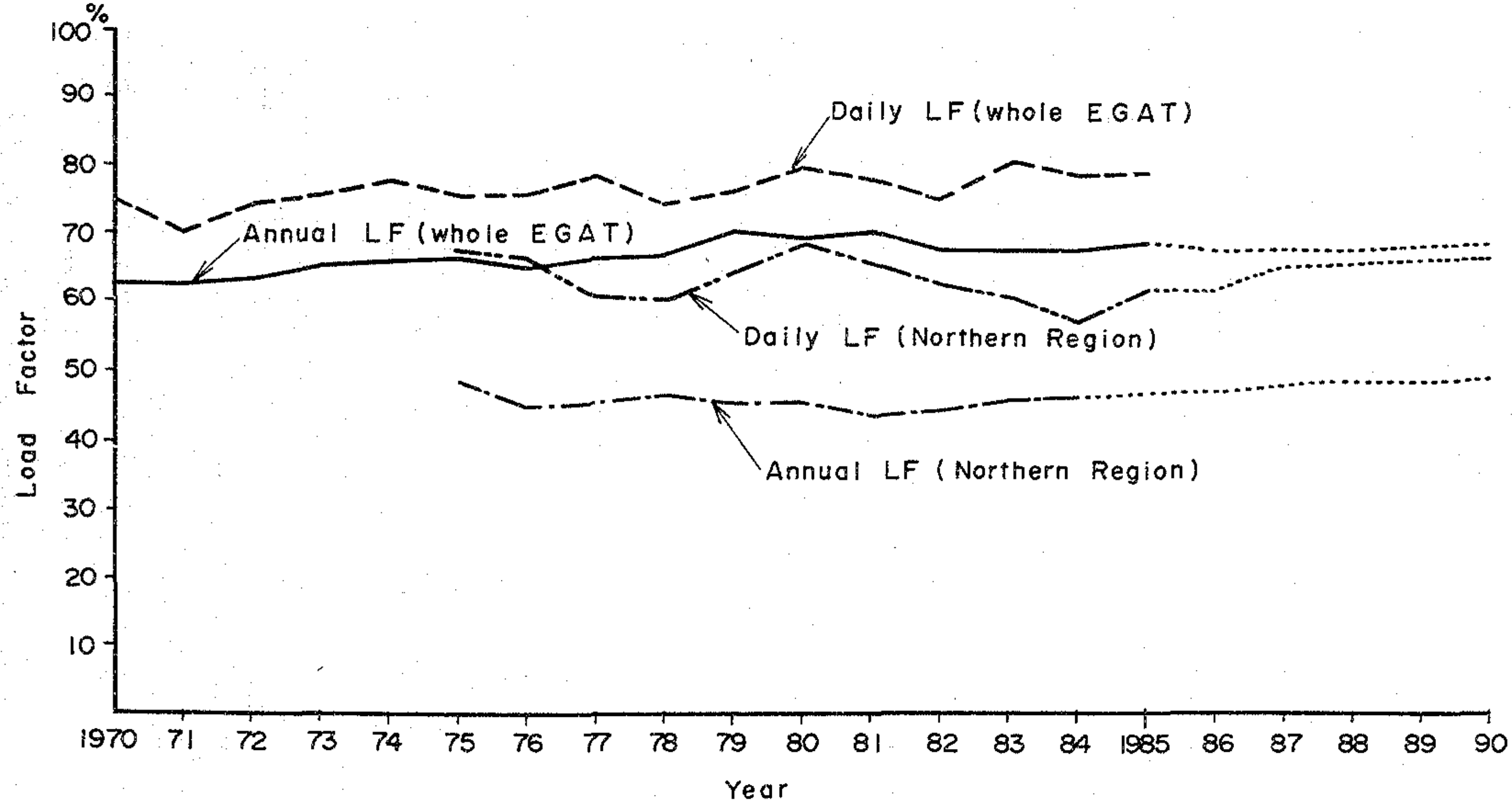
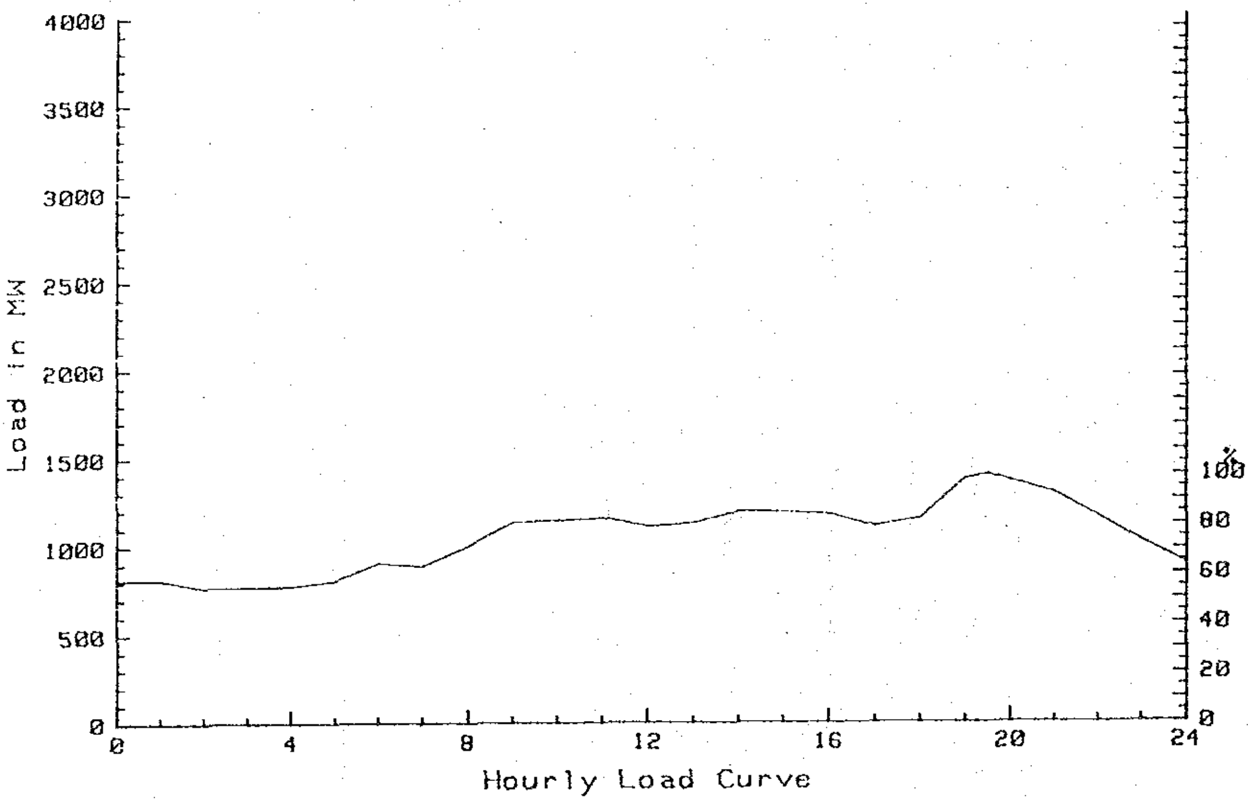



Fig. 2–4 Daily Load Factor vs. Annual Load Factor, Whole EGAT and Northern Region



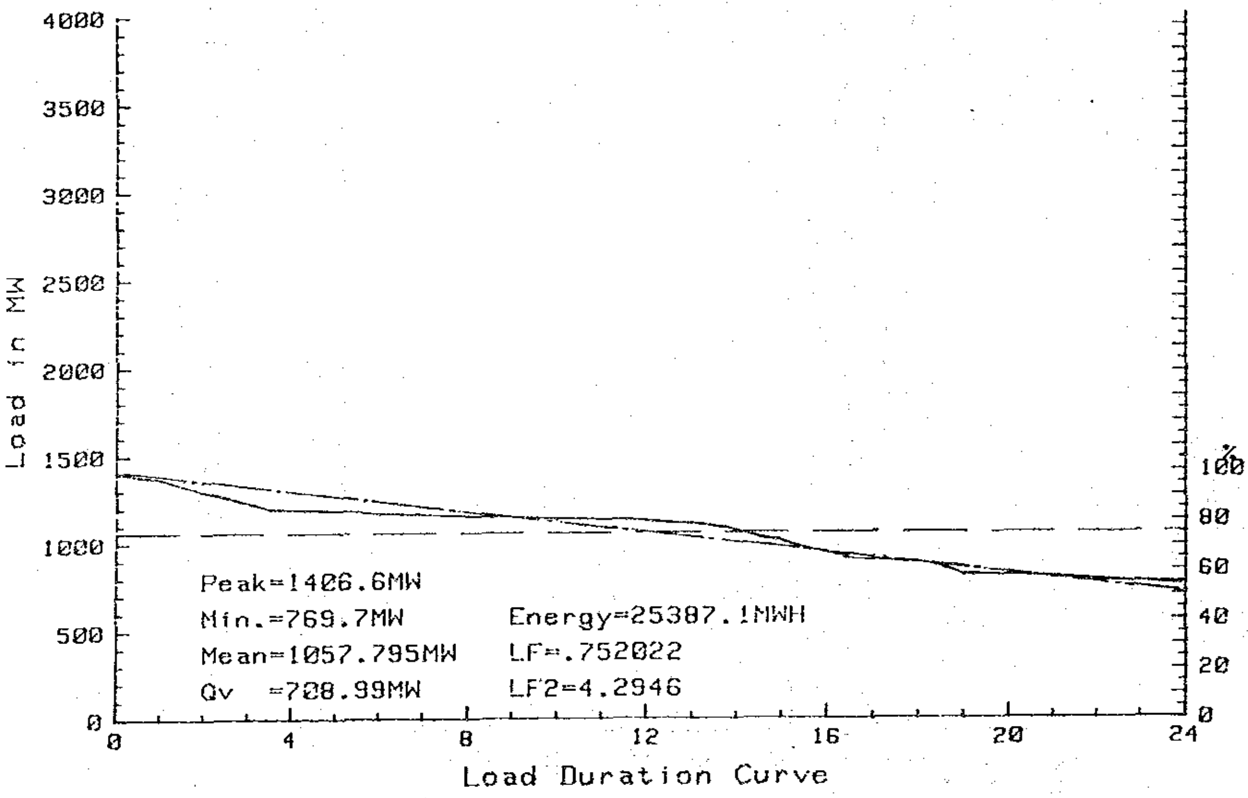
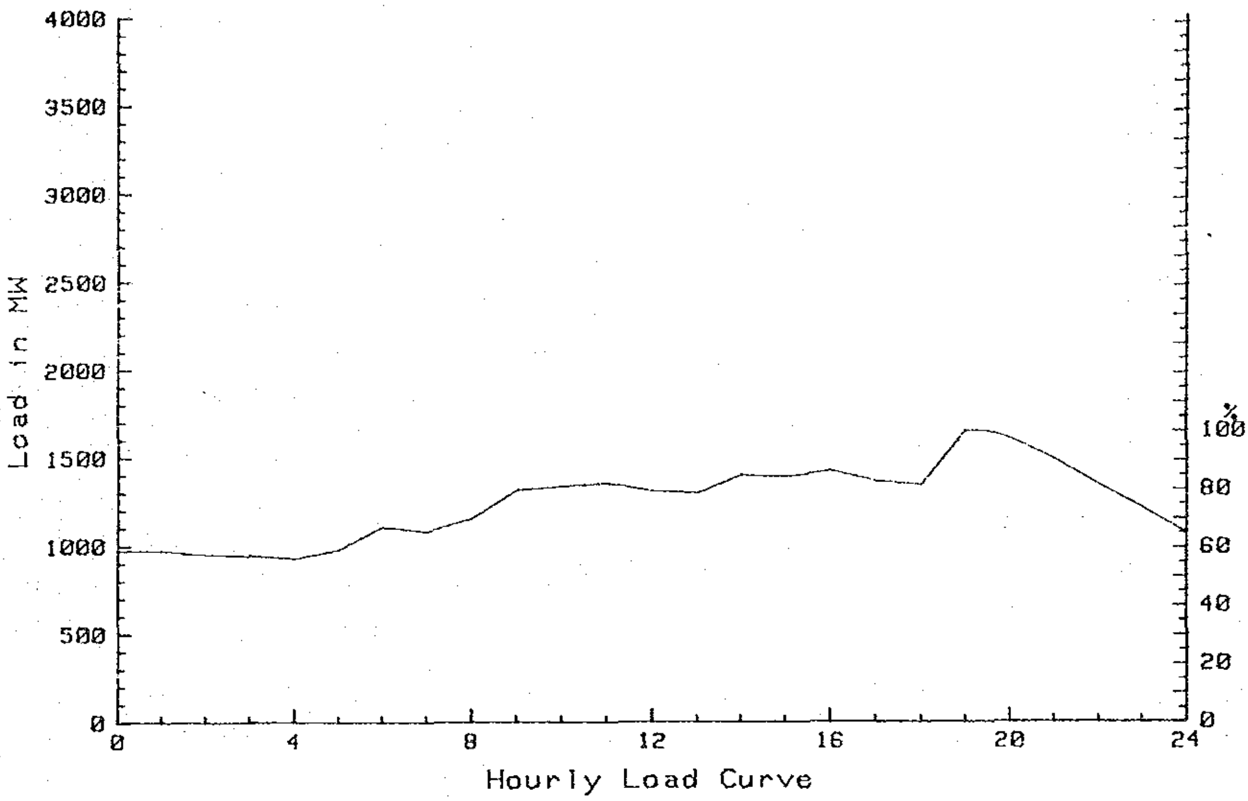




**Fig. 2–5 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 24 Sep., 1975**



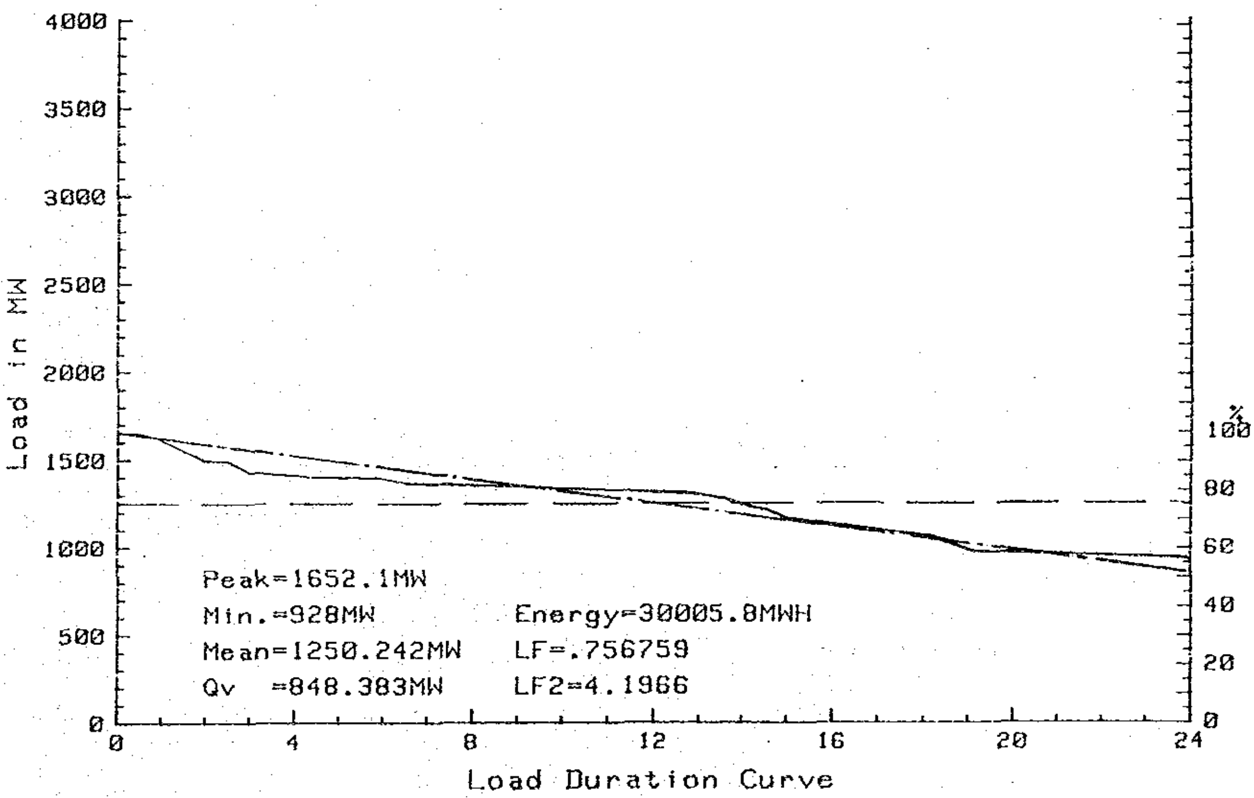




**Fig. 2–6 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 21 Sep., 1976**

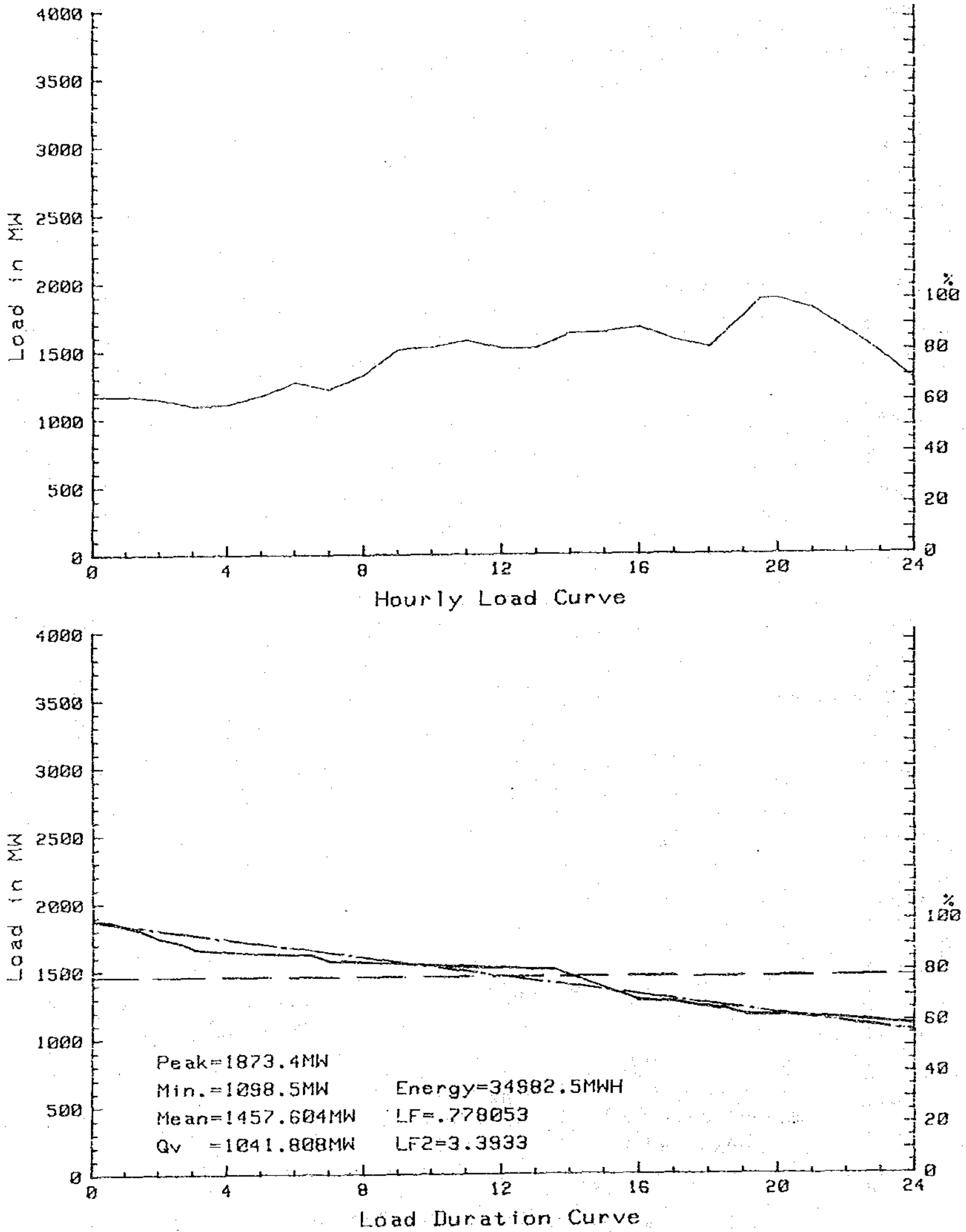



**Fig. 2–7 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 9 Jun., 1977**

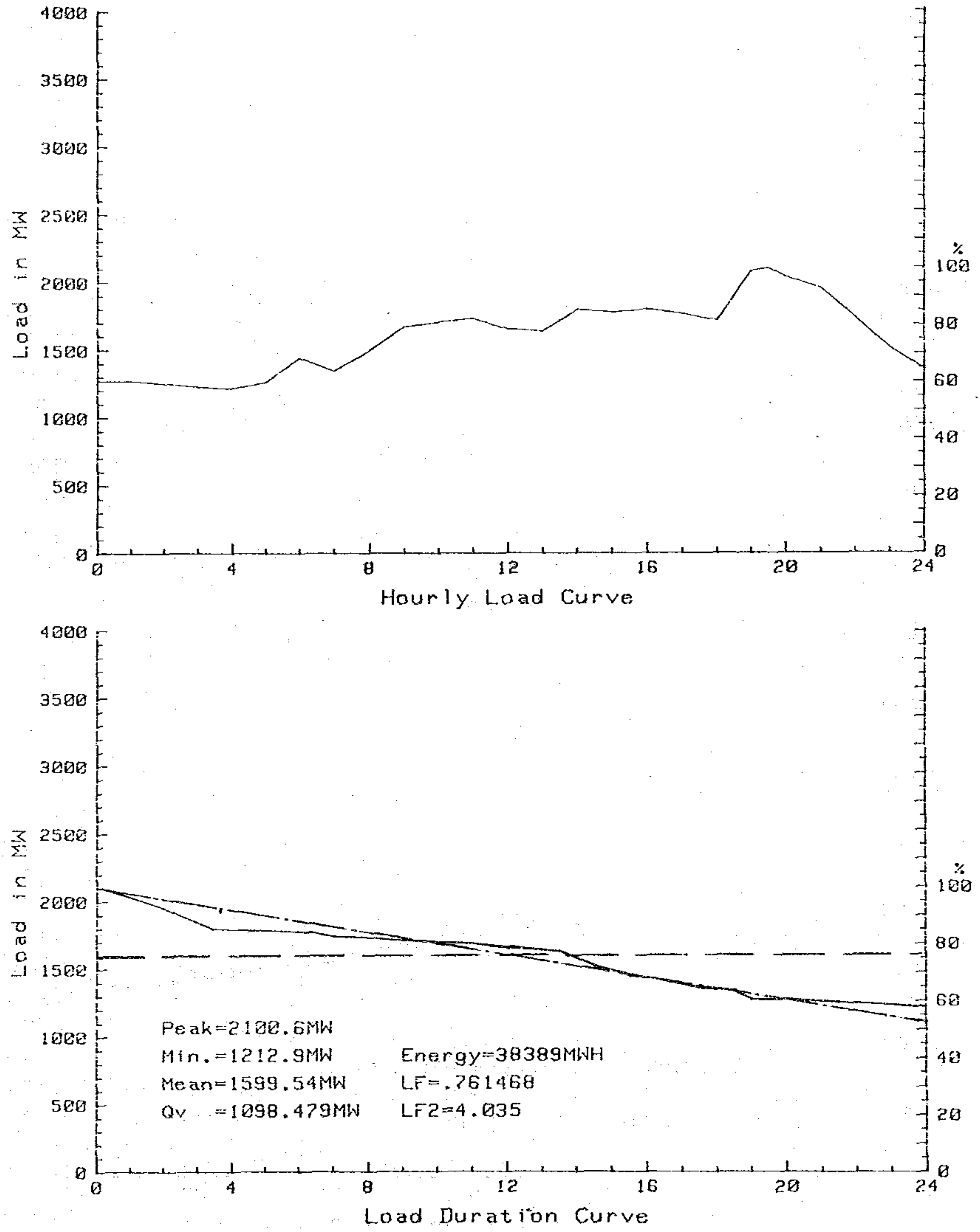



**Fig. 2–8 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 6 Sep., 1978**

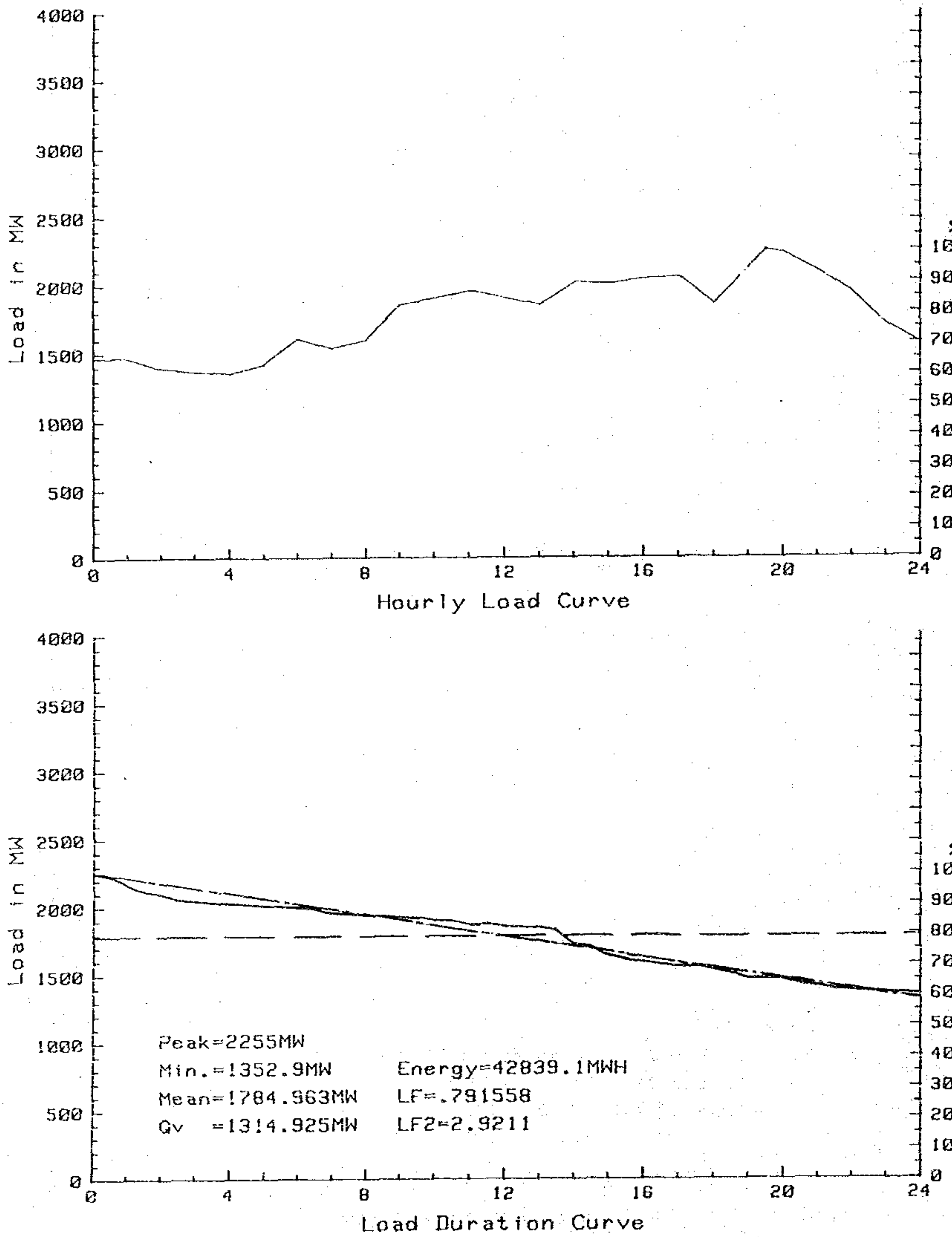
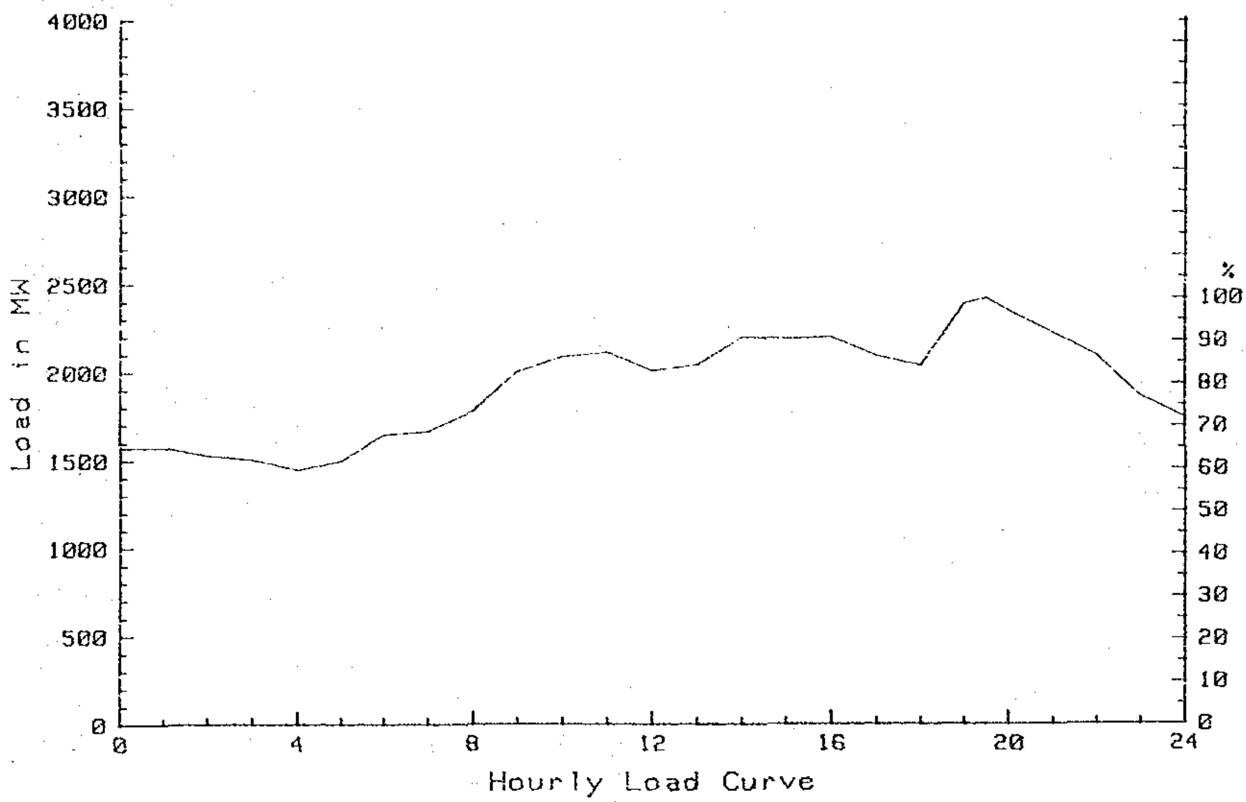



**Fig. 2–9 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 23 Aug., 1979**



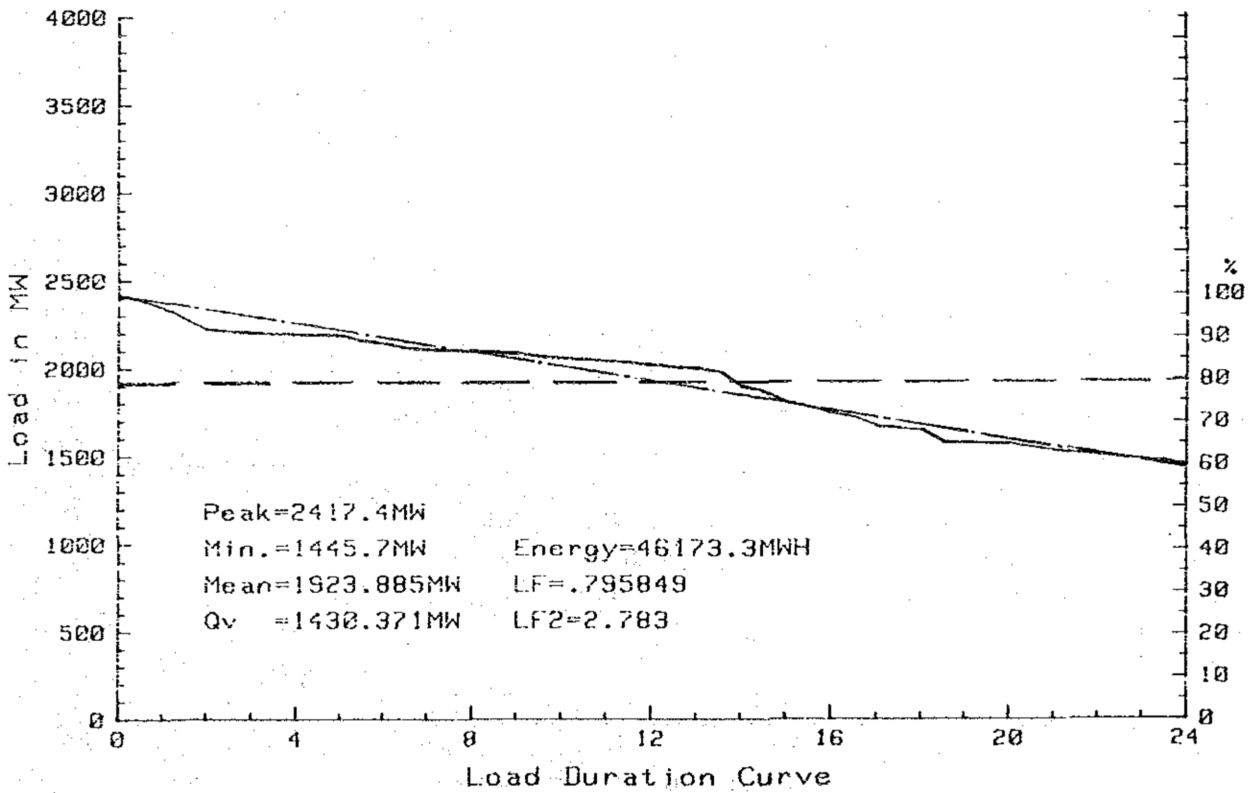




**Fig. 2–10 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 28 Mar., 1980**

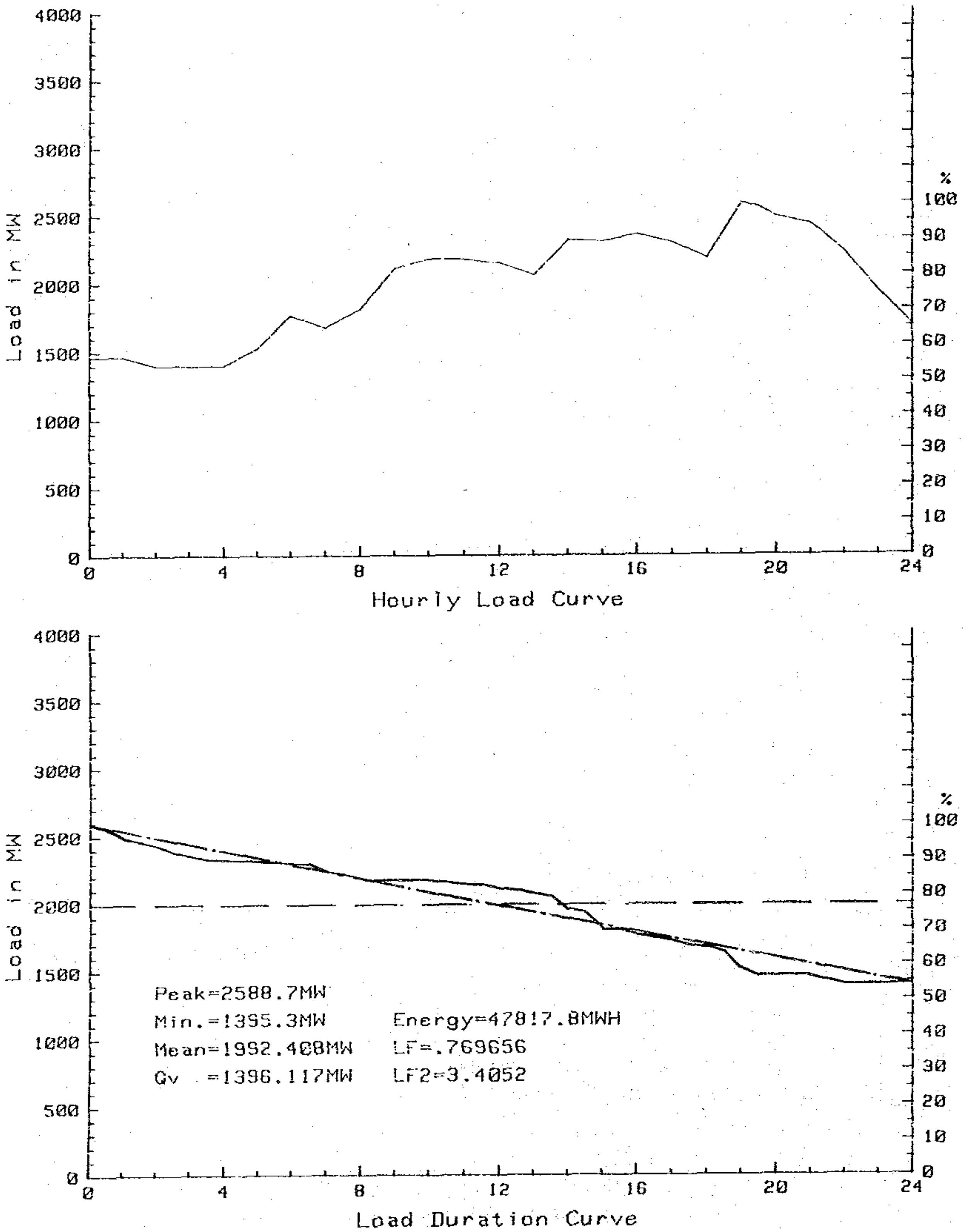



**Fig. 2–11 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 29 Sep., 1981**

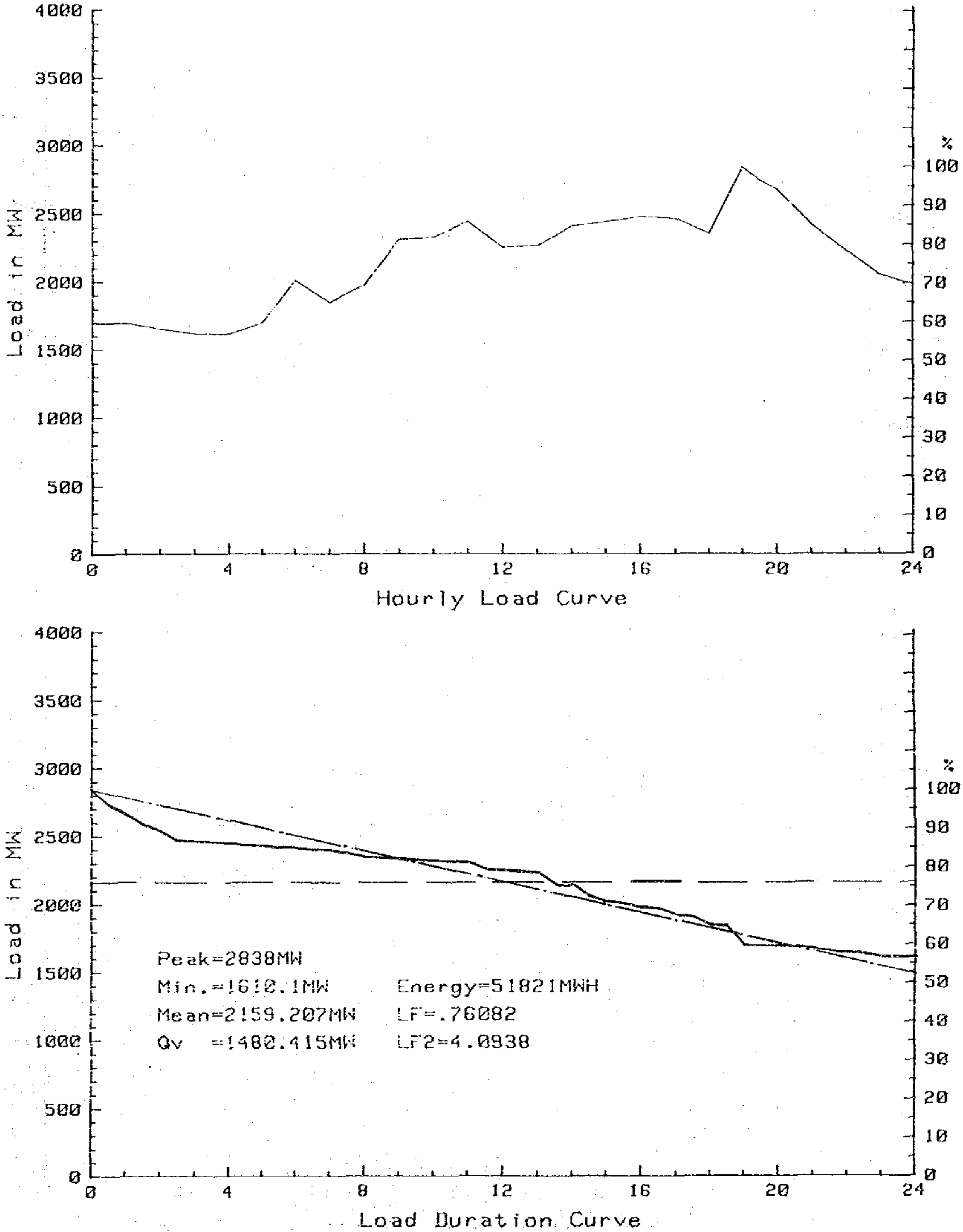
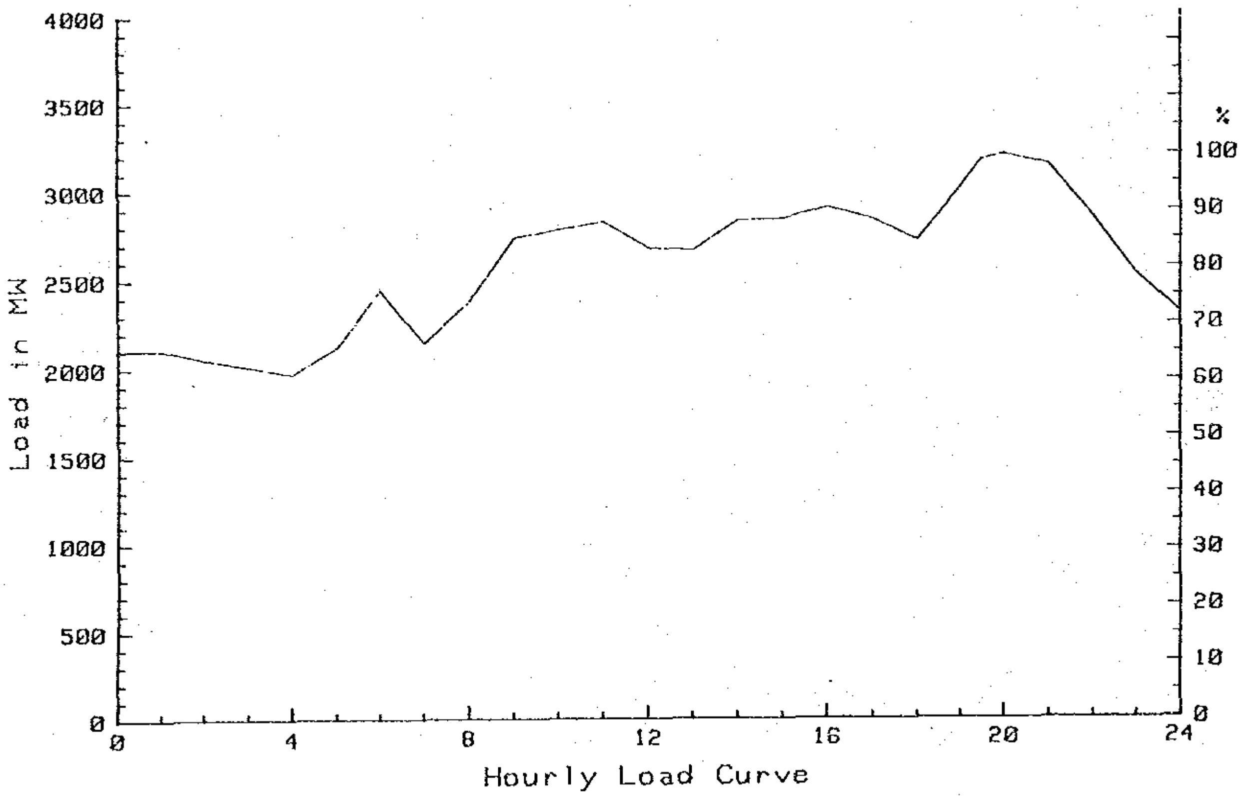



**Fig. 2–12 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 20 Sep., 1982**



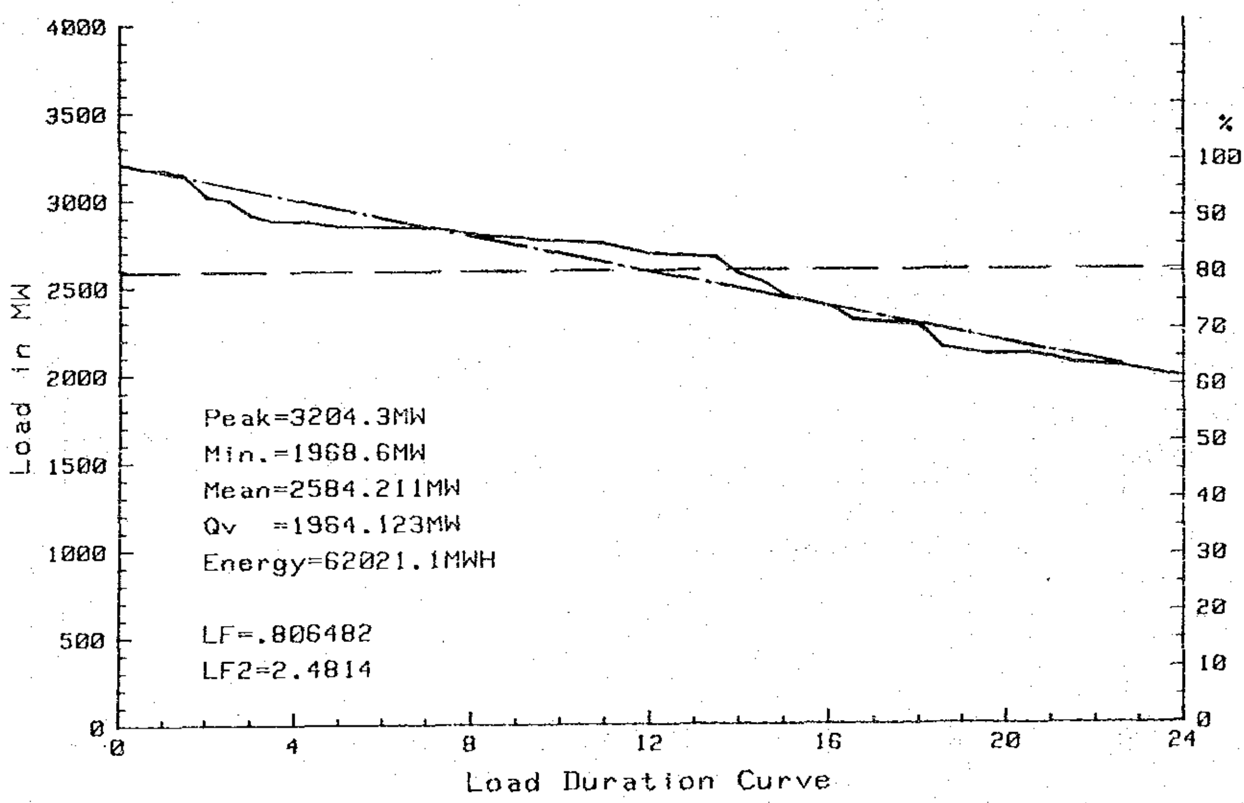
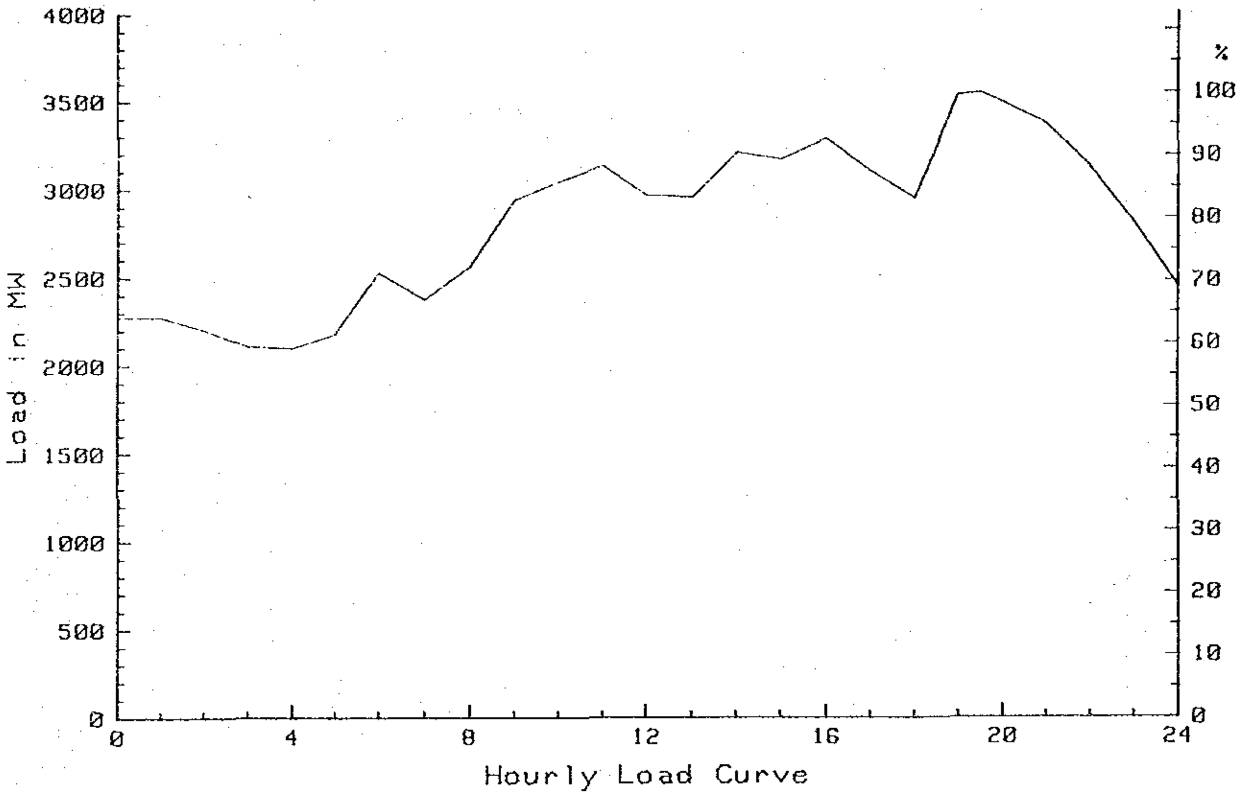




**Fig. 2–13 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 19 May, 1983**



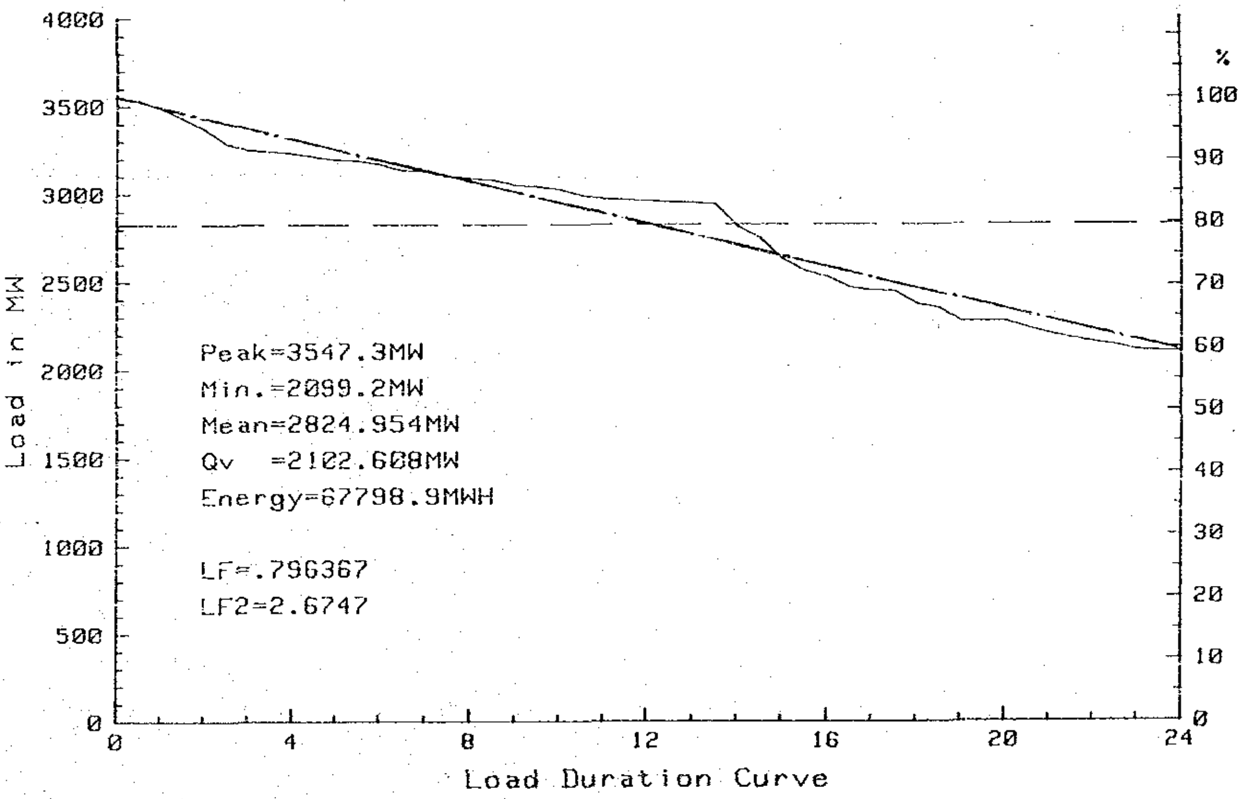




**Fig. 2–14 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 28 May, 1984**

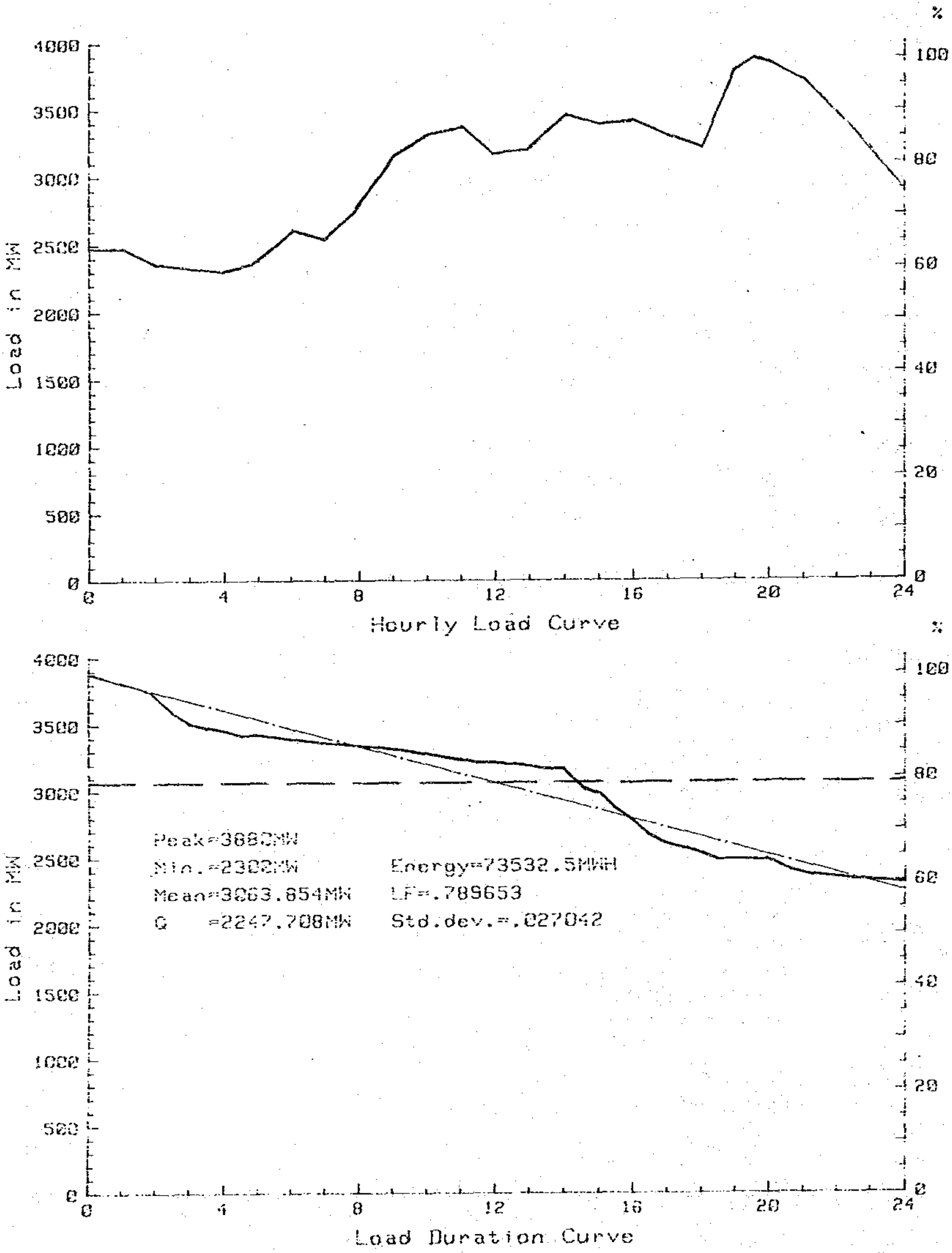
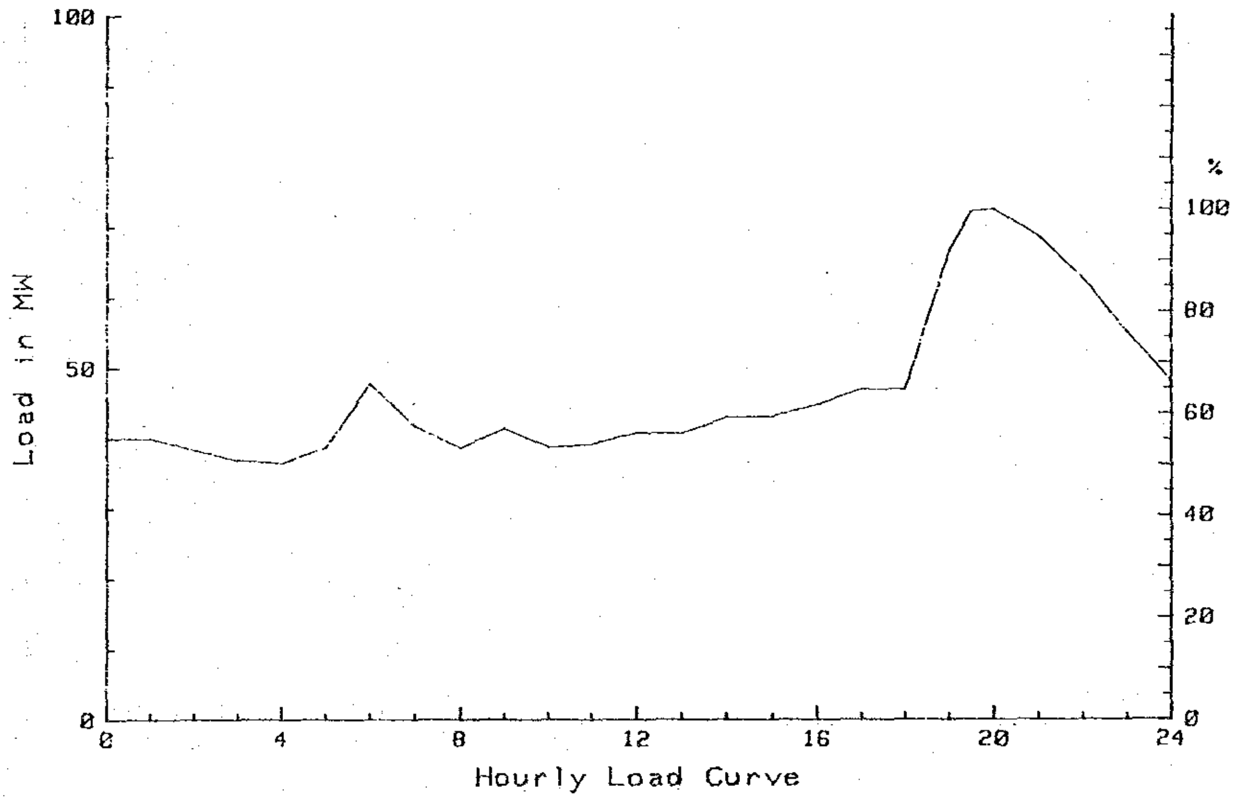



**Fig. 2–15 Hourly Load Curve and Load Duration Curve**
**EGAT (whole) 29 Mar., 1985**



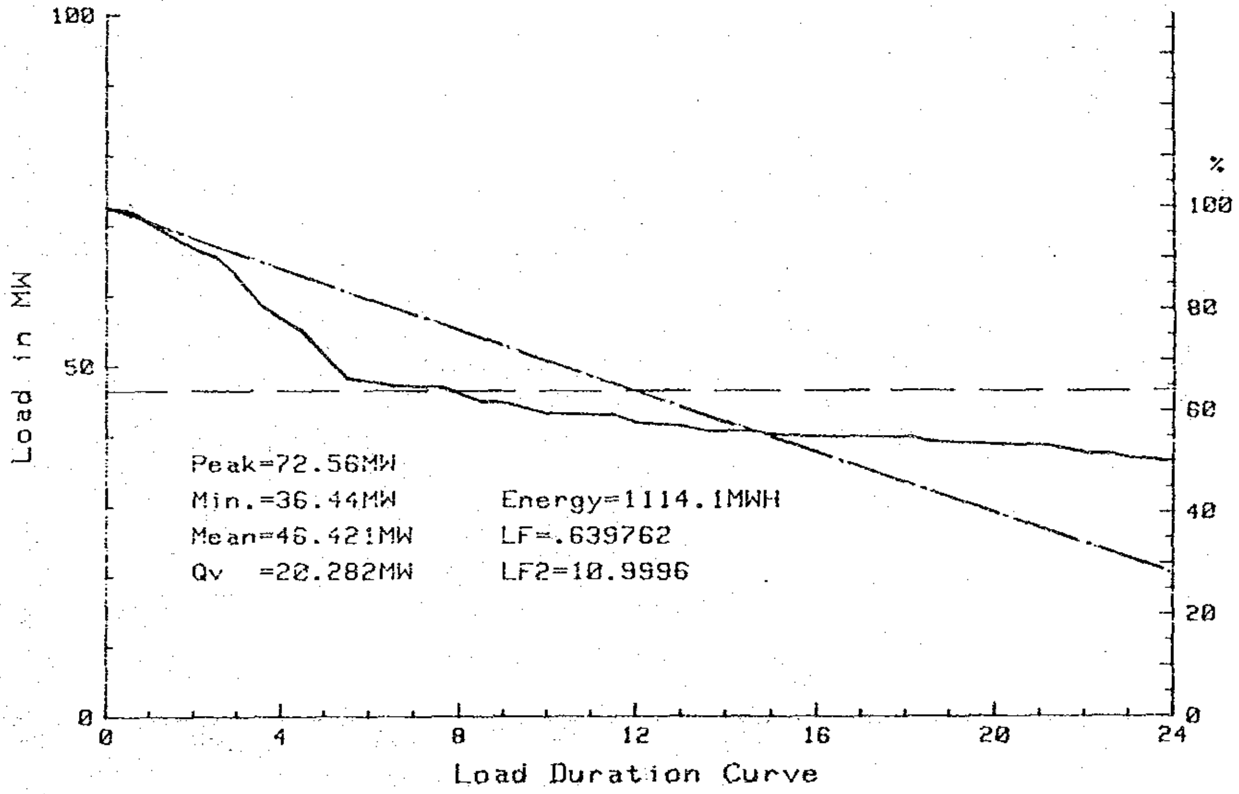
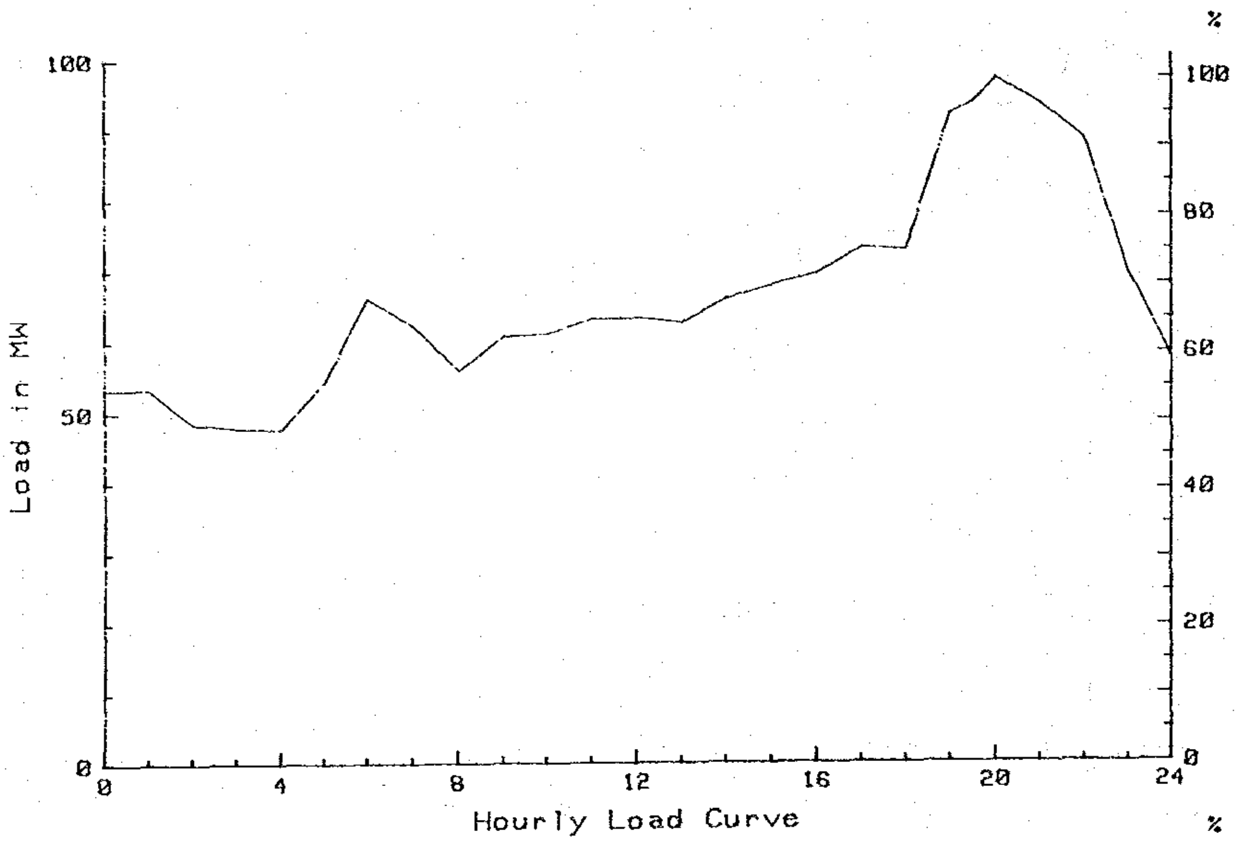




Fig. 2–16 Hourly Load Curve and Load Duration Curve, Northern Region (EGAT–R4) 1979



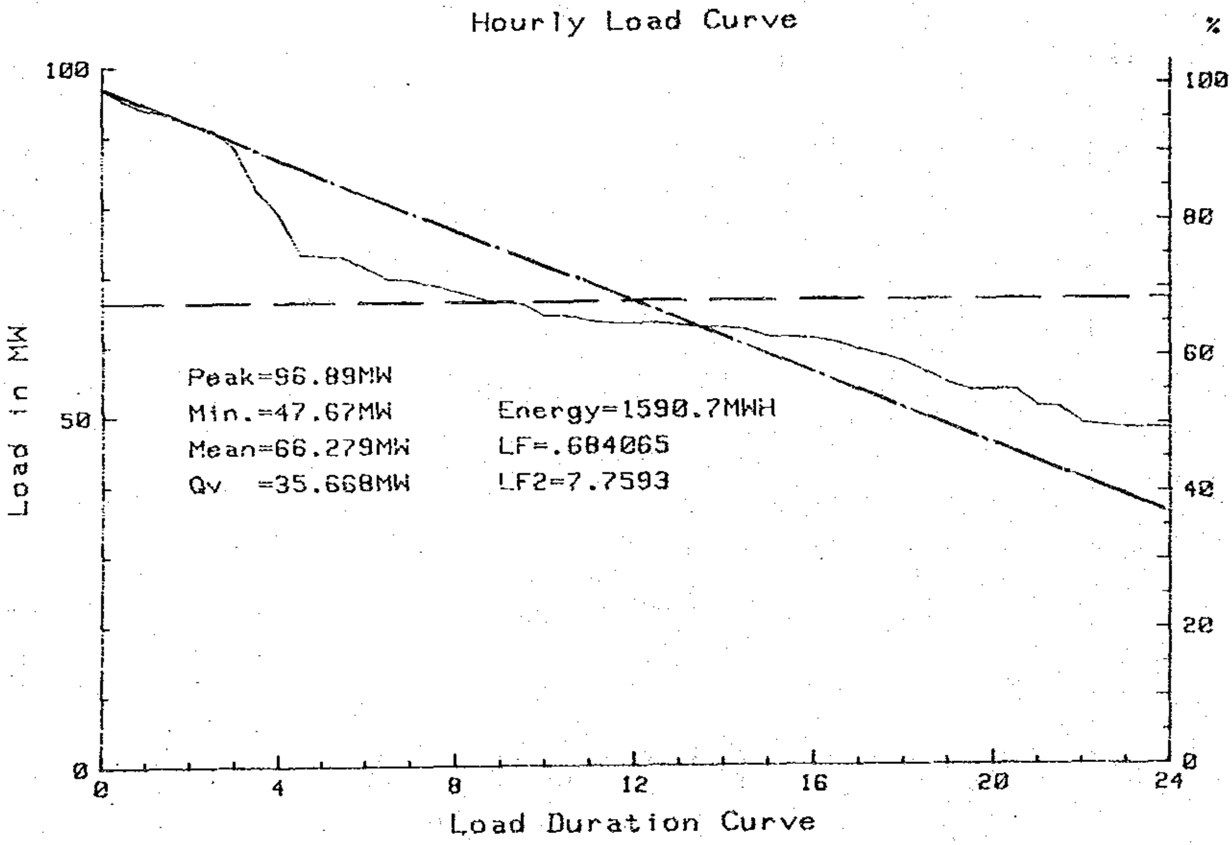
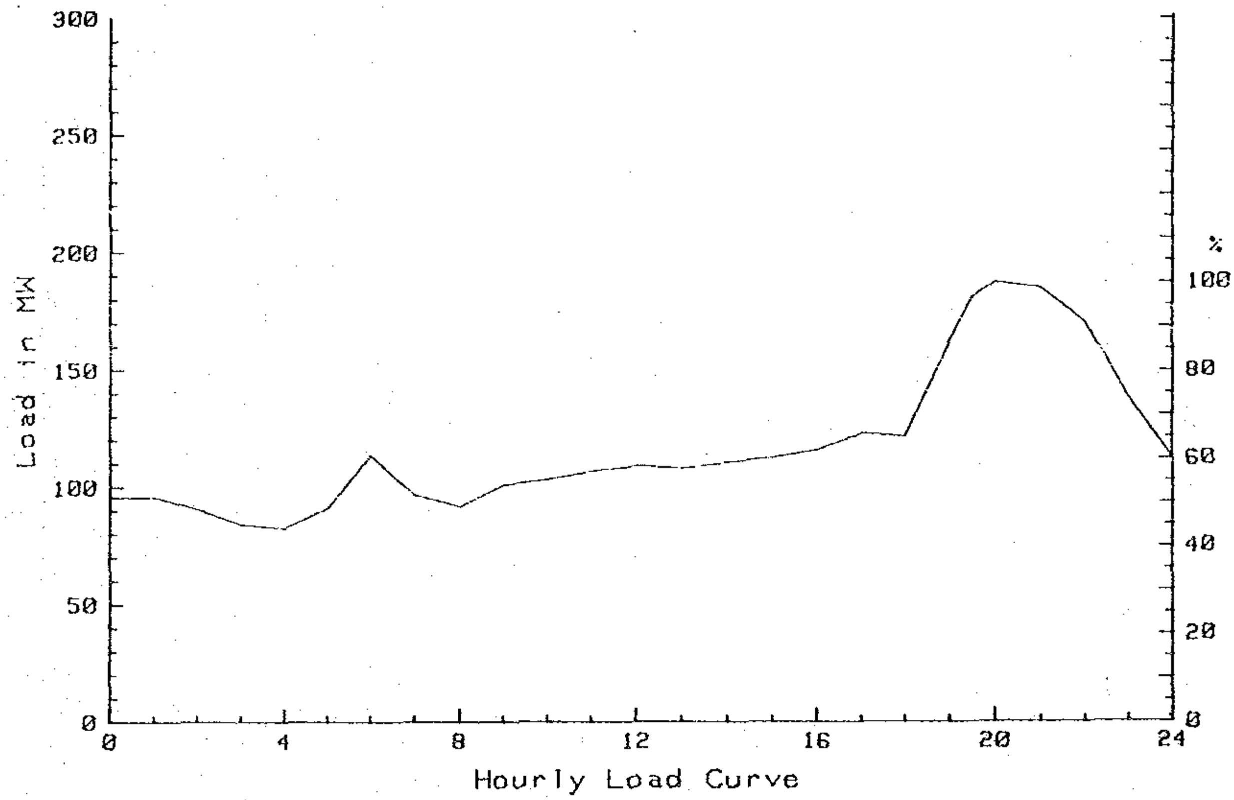




**Fig. 2–17 Hourly Load Curve and Load Duration Curve Northern Region (EGAT–R4) 1980**



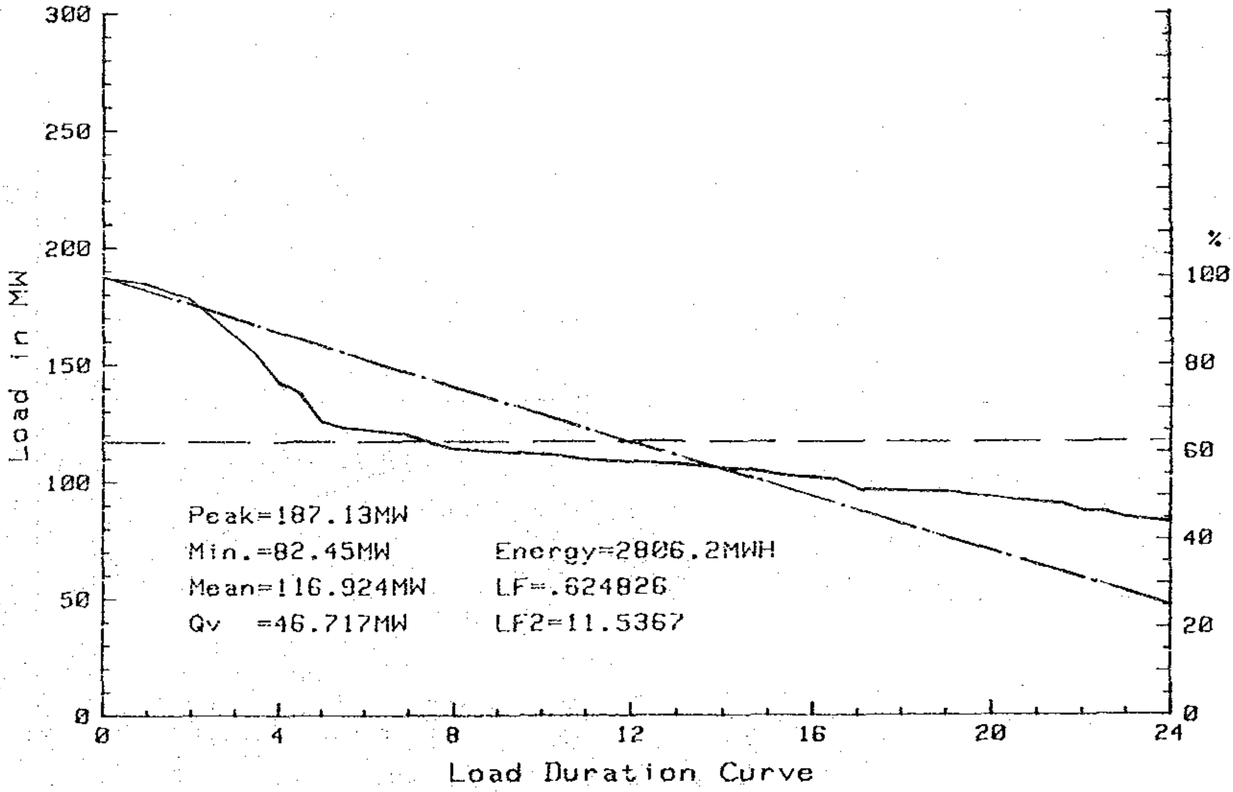
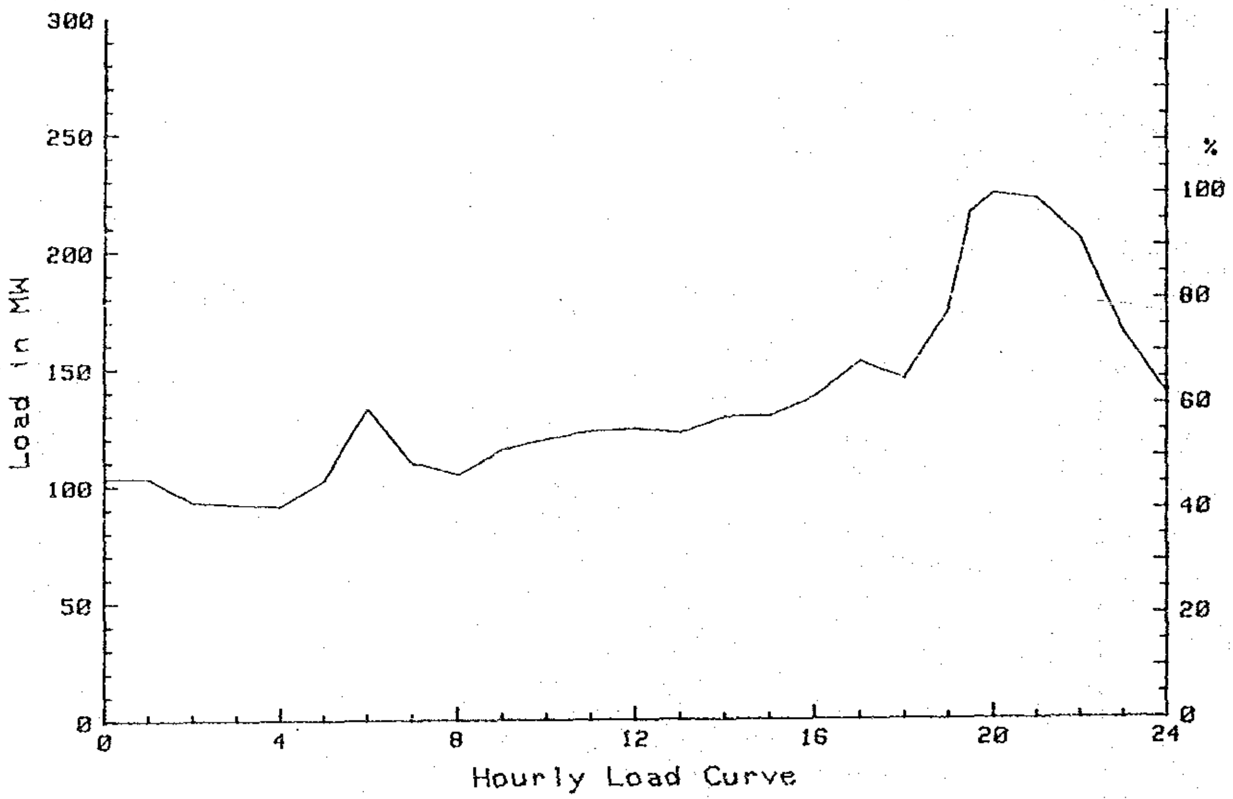




**Fig. 2–18 Hourly Load Curve and Load Duration Curve**
**Northern Region (EGAT–R4) 1982**



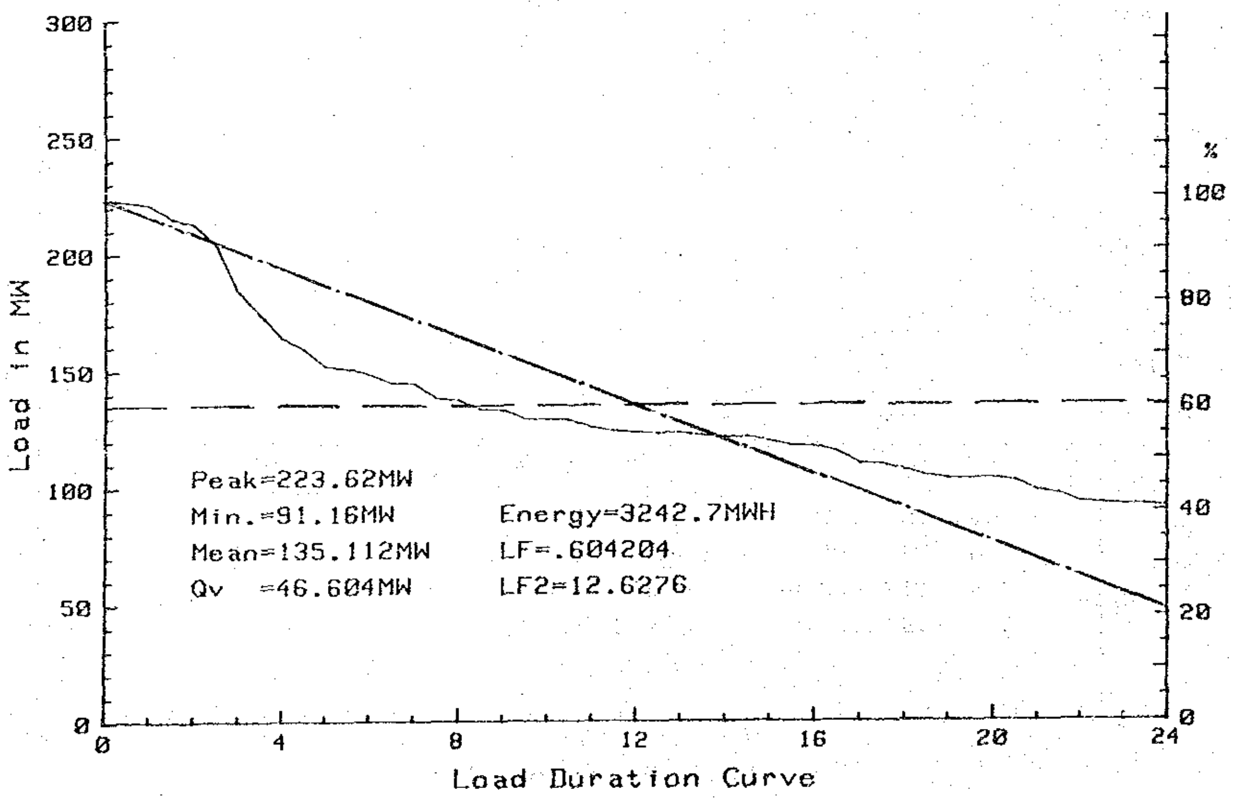
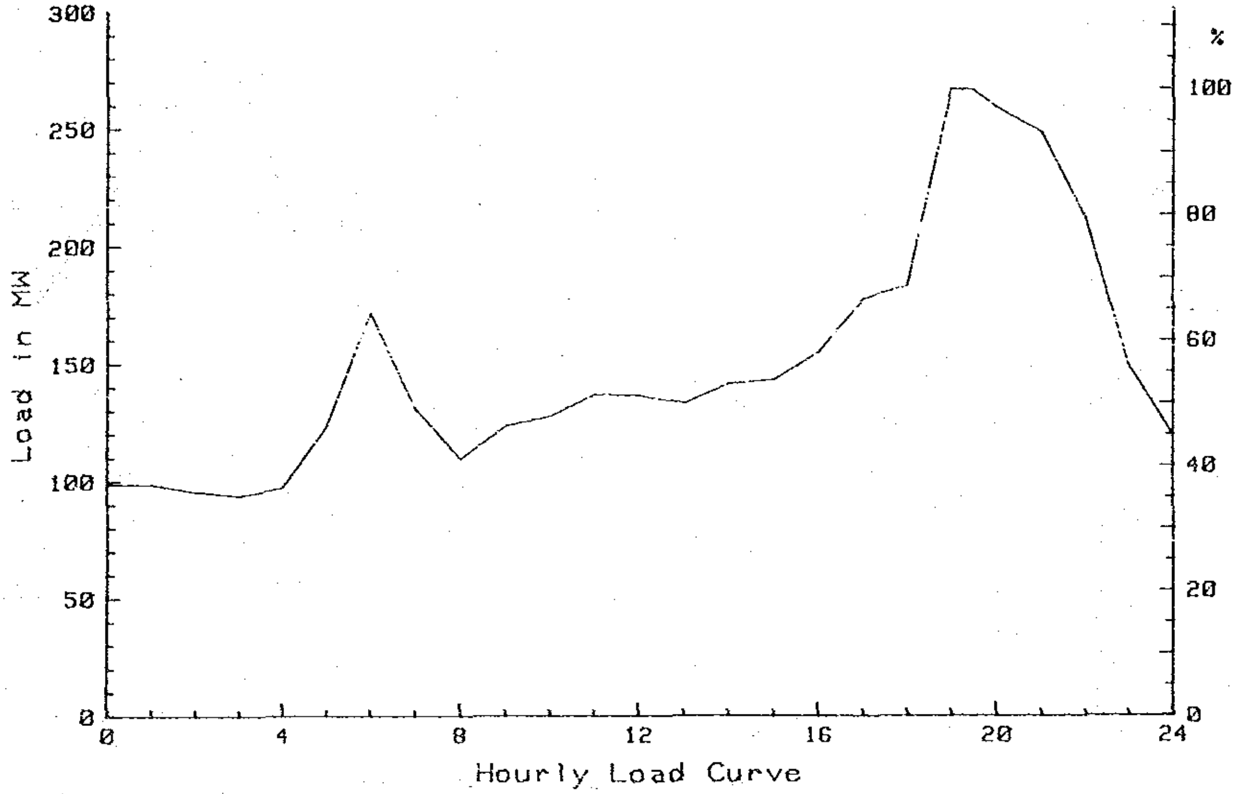




**Fig. 2–19 Hourly Load Curve and Load Duration Curve Northern Region (EGAT–R4) 1983**



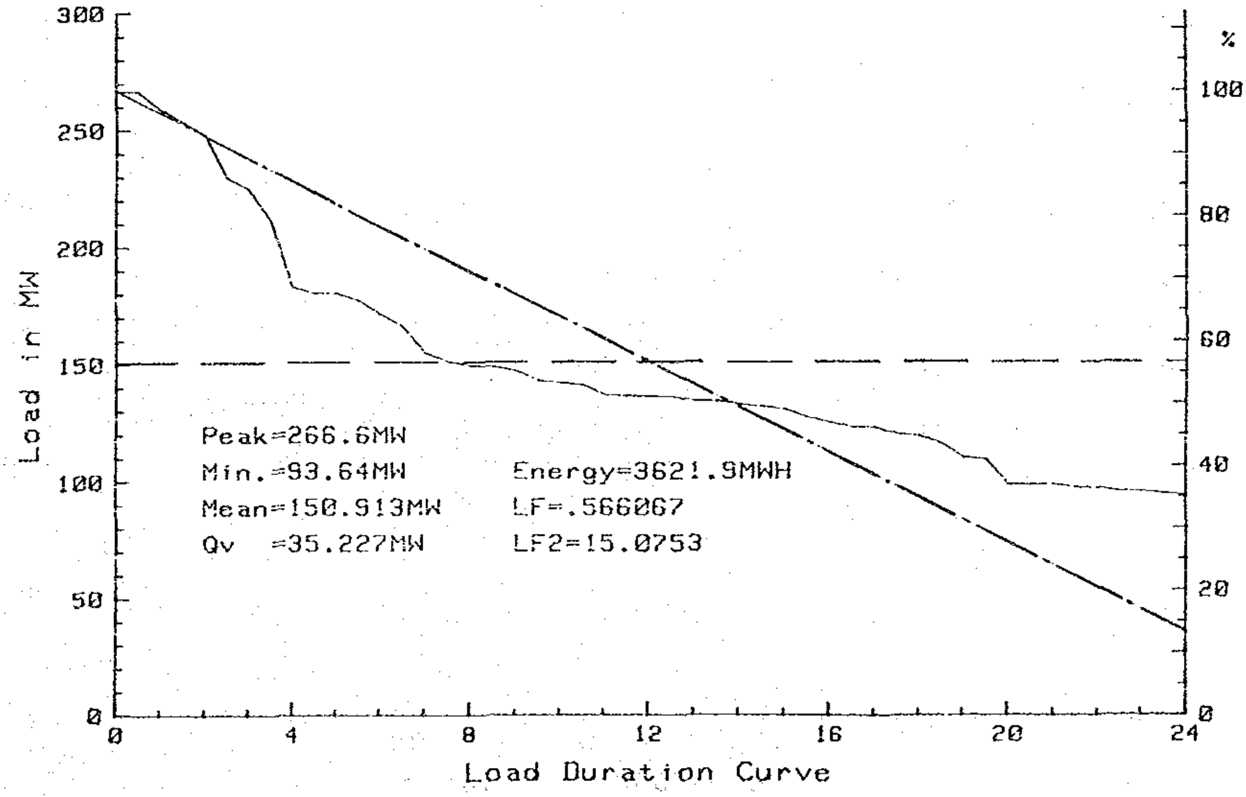




**Fig. 2–20 Hourly Load Curve and Load Duration Curve**
**Northern Region (EGAT–R4) 1984**

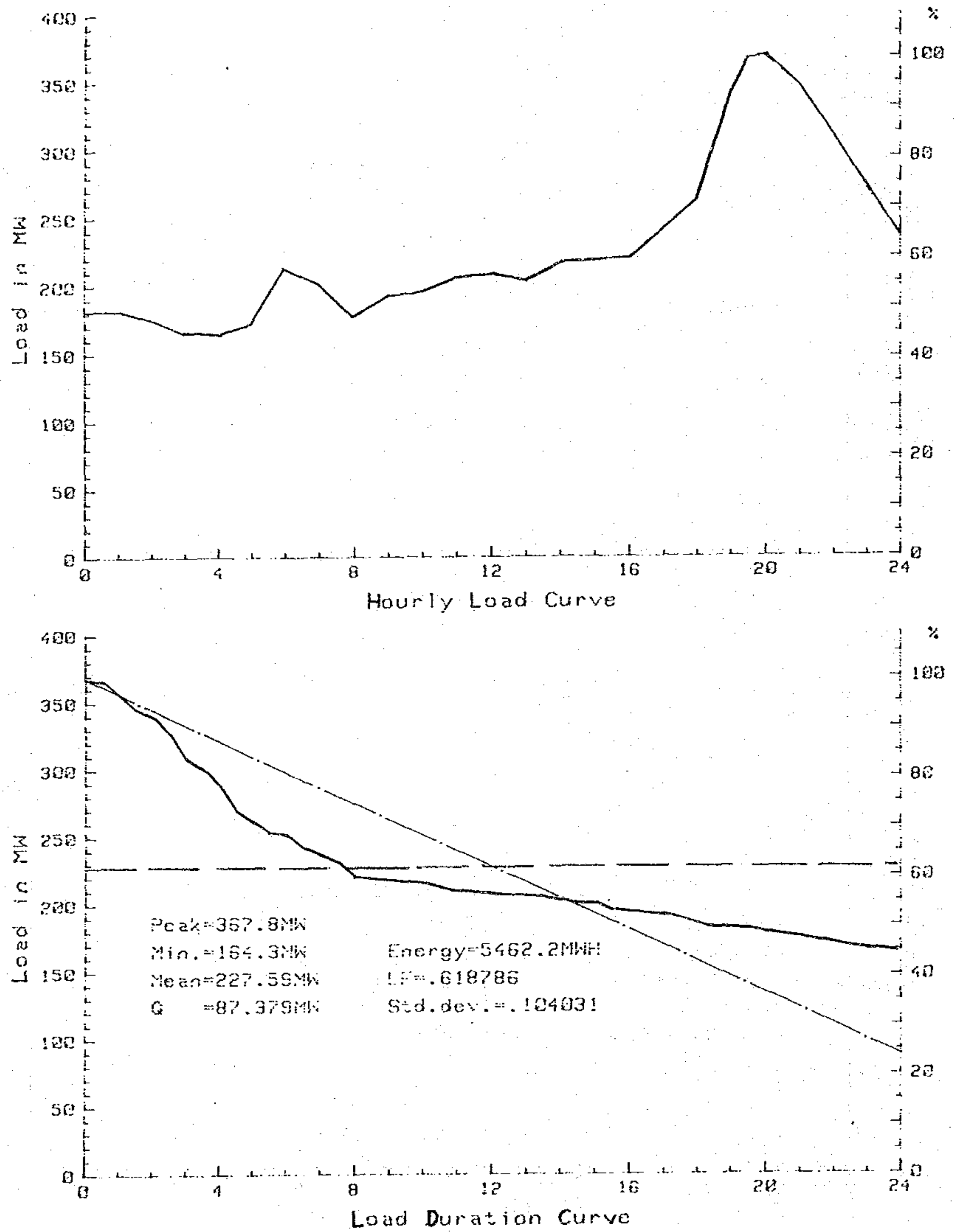



**Fig. 2–21 Hourly Load Curve and Load Duration Curve**
**Northern Region (EGAT–R4) 1985**

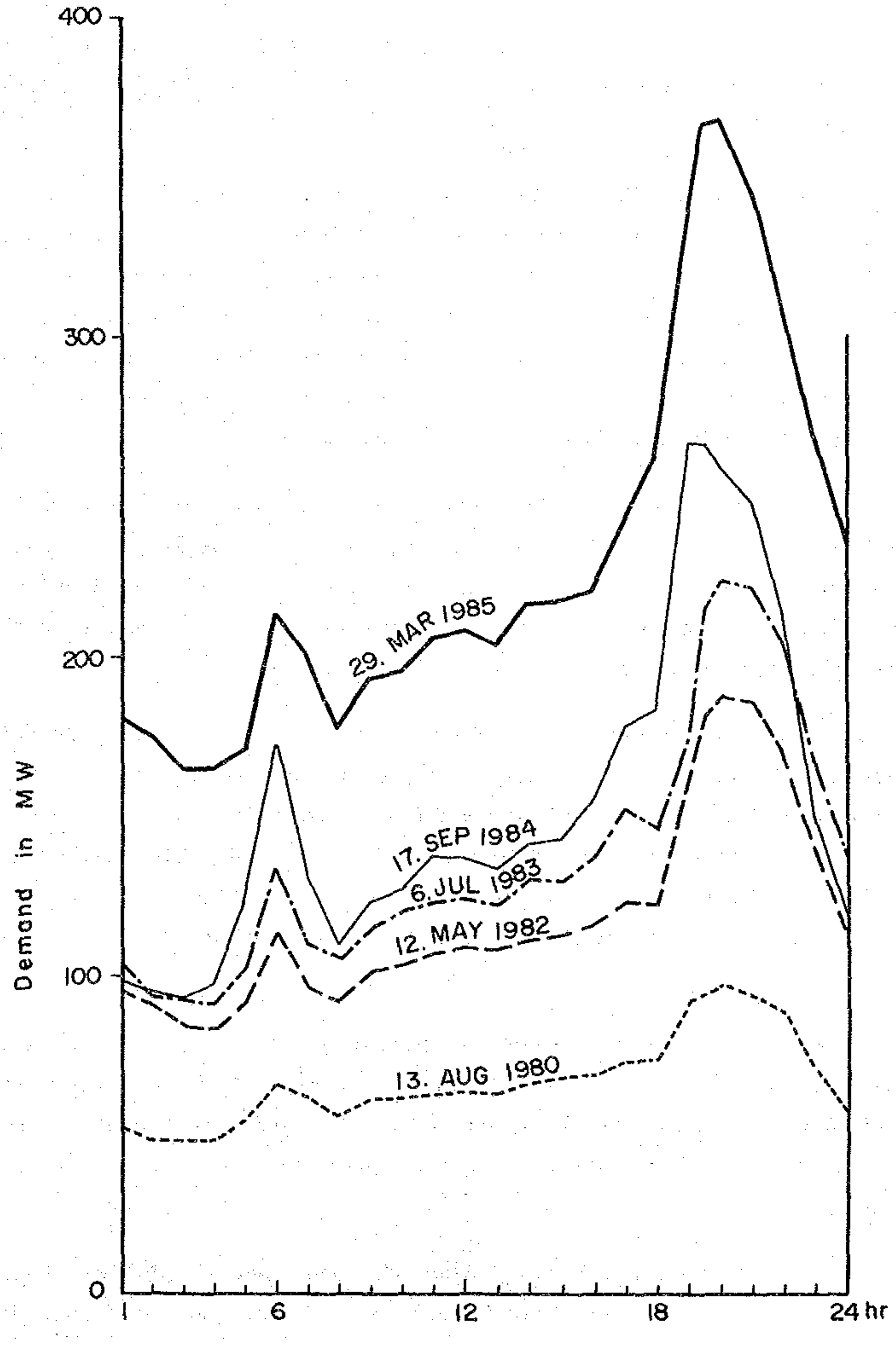



Fig. 2–22 Load Curve of Peak Demand Days in Northern Region (EGAT–R4)

## 2.6 Standard Deviation of Load Duration Curve

Before going into the captioned study let us take a look again at the load duration curves of EGAT (whole) and Northern Region (EGAT-R4) studied in the preceding section.

Take Fig. 2-15 and Fig. 2-21 up for example and compare them. The former is the load duration curve of the EGAT (whole) and the latter is the one of the Northern Region (EGAT-R4). It is clearly seen from this comparison that the shape of the former is less fluctuated than the latter, that is, the deviations of the curves from a certain intuitively drawn line (the line will be defined later) are much less in case of the former than the one of the latter case.

This is a reflection of the load charactors that the scale of the demand of the whole EGAT (peak = 3,880 MW) is much bigger than that of the Northern Region (peak = 368 MW) and the pattern of consumption of the former is much more matured than the latter. The similar tendencies are discernable in the other year's comparisons too.

Thus we can assume almost certainly that, a shape of a load duration curve will approach to a certain line as the scale of the demand increase and the pattern of consumption become matured. Therefore, if we have a measure of the deviations of the load duration curves from the line, it will be a new additional index (additional to the daily load factor) with which the charactors of the load duration curve are more precisely indicated.

In order to proceed the study along this idea, we must first define the line appropriately and uniquely. On Fig. 2-23, a conceptional load duration curve is drawn on the X-Y coordinates axes, where X represents the time (hour) in a day and Y the power demand (MW) at time X.

The top point P on the Y axis shows the peak demand (MW) of the day and T is the total hours (=24 hours) in the day. Now we draw a line P-Q on this figure such that

(i) the area (under this line but above the X-axis and bounded laterally by Y-axis and a line $X = T$) is equal to the area (under the load duration curve but above the X-axis and bounded laterally by Y-axis and a line $X = T$), and

(ii) the line P-Q starts at the point P on the Y-axis.

Then the line P-Q is defined uniquely provided that the load duration curve is given. Note that this is the line which is used as a substitute of the load duration curve in a quick study of the load charactor, because, in a sense, the line can be regarded as an expected load duration curve.

In a mathematical term, this line is expressed as

$$Y = a - mX \qquad (3)$$

where a and m are parameters. Next, put

E = total energy demand (MWH) in the day,

$L_f$ = daily load factor of the day and

Q = ordinate value (MW) of a point Q as shown on Fig. 2-23.

Since the line (3) passes the points P and Q, the parameters a and m are calculated by

$$a = P \text{ and } m = (P-Q)/T \qquad (4)$$

But by the definition of the load factor, the relation

$$E = P.L_f.T \qquad (5)$$

exists and by the definition of the line P-Q,

$$E = (P+Q)T/2. \qquad (6)$$

Then from (3), (4), (5) and (6), the following equations are easily obtained.

$$Y = P - \frac{2P(1-L_f)}{T} X \qquad (7)$$

$$Q = P(2L_f-1) \qquad (8)$$

Hence, given the values P and $L_f$, the equation (7) uniquely define the line P-Q.

Now that the expected line P-Q has been determined uniquely, we proceed to obtain the index to represent the deviations of the load duration curve from the line as originally aimed at. Let $A_t$ be a point on the line P-Q and $B_t$ be a point on the load duration curve such that both points stand on the common abscissa at t (See Fig. 2-23).

Then the deviation $D_t$ between $B_t$ and $A_t$ is expressed as

$$D_t = A_t - B_t \qquad (9)$$

where $A_t$ and $B_t$ represent the values of ordinates of points $A_t$ and $B_t$ respectively.

Since $A_t$ is a point on P-Q line, we get from (7)

$$A_t = P - \frac{2P(1-L_f)}{T} t \qquad (10)$$

It will be convenient that $A_t$, $B_t$ and $D_t$ are normalized as $A_t/P$, $B_t/P$ and $D_t/P$ with respect to P and used $A_t/P$, $B_t/P$ and $D_t/P$ instead of $A_t$, $B_t$ and $D_t$ in the following study.

Now on the analogy of the concept of the variance which is commonly used in a field of the statistics, put

$$D_2 = \sum_{t=0}^{T} \left(\frac{Dt}{P}\right)^2 \qquad (11)$$

and define the standard deviation s of the load duration curve from the expected line P-Q as

$$s = \sqrt{\frac{D_2}{T+1}} \qquad (12)$$

The summation of $D_t{}^2$ should be made on all the equally spaced t's between and including time 0 and T. The actual values of s calculated for each daily load duration curve of EGAT (whole) and Northern Region (EGAT-R4) are plotted on Fig. 2-5 through Fig. 2-21 in the foregoing section and listed in Table 2-11 and Table 2-12 too. Thus the new indices as above proposed are obtained numerically.

Our next target is to obtain some empirical formula to relate the standard deviation s with the daily load factor $L_f$.

Fig. 2-24 shows the scattergram of these two values which are taken from Table 2-11 and Table 2-12. All-together 21 points are plotted on the scattergram of which 11 points represent EGAT (whole) and 10 points come from Northern Region. It is interesting to see that although the points come from the different load systems, these points are approximately aligned on a certain imaginable line.

Thus a regression analysis of s on $L_f$ is attempted to estimate the imagined line. The result of the analysis give us a line

$$s = 0.421619 - 0.5035193 L_f \qquad (13)$$

as shown on Fig. 2-24, too.

The line (13) gives the linear relation of s to $L_f$ as if all the values of s and $L_f$ come from the same system.

Thus a future value of the standard deviation s can be estimated by (13) if the value of $L_f$ in that future time is given. The values of s of the Northern Region in 1985, 1995, 2000, 2005, 2010, 2015 and 2020 are estimated using (13) and are shown in Table 2-13. According to this result, the standard deviation at 0.1100 in 1985 will be decreased to 0.046 in 2020 as the load factor will be improved from 0.619 to 0.746.

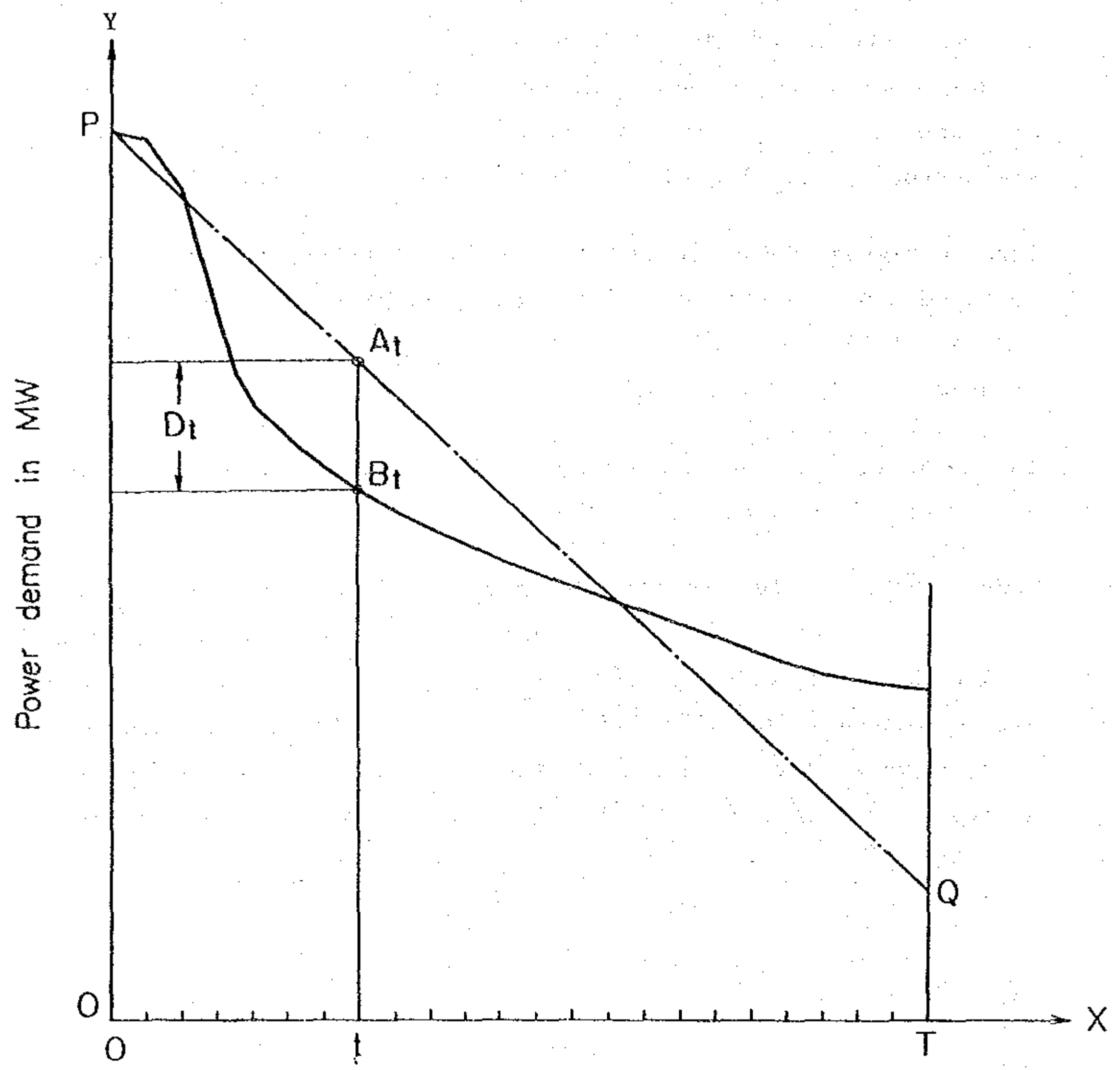



Fig. 2–23 Deviation of Load Duration Curve from Expected Line P–Q

Table 2–11 Maximum Demand of System, Coincident to Peak Load in EGAT Whole Supply Area

| Fiscal year & peak demand day | | Peak load MW | Energy demand MWH | Daily load factor Lf | Sum of squares D2 | Standard deviation (N=T+1=49) S | |
|---|---|---|---|---|---|---|---|
| 1975 | 24 Sep | 1,406.6 | 25,387.1 | 0.752022 | .056044 | .0338194 | |
| 76 | 21 Sep | 1,652.1 | 30,005.8 | 0.756744 | .056272 | .0338883 | |
| 77 | 9 Jun | 1,873.4 | 34,982.5 | 0.778053 | .033945 | .0263204 | |
| 78 | 6 Sep | 2,100.6 | 38,389.0 | 0.761468 | .047856 | .0312515 | |
| 79 | 23 Aug | 2,255.0 | 42,839.1 | 0.791558 | .021984 | .0211817 | |
| 80 | 28 Mar | 2,417.4 | 46,173.3 | 0.795849 | .026154 | .0231032 | |
| 81 | 29 Sep | 2,588.7 | 47,817.8 | 0.769656 | .040434 | .0287262 | |
| 82 | 20 Sep | 2,838.0 | 51,821.0 | 0.760820 | .053106 | .0329210 | |
| 83 | 19 May | 3,204.3 | 62,021.1 | 0.806482 | .025765 | .0229308 | |
| 84 | 28 May | 3,547.3 | 67,798.9 | 0.796367 | .025739 | .0229191 | |
| 85 | 29 Mar | 3,880.0 | 73,532.5 | 0.789653 | .035831 | .0270415 | |

Table 2-12 Maximum Demand of System Coincident to Peak Load in Northern Region (EGAT-R4)

| Fiscal year & peak demand day | | Peak[1] load MW | Daily energy demand MWH | Daily load factor Lf | Sum of squares D2 | Standard deviation (N=T+1=49) S | Numbers of Substations for which load data are available |
|---|---|---|---|---|---|---|---|
| 1975 | 24 Sep. | 17.49 | 288.1 | 0.686410 | .427554 | .0934109 | 3 |
| 76 | 21 Sep. | 24.55 | 395.4 | 0.671118 | .484564 | .0994437 | 3 |
| 77 | 26 Sep. | 37.54 | 547.6 | 0.607804 | .831603 | .1302747 | 6 |
| 78 | 6 Sep. | 56.15 | 807.7 | 0.599360 | .913062 | .1365061 | 7 |
| 79 | 20 Apr. | 72.56 | 1,114.1 | 0.639762 | .619042 | .1123088 | 8 |
| 80 | 13 Aug. | 96.89 | 1,590.7 | 0.684065 | .247681 | .0710965 | 11 |
| 81 | | N.A. | | | | | |
| 82 | 12 May | 187.13 | 2,806.2 | 0.624826 | .547389 | .1056939 | 15 |
| 83 | 6 Jul. | 223.62 | 3,242.6 | 0.604185 | .517767 | .1027943 | 15 |
| 84 | 17 Sep. | 266.60 | 3,621.9 | 0.566067 | .608219 | .1114120 | 18 |
| 85 | 29 Mar. | 367.8 | 5,462.2 | 0.618786 | .530299 | .1040309 | 21 |

Note: 1) Peak load in this column is a total peak loads of the substations for which hourly loads in the coincidental peak demand day are available. Since the data for several substations in the region are missing, the values of peak load do not coincide with those shown on Table 2-3.

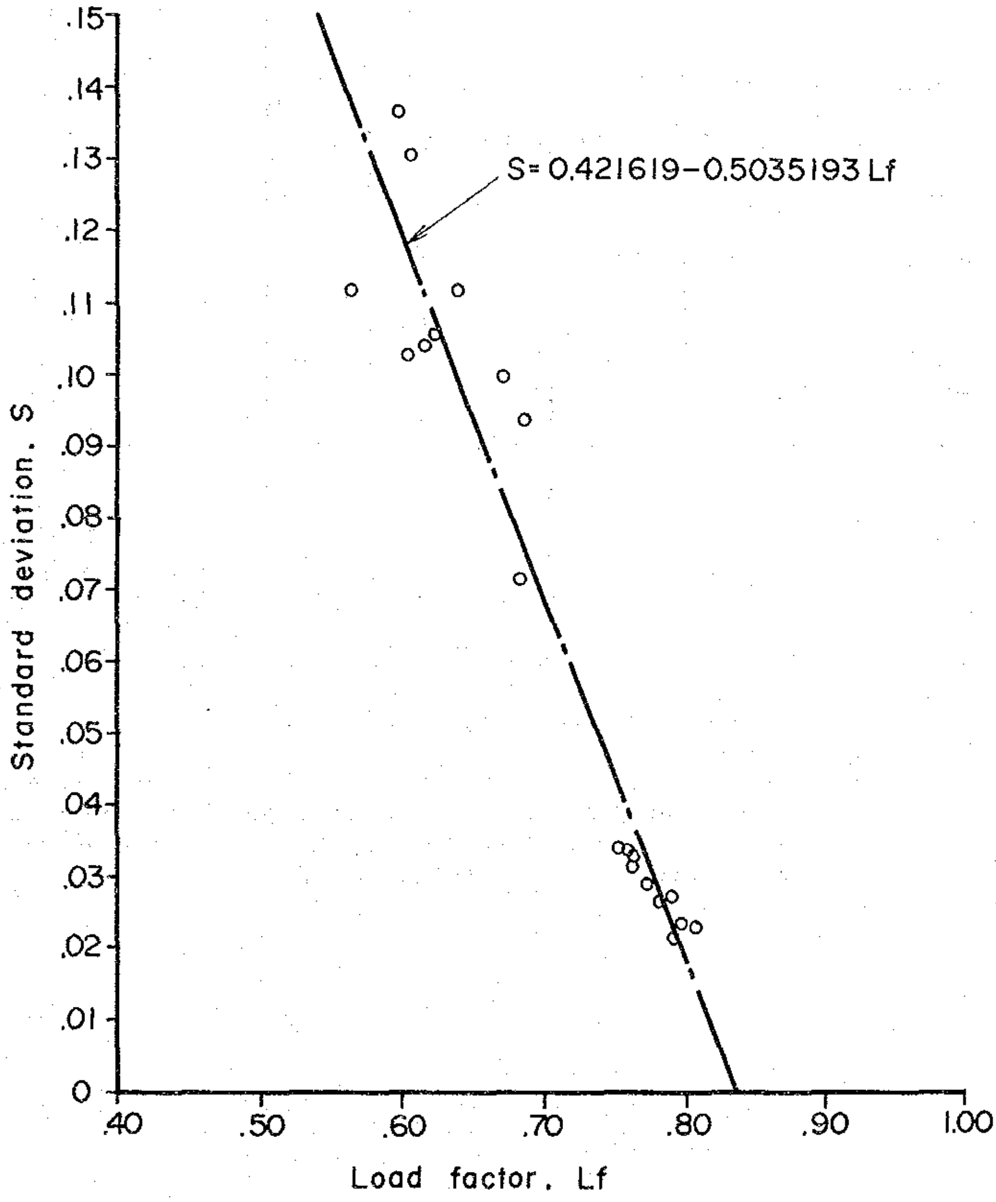



Fig. 2–24 Standard Deviation of Hourly Loads vs Daily Load Factor

Table 2-13 Parameters of Daily Load Duration Curves Northern Region

| Fiscal year | Peak load P MW [1)] | Daily load factor Lf [2)] | Standard deviation S [3)] | Ratio Su/Sv C | |
|---|---|---|---|---|---|
| 1985 base year | 416.5 | 0.6188 | 0.11004 [4)] | 1.000 | |
| 1995 | 904.0 | 0.6731 | 0.08270 | 0.752 | |
| 2000 | 1,220.5 | 0.6877 | 0.07535 | 0.685 | |
| 2005 | 1,573.3 | 0.7023 | 0.06800 | 0.618 | |
| 2010 | 1,935.4 | 0.7169 | 0.06065 | 0.551 | |
| 2015 | 2,293.5 | 0.7314 | 0.05792 | 0.527 | |
| 2020 | 2,719.4 | 0.7460 | 0.04599 | 0.418 | |

Note: 1) Values in this column come from Table 2-3 and Table 2-4.

2) Value in this column come from Tabel 2-10.

3) Calculated by s=0.421619-0.5035193 Lf

4) This value is slightly different from the corresponding value 0.10403 in Table 12, because the former is a value on the regression line whereas the latter is a value calculated from the actual record.

## 2.7 Estimation of Daily Load Duration Curve

The future load duration curve can now be estimated as follows.

As we have seen in the previous section, the deviations of the load duration curve from the expected load duration line will decrease as the system grow and become matured.

One of the ways to express this tendency is to set up the equation:

$$\frac{Du}{Pu} = C\,\frac{Dv}{Pv} \qquad (14)$$

where Du and Pu are the deviation and the peak demand in a target year respectively and Dv and Pv are those in a base year respectively. (see Fig. 2-25)

C is a constnat to be estimated which indicates the reduction ratio of the deviations.

From (11),

$$D_{2v} = \sum_{t=0}^{T} \left(\frac{Dvt}{Pv}\right)^2$$

$$(15)$$

$$D_{2u} = \sum_{t=0}^{T} \left(\frac{Dut}{Pu}\right)^2$$

and from (14),

$$\sum_{t=0}^{T} \left(\frac{Dut}{Pu}\right)^2 = C^2 \sum_{t=0}^{T} \left(\frac{Dvt}{Pv}\right)^2 \qquad (16)$$

where the subscript v and u indicate the base year and the target year respectively. Combining (15) and (16),

$$C^2 = \frac{D_{2u}}{D_{2v}} \qquad (17)$$

and substituting (12) into (17), we get,

$$C = \frac{Su}{Sv} \qquad (18)$$

Hence C is in fact the reduction ratio of the standard deviation of the target year to that of the base year. Moreover, from (14) the deviation $D_u$ can be expressed as

$$D_u = C \frac{D_v}{Pv} . Pu \qquad (19)$$

Therefore, by using the value C, calculated by (18), the shape and magnitude of the load duration curve of the target year can be estimated by (19) basing upon the load duration curve in the base year.

The values of C of the Northern Region are calculated for 1995, 2000, 2005, 2010, 2015 and 2020, taking 1984 as the base year, and are listed on Table 2-13.

Then, the load duration curves of Northern Region are estimated using (19). The calculated results are shown in Table 2-14 and the curves are plotted on Fig. 2-26 through 2-31.

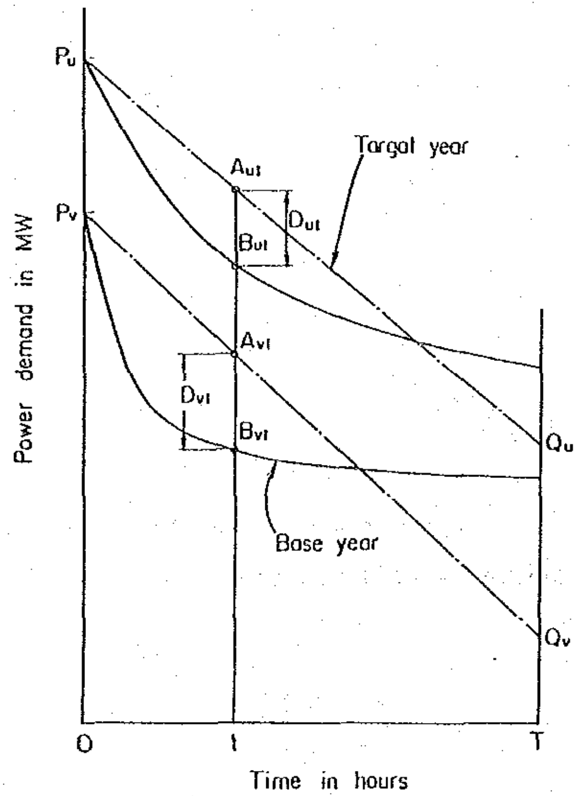



Fig. 2–25 Evaluation of Load Duration Curve

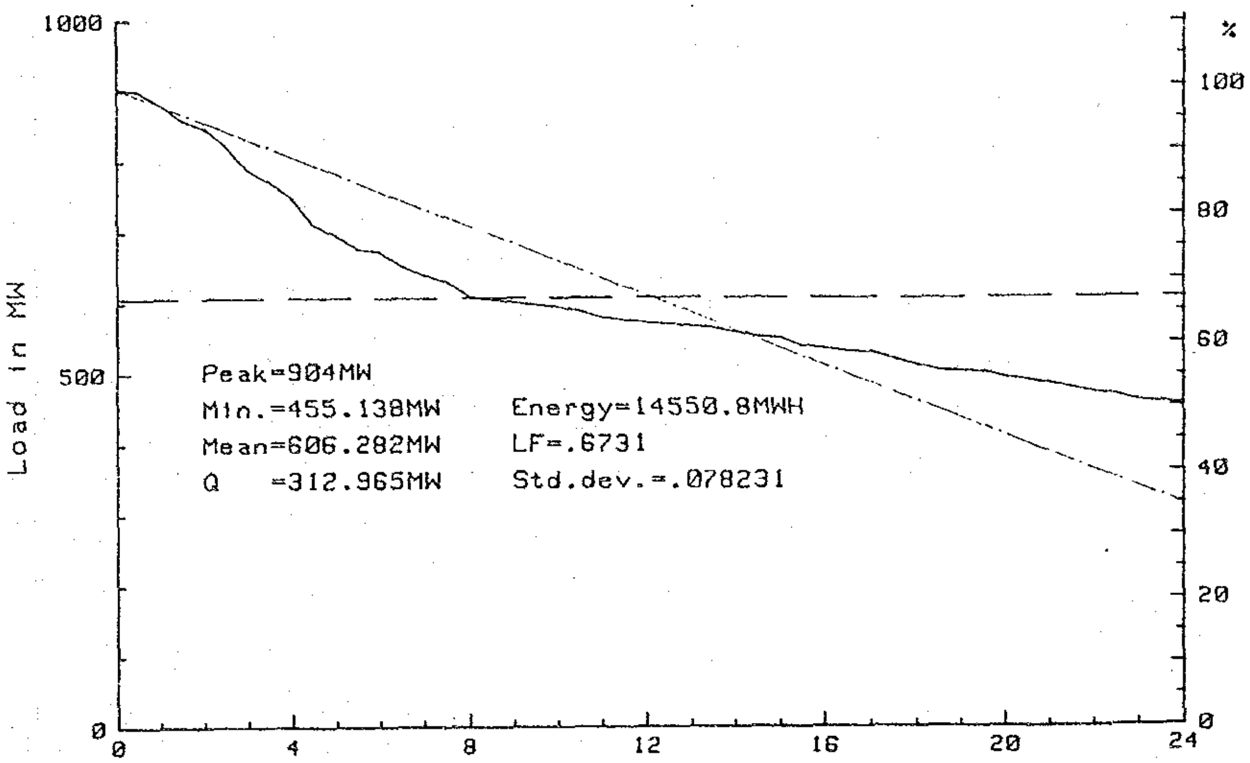



Fig. 2–26 Load Duration Curve Northern Region 1995

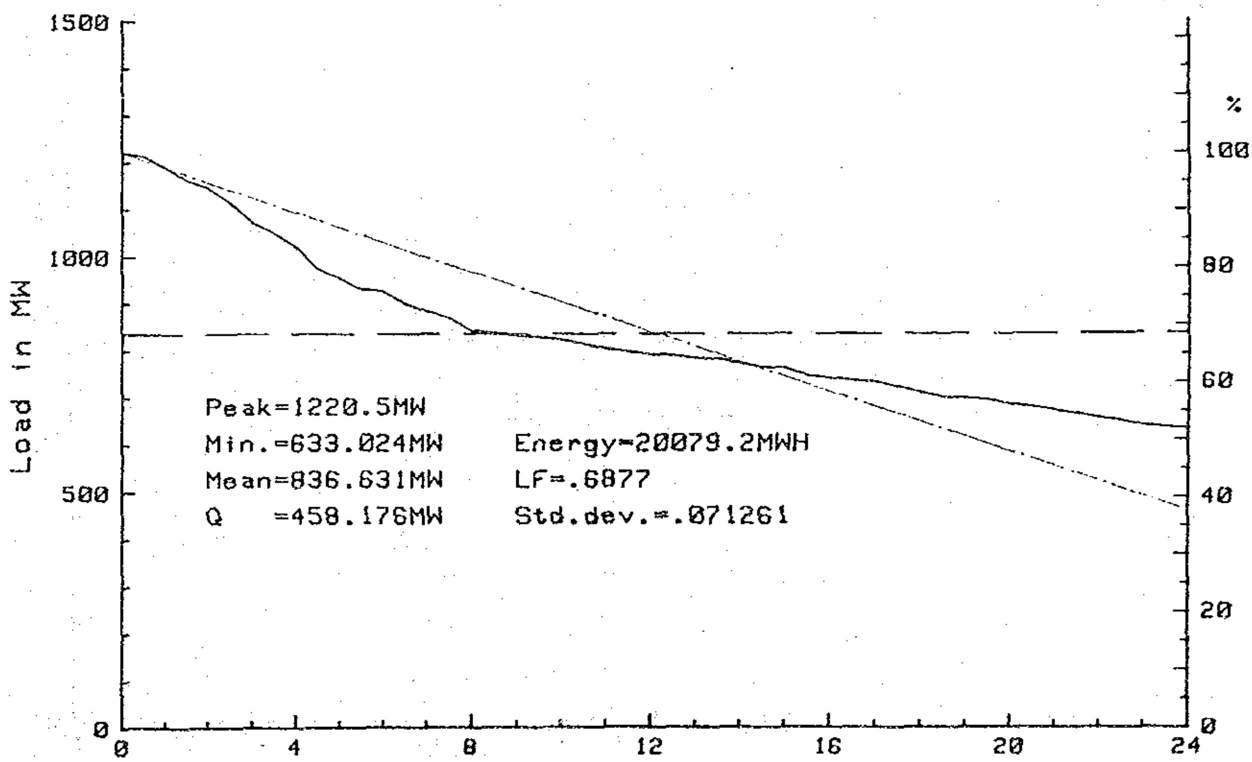



Fig. 2–27 Load Duration Curve Northern Region 2000

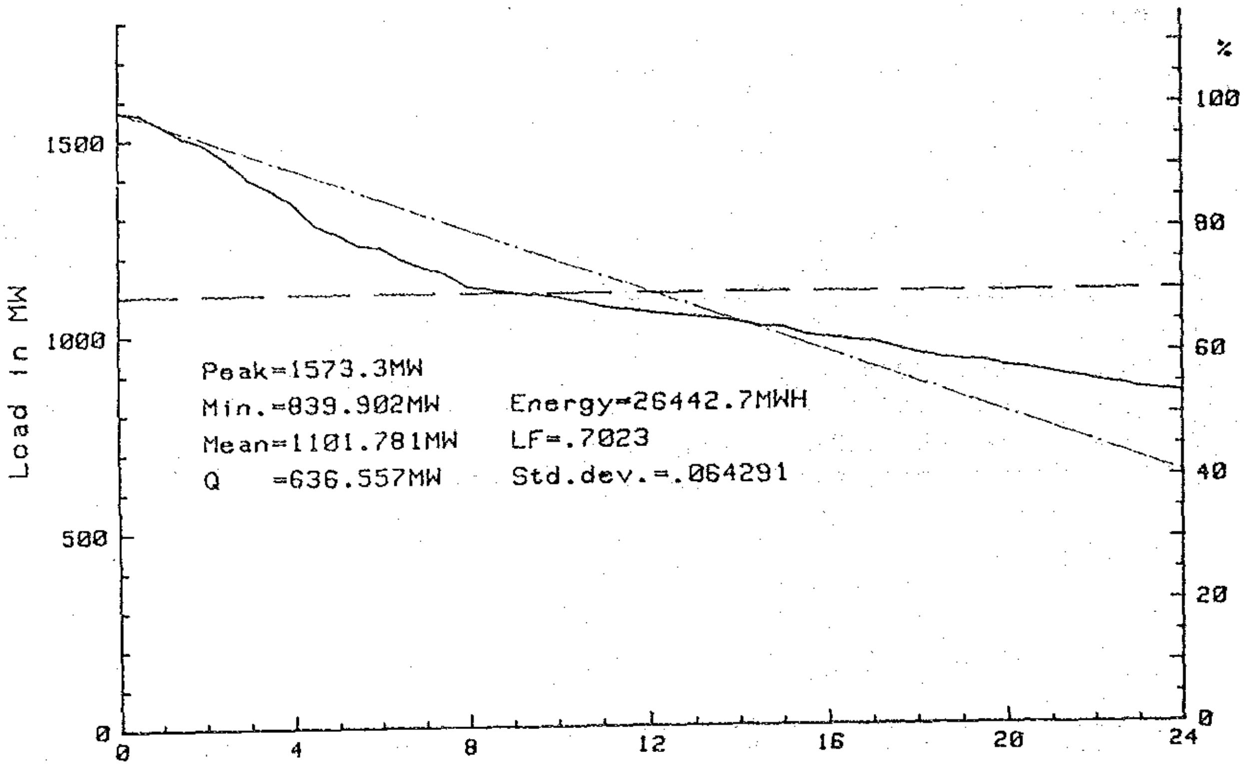



Fig. 2–28 Load Duration Curve Northern Region 2005

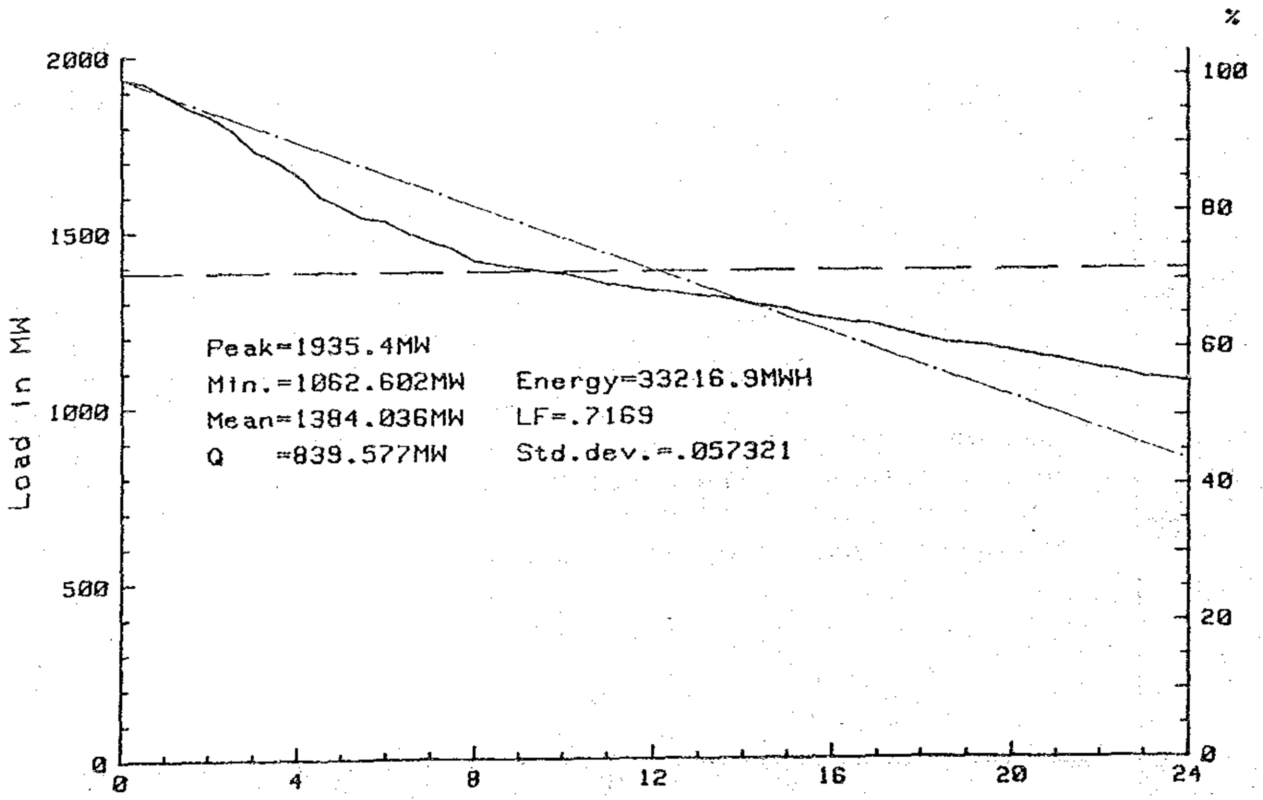



Fig. 2–29 Load Duration Curve Northern Region 2010

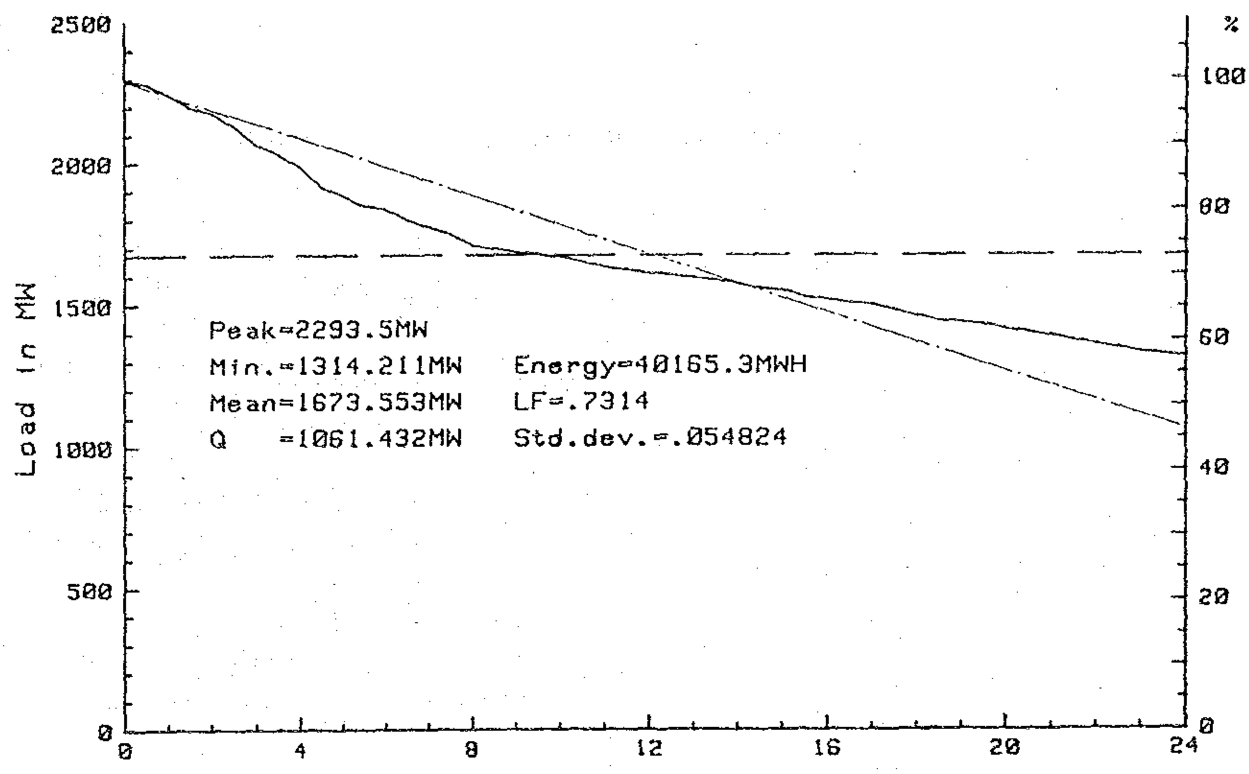



Fig. 2–30 Load Duration Curve Northern Region 2015

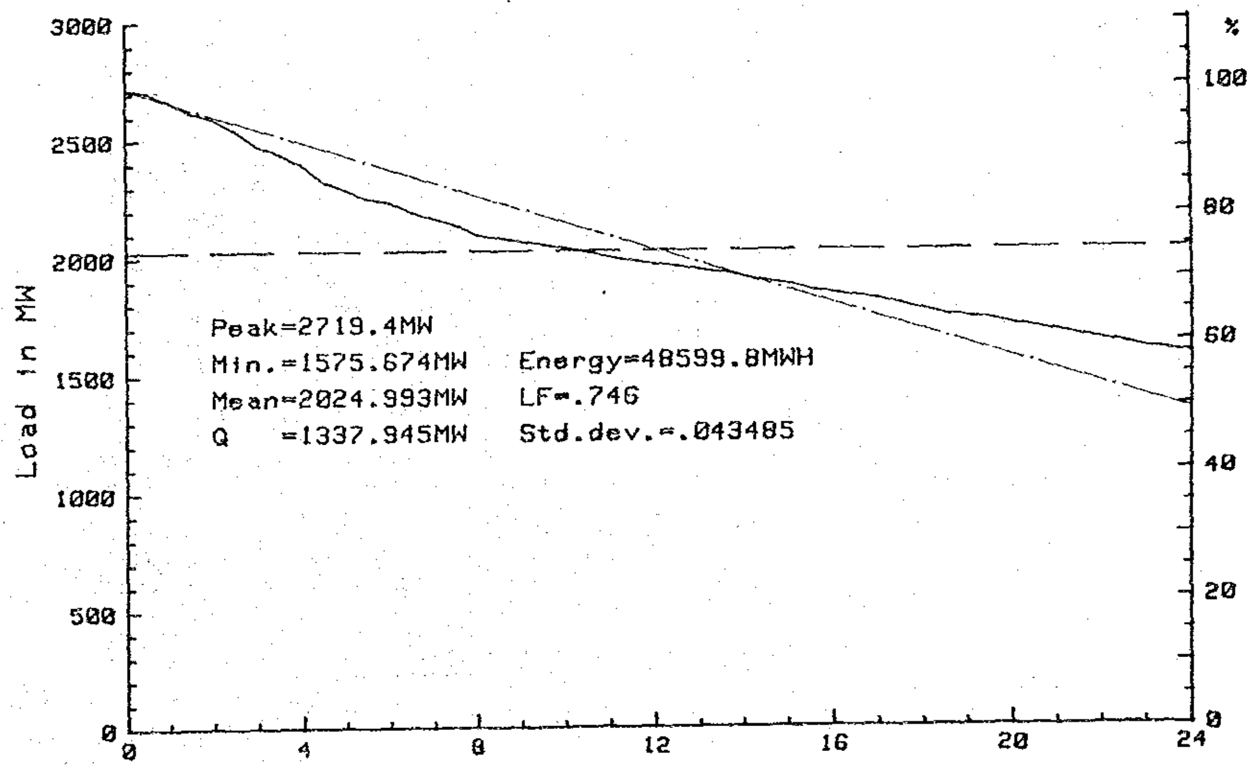



Fig. 2–31 Load Duration Curve Northern Region 2020

## Table 2–14 Estimated Load Duration Curves of Northern Region

| | 1985 | | | 1995 | | | 2000 | | | 2005 | | | 2010 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LDC MW | Normalized LDC % | DI/P | LDC MW | Normalized LDC % | DI/P | LDC MW | Normalized LDC % | DI/P | LDC MW | Normalized LDC % | DI/P | LDC MW | Normalized LDC % | DI/P |
| 0.0 | 367.80 | 100.00 | 0 | 990.70 | 100.00 | 0 | 1334.00 | 100.00 | 0 | 1771.80 | 100.00 | 0 | 2313.10 | 100.00 | 0 |
| 0.5 | 366.30 | 99.92 | -.0173 | 989.18 | 99.85 | -.0152 | 1331.34 | 99.80 | -.0139 | 1767.11 | 99.74 | -.0120 | 2304.85 | 99.64 | -.0094 |
| 1.0 | 356.80 | 97.08 | -.0070 | 963.66 | 97.27 | -.0061 | 1299.18 | 97.39 | -.0056 | 1728.53 | 97.56 | -.0048 | 2262.06 | 97.79 | -.0038 |
| | 345.80 | 95.09 | -.0051 | 945.47 | 95.43 | -.0048 | 1276.04 | 95.66 | -.0041 | 1700.31 | 95.97 | -.0035 | 2229.83 | 96.40 | -.0028 |
| 2.0 | 340.20 | 93.09 | -.0032 | 927.28 | 93.60 | -.0028 | 1252.90 | 93.92 | -.0026 | 1672.09 | 94.37 | -.0022 | 2197.59 | 95.01 | -.0018 |
| | 327.80 | 86.24 | .0472 | 866.86 | 87.50 | .0414 | 1177.87 | 88.30 | .0378 | 1584.24 | 89.41 | .0327 | 2104.60 | 90.99 | .0255 |
| 3.0 | 309.80 | 84.33 | .0482 | 849.44 | 85.74 | .0423 | 1155.67 | 86.63 | .0386 | 1557.11 | 87.88 | .0334 | 2073.47 | 89.64 | .0261 |
| | 301.25 | 79.39 | .0796 | 805.61 | 81.32 | .0698 | 1101.03 | 82.54 | .0637 | 1492.68 | 84.25 | .0551 | 2004.34 | 86.65 | .0430 |
| 4.0 | 289.85 | 68.66 | .1687 | 711.49 | 71.82 | .1481 | 984.62 | 73.81 | .1351 | 1357.29 | 76.61 | .1169 | 1862.68 | 80.54 | .0913 |
| | 269.90 | 67.71 | .1602 | 702.38 | 70.90 | .1406 | 972.62 | 72.91 | .1283 | 1341.87 | 75.74 | .1110 | 1843.70 | 79.71 | .0866 |
| 5.0 | 262.30 | 67.65 | .1427 | 701.03 | 70.76 | .1253 | 970.16 | 72.73 | .1143 | 1337.42 | 75.48 | .0989 | 1835.69 | 79.36 | .0772 |
| | 253.00 | 66.64 | .1347 | 691.39 | 69.79 | .1183 | 957.52 | 71.78 | .1079 | 1321.26 | 74.57 | .0934 | 1815.75 | 78.50 | .0729 |
| 6.0 | 252.25 | 64.37 | .1393 | 670.85 | 67.71 | .1223 | 931.50 | 69.83 | .1116 | 1289.72 | 72.79 | .0965 | 1780.14 | 76.96 | .0754 |
| | 242.20 | 62.39 | .1411 | 652.73 | 65.89 | .1239 | 908.43 | 68.10 | .1130 | 1261.59 | 71.20 | .0978 | 1748.00 | 75.57 | .0763 |
| 7.0 | 236.10 | 58.13 | .1656 | 614.90 | 62.07 | .1454 | 861.17 | 64.56 | .1326 | 1205.65 | 68.05 | .1147 | 1687.51 | 72.95 | .0896 |
| | 231.30 | 56.72 | .1616 | 601.82 | 60.75 | .1419 | 844.30 | 63.29 | .1294 | 1184.63 | 66.86 | .1120 | 1662.62 | 71.88 | .0874 |
| 8.0 | 220.40 | 56.04 | .1504 | 595.00 | 60.06 | .1320 | 835.12 | 62.60 | .1204 | 1172.46 | 66.17 | .1042 | 1646.75 | 71.19 | .0813 |
| | 219.10 | 55.90 | .1337 | 592.96 | 59.85 | .1174 | 831.82 | 62.36 | .1071 | 1167.04 | 65.87 | .0926 | 1637.75 | 70.80 | .0723 |
| 9.0 | 217.80 | 55.27 | .1218 | 586.70 | 59.22 | .1070 | 823.33 | 61.72 | .0976 | 1155.65 | 65.22 | .0844 | 1622.67 | 70.15 | .0659 |
| | 216.90 | 53.66 | .1199 | 571.86 | 57.72 | .1052 | 804.30 | 60.29 | .0960 | 1132.15 | 63.90 | .0831 | 1595.25 | 68.97 | .0648 |
| 10.0 | 216.00 | 53.33 | .1051 | 568.12 | 57.35 | .0923 | 798.91 | 59.89 | .0842 | 1124.33 | 63.46 | .0729 | 1583.81 | 68.47 | .0569 |
| | 213.20 | 52.99 | .0904 | 564.39 | 56.97 | .0794 | 793.53 | 59.48 | .0724 | 1116.51 | 63.02 | .0626 | 1572.37 | 67.98 | .0489 |
| 11.0 | 209.55 | 51.41 | .0881 | 549.77 | 55.49 | .0774 | 774.77 | 58.08 | .0706 | 1093.33 | 61.71 | .0611 | 1545.28 | 66.81 | .0477 |
| | 208.20 | 51.26 | .0715 | 547.66 | 55.28 | .0628 | 771.37 | 57.82 | .0573 | 1087.80 | 61.39 | .0496 | 1536.17 | 66.41 | .0387 |
| 12.0 | 207.00 | 51.18 | .0542 | 546.16 | 55.13 | .0476 | 768.73 | 57.63 | .0434 | 1083.13 | 61.13 | .0376 | 1527.94 | 66.06 | .0293 |
| | 207.00 | 51.11 | .0369 | 544.66 | 54.98 | .0324 | 766.09 | 57.43 | .0296 | 1078.47 | 60.87 | .0256 | 1519.72 | 65.70 | .0200 |
| 13.0 | 205.80 | 50.47 | .0253 | 538.25 | 54.33 | .0222 | 757.42 | 56.78 | .0202 | 1066.87 | 60.21 | .0175 | 1504.43 | 65.04 | .0137 |
| | 205.65 | 50.40 | .0078 | 536.83 | 54.19 | .0069 | 754.88 | 56.59 | .0063 | 1062.32 | 59.96 | .0054 | 1496.32 | 64.69 | .0043 |
| 14.0 | 203.10 | 49.82 | -.0045 | 531.01 | 53.60 | -.0039 | 746.93 | 55.99 | -.0036 | 1051.56 | 59.35 | -.0031 | 1481.88 | 64.06 | -.0024 |
| | 200.80 | 49.53 | -.0196 | 527.64 | 53.26 | -.0173 | 741.98 | 55.62 | -.0157 | 1044.25 | 58.94 | -.0136 | 1470.96 | 63.59 | -.0106 |
| 15.0 | 200.50 | 49.07 | -.0332 | 522.82 | 52.77 | -.0291 | 735.27 | 55.12 | -.0266 | 1034.91 | 58.41 | -.0230 | 1457.97 | 63.03 | -.0179 |
| | 195.20 | 47.80 | -.0385 | 510.93 | 51.57 | -.0338 | 719.87 | 53.96 | -.0309 | 1015.57 | 57.32 | -.0267 | 1434.80 | 62.03 | -.0208 |
| 16.0 | 194.15 | 47.02 | -.0488 | 503.29 | 50.80 | -.0428 | 709.67 | 53.20 | -.0391 | 1002.23 | 56.57 | -.0338 | 1417.73 | 61.29 | -.0264 |
| | 193.10 | 46.23 | -.0590 | 495.64 | 50.03 | -.0518 | 699.48 | 52.43 | -.0473 | 988.88 | 55.81 | -.0409 | 1400.65 | 60.55 | -.0319 |
| 17.0 | 192.85 | 46.17 | -.0764 | 494.25 | 49.89 | -.0671 | 696.98 | 52.25 | -.0612 | 984.38 | 55.56 | -.0530 | 1392.59 | 60.20 | -.0414 |
| | 188.85 | 45.06 | -.0834 | 483.75 | 48.83 | -.0732 | 683.27 | 51.22 | -.0668 | 967.01 | 54.58 | -.0578 | 1371.42 | 59.29 | -.0451 |
| 18.0 | 185.00 | 44.76 | -.0985 | 480.32 | 48.48 | -.0865 | 678.27 | 50.84 | -.0789 | 959.63 | 54.16 | -.0683 | 1360.42 | 58.81 | -.0533 |
| | 181.70 | 43.64 | -.1054 | 469.74 | 47.41 | -.0925 | 664.47 | 49.81 | -.0844 | 942.13 | 53.17 | -.0730 | 1339.13 | 57.89 | -.0570 |
| 19.0 | 181.70 | 41.33 | -.1004 | 448.83 | 45.30 | -.0881 | 637.98 | 47.82 | -.0804 | 910.07 | 51.36 | -.0696 | 1302.97 | 56.33 | -.0543 |
| | 181.70 | 41.04 | -.1156 | 445.50 | 44.97 | -.1015 | 633.09 | 47.46 | -.0926 | 902.82 | 50.96 | -.0801 | 1292.12 | 55.86 | -.0625 |
| 20.0 | 178.35 | 36.99 | -.0931 | 409.40 | 41.32 | -.0817 | 587.95 | 44.07 | -.0746 | 849.32 | 47.94 | -.0645 | 1234.12 | 53.35 | -.0504 |
| | 176.90 | 36.99 | -.1112 | 408.57 | 41.24 | -.0976 | 586.13 | 43.94 | -.0891 | 845.60 | 47.73 | -.0771 | 1226.86 | 53.04 | -.0602 |
| 21.0 | 175.00 | 36.99 | -.1293 | 407.74 | 41.16 | -.1135 | 584.31 | 43.80 | -.1035 | 841.88 | 47.52 | -.0896 | 1219.60 | 52.73 | -.0699 |
| | 172.50 | 36.49 | -.1424 | 402.57 | 40.64 | -.1250 | 577.16 | 43.27 | -.1140 | 832.03 | 46.96 | -.0987 | 1206.09 | 52.14 | -.0770 |
| 22.0 | 170.05 | 36.40 | -.1596 | 401.01 | 40.48 | -.1401 | 574.44 | 43.06 | -.1278 | 827.28 | 46.69 | -.1106 | 1197.78 | 51.78 | -.0863 |
| | 168.40 | 35.82 | -.1718 | 395.10 | 39.88 | -.1509 | 566.39 | 42.46 | -.1376 | 816.40 | 46.08 | -.1191 | 1183.22 | 51.15 | -.0930 |
| 23.0 | 165.10 | 35.81 | -.1898 | 394.14 | 39.78 | -.1666 | 564.41 | 42.31 | -.1520 | 812.49 | 45.86 | -.1315 | 1175.77 | 50.83 | -.1027 |
| | 164.70 | 35.47 | -.2045 | 390.41 | 39.41 | -.1796 | 559.03 | 41.91 | -.1638 | 804.67 | 45.42 | -.1417 | 1164.33 | 50.34 | -.1106 |
| 24.0 | 164.30 | 35.12 | -.2191 | 386.55 | 39.02 | -.1924 | 553.48 | 41.49 | -.1755 | 796.67 | 44.96 | -.1518 | 1152.70 | 49.83 | -.1185 |

LDC = Load Duration Curve

## 2.8 Integrated Load Function

An integrated load function is a curve that loads (or required capacity) are plotted as ordinates and cumulative energies as abscissae, hence a certain value of cumulative energy corresponds to a certain load level such that from the peak load down to this load level the total energy required is equal to that cumulative energy.

On the load duration curve, this cumulative energy is represented by the area of the upper triangle-like portion (not exactly triangle but approximately shaped), as against the integrated load function on which it is represented by the length of the abscissa.

Therefore the integrated load function is obtained by integrating the areas under the load duration curves from the peak down to the corresponding load levels. The integrated load function is very useful for estimating the firm capacity and other related values of a proposed hydro power project.

The calculated integrated load function of Northern Region in 1995, 2000, 2005, 2010, 2015 and 2020 are shown on Table 2-15 and are plotted on Fig. 2-32 through Fig. 2-37.

Table 2–15 Integrated Load Function of Northern Region

| Depth of load level from peak (MW) | Cumulative energy to meet load (MWH) | | | |
|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2010 |
| 10.0 | 4.6 | 4.3 | 3.8 | 2.9 |
| 20.0 | 9.6 | 9.3 | 8.8 | 7.9 |
| 30.0 | 22.5 | 14.3 | 13.8 | 12.9 |
| 40.0 | 32.5 | 30.0 | 18.8 | 17.9 |
| 50.0 | 49.4 | 40.0 | 36.8 | 22.9 |
| 60.0 | 64.4 | 56.8 | 46.8 | 43.1 |
| 70.0 | 87.3 | 71.8 | 56.8 | 53.1 |
| 80.0 | 107.3 | 86.8 | 78.1 | 63.1 |
| 90.0 | 127.3 | 112.0 | 93.1 | 84.5 |
| 100.0 | 147.3 | 132.0 | 115.3 | 99.5 |
| 110.0 | 167.3 | 152.0 | 135.3 | 114.5 |
| 120.0 | 187.3 | 172.0 | 155.3 | 139.8 |
| 130.0 | 225.4 | 192.0 | 175.3 | 159.8 |
| 140.0 | 250.4 | 212.0 | 195.3 | 179.8 |
| 150.0 | 284.2 | 232.0 | 215.3 | 199.8 |
| 160.0 | 314.2 | 272.7 | 235.3 | 219.8 |
| 170.0 | 344.2 | 297.7 | 255.3 | 239.8 |
| 180.0 | 374.2 | 329.1 | 275.3 | 259.8 |
| 190.0 | 417.6 | 359.1 | 318.5 | 279.8 |
| 200.0 | 452.6 | 389.1 | 343.5 | 299.8 |
| 210.0 | 487.6 | 419.1 | 368.5 | 343.8 |
| 220.0 | 522.6 | 449.1 | 403.0 | 368.8 |
| 230.0 | 557.6 | 479.1 | 433.0 | 393.8 |
| 240.0 | 592.6 | 526.3 | 463.0 | 426.8 |
| 250.0 | 627.6 | 561.3 | 493.0 | 456.8 |
| 260.0 | 662.6 | 596.3 | 523.0 | 486.8 |
| 270.0 | 697.6 | 631.3 | 553.0 | 516.8 |
| 280.0 | 756.5 | 666.3 | 599.5 | 546.8 |
| 290.0 | 800.1 | 701.3 | 634.0 | 576.8 |
| 300.0 | 852.9 | 736.3 | 669.5 | 606.8 |
| 310.0 | 907.9 | 771.3 | 704.5 | 654.7 |
| 320.0 | 968.1 | 806.3 | 739.5 | 689.7 |
| 330.0 | 1028.1 | 841.3 | 774.5 | 724.7 |
| 340.0 | 1093.6 | 876.3 | 809.5 | 759.7 |
| 350.0 | 1158.6 | 940.7 | 844.5 | 794.7 |
| 360.0 | 1223.6 | 980.7 | 879.5 | 829.7 |
| 370.0 | 1288.6 | 1031.7 | 914.5 | 864.7 |
| 380.0 | 1365.2 | 1086.6 | 949.5 | 899.7 |
| 390.0 | 1439.0 | 1141.6 | 984.5 | 934.7 |
| 400.0 | 1519.5 | 1196.6 | 1019.5 | 969.7 |

(continued)

| Depth of load level from peak (MW) | Cumulative energy to meet load (MWH) | | | |
|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2010 |
| 410.0 | 1609.1 | 1261.9 | 1054.5 | 1004.7 |
| 420.0 | 1703.4 | 1321.9 | 1126.1 | 1039.7 |
| 430.0 | 1805.8 | 1389.8 | 1170.0 | 1074.7 |
| 440.0 | 1910.8 | 1454.8 | 1218.9 | 1109.7 |
| 450.0 | 2033.4 | 1519.8 | 1268.9 | 1144.7 |
| 460.0 | 2168.8 | 1584.8 | 1327.7 | 1220.0 |
| 470.0 | 2315.4 | 1649.8 | 1382.7 | 1265.1 |
| 480.0 | 2468.5 | 1730.2 | 1437.7 | 1313.4 |
| 490.0 | 2626.7 | 1804.6 | 1504.5 | 1363.4 |
| 500.0 | 2793.2 | 1882.5 | 1564.5 | 1419.7 |
| 510.0 | 2967.4 | 1967.2 | 1624.5 | 1474.7 |
| 520.0 | 3148.0 | 2059.0 | 1696.5 | 1529.7 |
| 530.0 | 3335.2 | 2153.9 | 1761.5 | 1584.7 |
| 540.0 | 3520.2 | 2252.7 | 1826.5 | 1652.1 |
| 550.0 | 3717.7 | 2358.8 | 1891.5 | 1712.1 |
| 560.0 | 3912.7 | 2468.9 | 1956.5 | 1772.1 |
| 570.0 | 4107.7 | 2588.1 | 2037.4 | 1842.6 |
| 580.0 | 4302.7 | 2718.1 | 2107.4 | 1907.6 |
| 590.0 | 4521.7 | 2856.5 | 2184.0 | 1972.6 |
| 600.0 | 4747.4 | 3004.1 | 2262.4 | 2037.6 |
| (604.2) | 4846.8 | — | — | — |
| 610.0 | | 3154.1 | 2346.4 | 2102.6 |
| 620.0 | | 3310.9 | 2436.2 | 2167.6 |
| 630.0 | | 3471.3 | 2526.2 | 2249.9 |
| 640.0 | | 3638.7 | 2622.2 | 2319.9 |
| 650.0 | | 3808.7 | 2720.4 | 2389.9 |
| 660.0 | | 3990.1 | 2824.7 | 2470.9 |
| 670.0 | | 4173.8 | 2929.7 | 2551.7 |
| 680.0 | | 4358.8 | 3041.3 | 2636.3 |
| 690.0 | | 4543.8 | 3157.5 | 2721.3 |
| 700.0 | | 4737.4 | 3282.0 | 2814.8 |
| 710.0 | | 4933.2 | 3413.9 | 2904.8 |
| 720.0 | | 5128.2 | 3548.9 | 3002.7 |
| 730.0 | | 5323.2 | 3694.5 | 3101.0 |
| 740.0 | | 5518.2 | 3843.4 | 3201.0 |
| 750.0 | | 5728.6 | 3993.4 | 3308.5 |
| 760.0 | | 5942.8 | 4150.1 | 3413.5 |
| 770.0 | | 6166.7 | 4308.6 | 3526.3 |
| 780.0 | | 6400.6 | 4468.6 | 3640.1 |
| (780.5) | | 6414.2 | — | — |
| 790.0 | | | 4637.9 | 3759.6 |
| 800.0 | | | 4807.9 | 3885.0 |
| 810.0 | | | 4984.9 | 4014.5 |

(continued)

| Depth of load level from peak (MW) | Cumulative energy to meet load (MWH) | | | |
|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2010 |
| 820.0 | | | 5165.6 | 4148.1 |
| 830.0 | | | 5350.2 | 4283.1 |
| 840.0 | | | 5535.2 | 4426.1 |
| 850.0 | | | 5720.2 | 4572.8 |
| 860.0 | | | 5905.2 | 4723.4 |
| 870.0 | | | 6104.7 | 4873.4 |
| 880.0 | | | 6299.7 | 5030.1 |
| 890.0 | | | 6494.7 | 5185.1 |
| 900.0 | | | 6689.7 | 5346.7 |
| 910.0 | | | 6884.7 | 5506.7 |
| 920.0 | | | 7079.7 | 5674.7 |
| 930.0 | | | 7295.6 | 5846.5 |
| 940.0 | | | 7508.2 | 6016.5 |
| 950.0 | | | 7727.1 | 6195.9 |
| 960.0 | | | 7953.4 | 6377.3 |
| 970.0 | | | 8186.8 | 6357.3 |
| (975.1) | | | 8309.3 | — |
| 980.0 | | | | 6745.7 |
| 990.0 | | | | 6930.7 |
| (990.7) | 14123.9 | — | — | — |
| 1000.0 | | | | 7115.7 |
| 1010.0 | | | | 7300.7 |
| 1020.0 | | | | 7499.6 |
| 1030.0 | | | | 7696.9 |
| 1040.0 | | | | 7891.9 |
| 1050.0 | | | | 8086.9 |
| 1060.0 | | | | 8281.9 |
| 1070.0 | | | | 8476.9 |
| 1080.0 | | | | 8686.9 |
| 1090.0 | | | | 8890.6 |
| 1100.0 | | | | 9100.6 |
| 1110.0 | | | | 9315.5 |
| 1120.0 | | | | 9534.9 |
| 1130.0 | | | | 9758.6 |
| 1140.0 | | | | 9986.8 |
| 1150.0 | | | | 10220.3 |
| 1160.0 | | | | 10455.3 |
| (1160.4) | | | | 10467.6 |
| 1334.0 | — | 19697.7 | — | — |
| 1771.8 | — | — | 27429.5 | — |
| 2313.1 | — | — | — | 38132.4 |

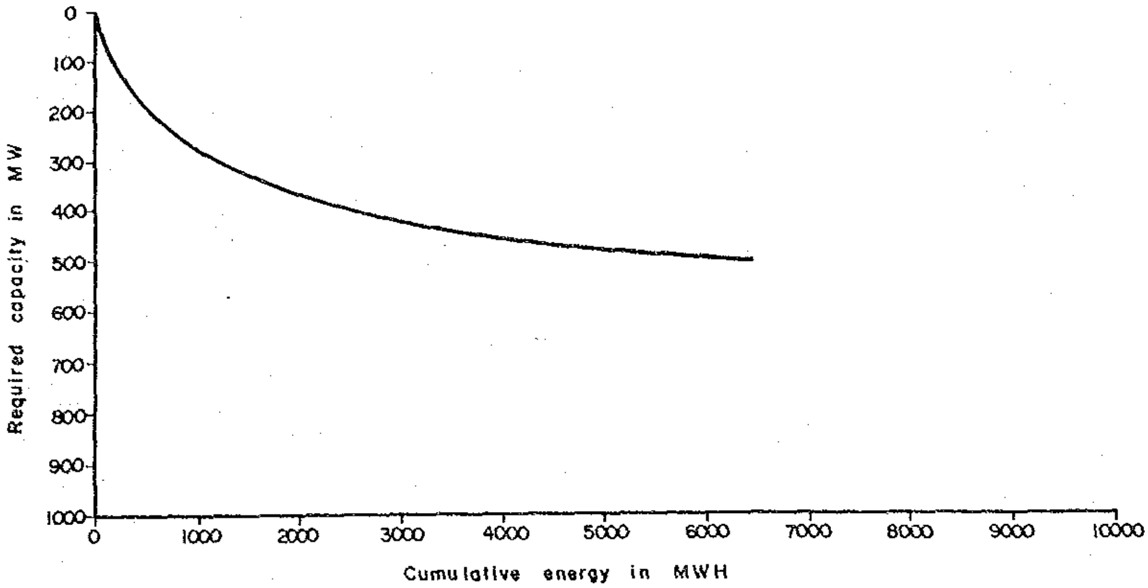



Fig. 2–32 Integrated Load Function of Peak Demand Day Northern Region 1995

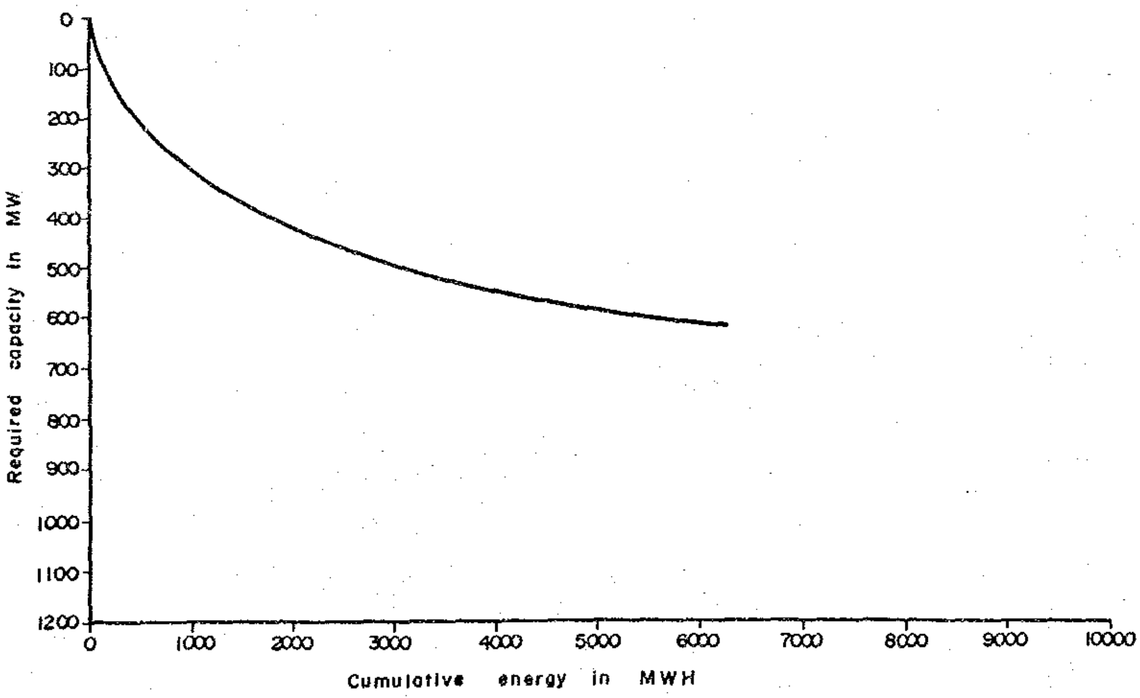



Fig. 2–33 Integrated Load Function of Peak Demand Day Northern Region 2000

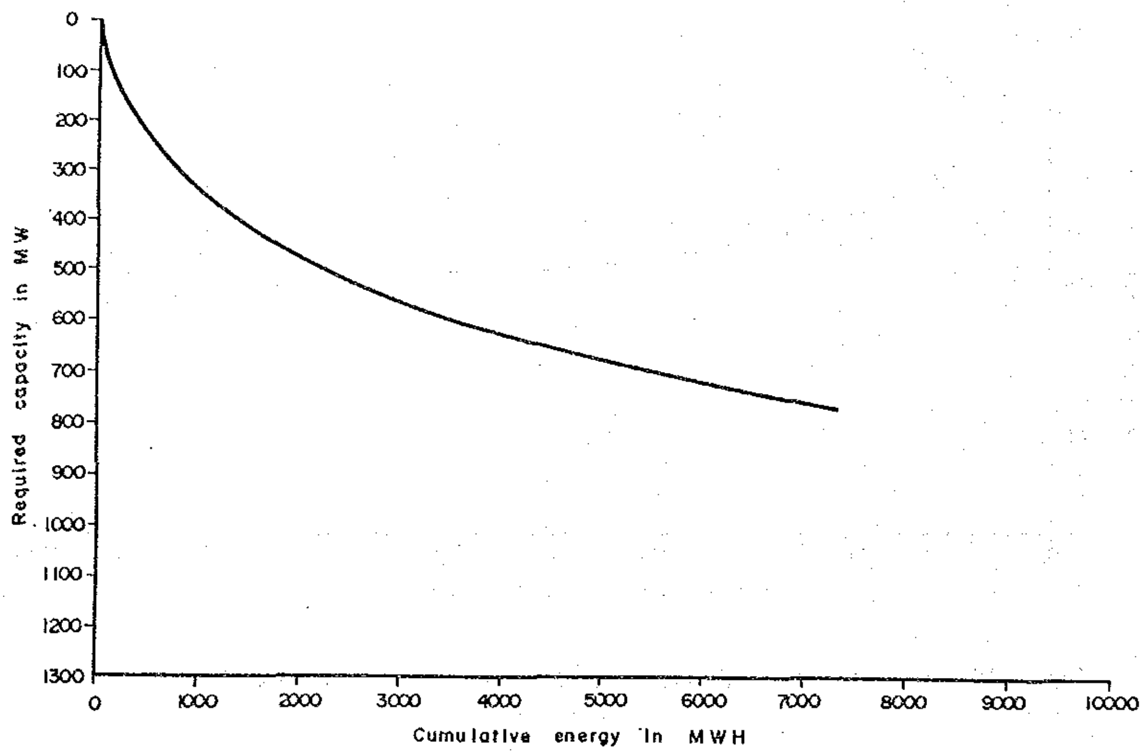



Fig. 2–34 Integrated Load Function of Peak Demand Day Northern Region 2005

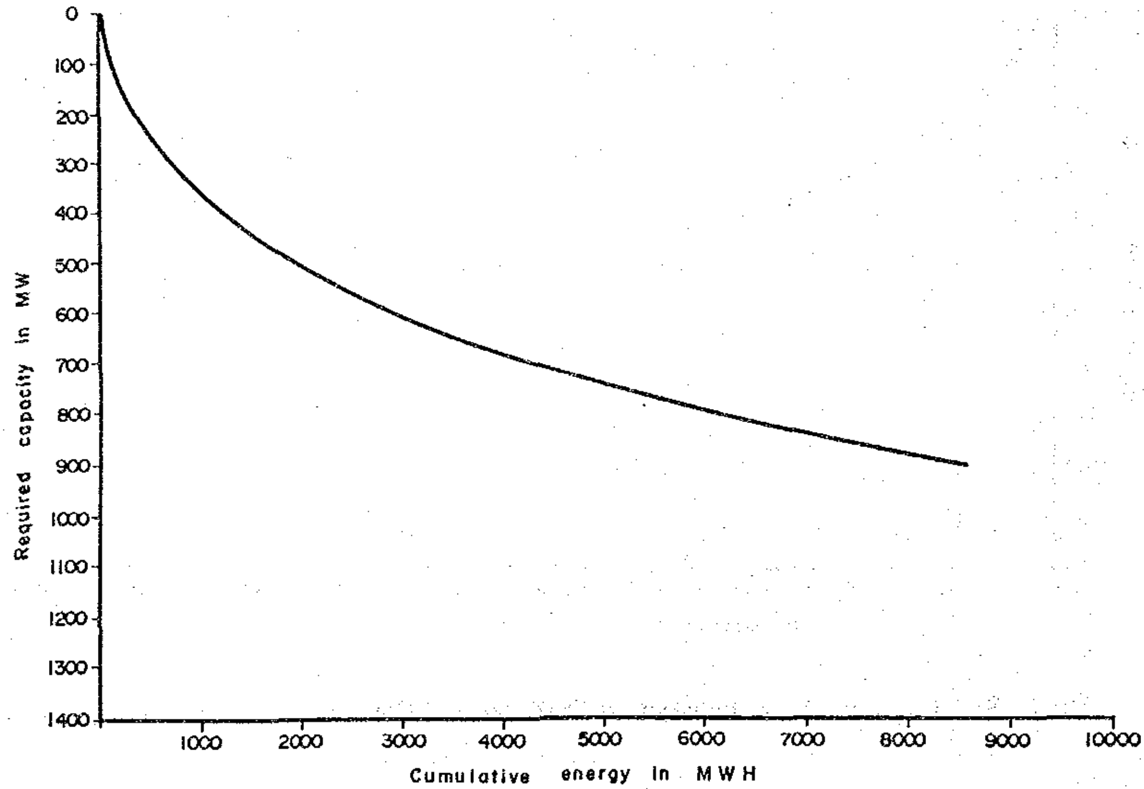



Fig. 2–35 Integrated Load Function of Peak Demand Day Northern Region 2010

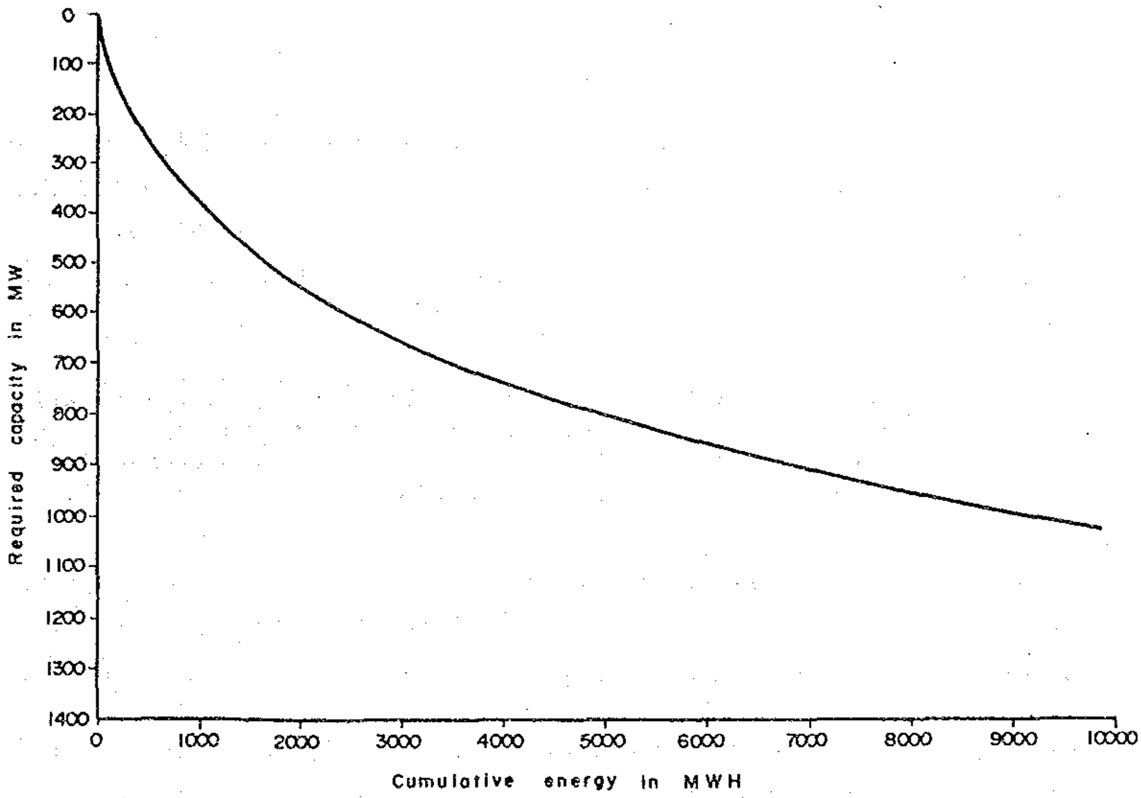



Fig. 2–36 Integrated Load Function of Peak Demand Day Northern Region 2015

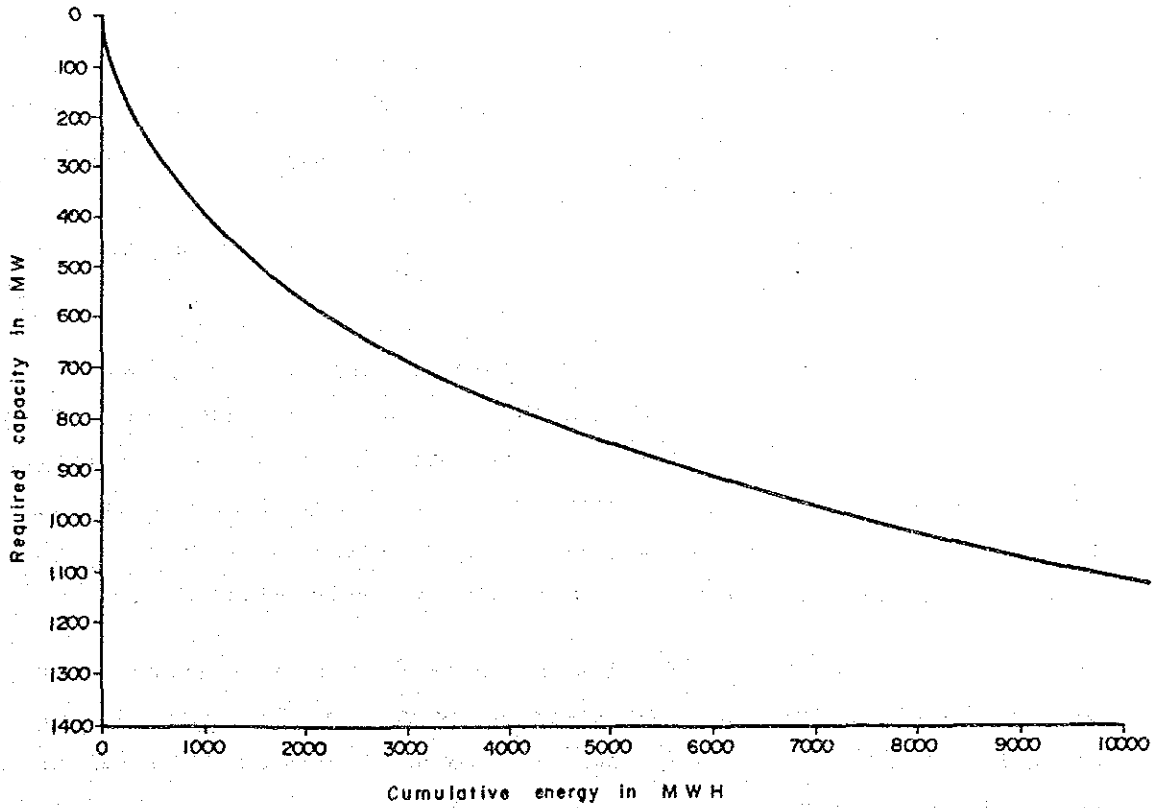



Fig. 2–37 Integrated Load Function of Peak Demand Day Northern Region 2020

## 2.9 Daily Plant Factor

This section deals with an estimation of a daily plant factor of a hydro power project. 1) In the previous section we have estimated the load duration curves and the integrated load functions of the Northern Region of the maximum demand days in 1995, 2000, 2005, 2010, 2015 and 2020.

1) The daily plant factor should not be confused with the daily load factor which is discussed in the previous sections. The former refers to an individual power plant, whereas the latter considers a power system as a whole.

In Chapter 5, the reservoir simulations were performed for various projects in the Yuam river basin and the daily firm energies were obtained for each alternative project.

Usually storage type and pondage type hydro power plants supply energy for the peak portion of the load duration curve. Since the proposed hydro power plants in this study are mainly of these types, their relative position should be higher in the load duration curve.

Hence, if there are no peaking power plants existed in the system and if only one hydro power plant is newly proposed, the firm capacity of the hydro power plant is easily determined by fitting its firm energy into the top portion of the load duration curve (i.e. let the area of the top portion equal to the firm energy) and read off the height (in MW) of this fit portion.

However, if there are several peaking power plants already existed or will come into operation in near future, we must take them all together into account and study the positions at which these peaking power plants occupy cooperatively under the load duration curve, because there are no reasons why the newly proposed hydro power plant should be positioned higher than other peaking hydro power plants.

Therefore the total firm energies of these conventional hydro power plants should fit to the load duration curve and the combined firm capacity should be read off, and the common plant factor to all of them will be calculated.

Then this plant factor should be adopted to the newly proposed hydro power plant. According to the EGAT hydro power development plan, several hydro power projects are proposed in the Northern Region other than the projects proposed in this study. Among those the Lower Yuam hydropower project is one of the most promising projects. Therefore, the plant factor of our projects should be determined on a base of the integrated development planning of the Yuam river basin as a whole. Although this is a purely theoretical procedure, we trially assume three daily plant factors, 15%, 20% and 25%, compare respective results and adopt the factor that will give the most economical one.

# CHAPTER 3. GEOLOGY

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## 3.1 Introduction

The investigation just made is a master plan study for the hydro-electric power development project described in Chapter 1, and was carried out from 1985 into 1986.

Field geological investigations for the purpose of obtaining basic data required for preparation of a master plan for the Project were carried out three times, from July to August 1985, from October 1985 to January 1986, and from June to July 1986.

The geological studies in this Report were made based on the results of the various investigations such as photogeological interpretation, surface geological reconnaissance, and drilling investigations carried out in the field during the abovementioned periods.

## 3.2 Geological Investigation Works

### 3.2.1 Investigation Area

The present hydroelectric power development project was studied considering following sites.

Upper Mae Yuam 1
Upper Mae Yuam 2
Upper Mae Yuam 3
Nam Mae Rit
Upper Nam Mae Rit 1
Upper Mae Rit 2
Upper Mae Rit 2a (alternative to Upper Mae Rit 2)
Upper Mae Rit 3
Nam Mae Ngao No. 2
Nam Mae Ngao No. 3 (alternative to Nam Mae Ngao No. 2)
Upper Mae Ngao

Among the abovementioned sites, the six sites of Upper Mae Yuam 1, Upper Mae Yuam 2, Nam Mae Rit, Upper Mae Rit 2a, Nam Mae Ngao No. 2, and Nam Mae Ngao No. 3 were selected at the beginning of the study and field geological investigations were planned. However, a field reconnaissance could not be made for the Upper Mae Rit 2a site because of lack of access to the dam site, and topographic and geological conditions were grasped through photogeological interpretations and studies of existing data.

Of these individual dam sites, it was decided as a result of discussions between EGAT and JICA Survey Team during the second field investigations, that studies would be made mainly on the four sites of Upper Mae Yuam 1, Nam Mae Rit, Upper Mae Rit 2a, and Nam Mae Ngao No. 2. And of these four, the Nam Mae Ngao No. 2 site was recognized as being the most promising from an economic point of view.

### 3.2.2 Investigation Method and Quantity

The geological investigations in this project consist of photogeological interpretations, surface geological reconnaissances (including construction materials investigations), and core drillings, but surface geological reconnaissance and drilling works were not done at Upper Mae Rit 2a of the six sites mentioned previously, for the reason that it was inaccessible. Drilling works were planned at the other sites, but really executed at four site except Nam Mae Ngao No.3. In construction materials investigations, confirmations were made of locations where samples were collected for impervious core materials in geological reconnaissances, but geological reconnaissances could not be made of rock quarry sites and locations were selected based solely on photogeological interpretations.

As for borrow areas of impervious core materials, sample collection and laboratory tests were carried out by EGAT.

The methods of investigation and quantities in the present study are as follows:

a) Photogeological Interpretation

Photo scale: 1:20,000

Interpretation extent:

| | |
|---|---|
| Yuam River Basin | 100 $km^2$ |
| Rit River Basin | 120 $km^2$ |
| Ngao River Basin | 100 $km^2$ |

b) Surface Geological Reconnaissance

Reconnaissanced area:

Dam site and surroundings

Reservoir area and along neighboring streams

Topographic map scales

| | | |
|---|---|---|
| Nam Mae Ngao No. 2 | 1:5,000 | (aerial map) |
| Nam Mae Ngao No. 3 | 1:5,000 | (aerial map) |
| Upper Mae Yuam 1 | 1:50,000 | |
| Upper Mae Yuam 2 | 1:50,000 | |
| Nam Mae Rit | 1:5,000 | (aerial map) |
| Upper Mae Rit 2a | 1:50,000 | |

c) Core Drilling (Including Permeability Test)

| | | | |
|---|---|---|---|
| Four project sites | 17 holes | Total length 1,057.3 m | |
| Nam Mae Ngao No. 2 | | 7 holes | 467 m |
| Upper Mae Yuam 1 | | 2 " | 100 m |
| Upper Mae Yuam 2 | | 3 " | 170 m |
| Nam Mae Rit | | 5 " | 320.3 m |

Details of the individual holes are given in Table 3.1.

d) Test Pits for Impervious Core Materials

| | | |
|---|---|---|
| Four project sites | 51 pits | Total length 212.3 m |
| Nam Mae Ngao No.2 | 14 " | 55 m |
| Upper Mae Yuam 1 | 12 " | 57 m |
| Upper Mae Yuam 2 | 12 " | 55.2 m |
| Nam Mae Rit | 13 " | 45.1 m |

e) Chemical Analysis of Rocks

6 samples

f) Microscopic Observation of Rocks

4 samples

## Table 3–1 List of Drill Holes

| Site | Hole No. | Coordinate | Elevation (m) | Angle from Horizontal | Length (m) | Permeability Test (times) |
|---|---|---|---|---|---|---|
| Nam Mae Ngao No. 2 | DR-0 | 1,967,292.658N 393,859.171E | 271.906 | 90° | 35.0 | - |
| | DR-1 | 1,967,248.685N 393,919.829E | 271.250 | 90° | 90.0 | 11 |
| | DR-2 | 1,967,208.138N 393,792.266E | 223.833 | 90° | 35.0 | - |
| | DR-3 | 1,967,177,086N 393,668.690E | 180.650 | 90° | 55.0 | 9 |
| | DR-4 | 1,967,131,422N 393,520.217E | 161.050 | 90° | 90.0 | 15 |
| | DL-1 | 1,967,083,846N 393,344.150E | 220.380 | 90° | 70.0 | 7 |
| | DL-2 | 1,967,051,193N 393,227.917E | 302.412 | 90° | 92.0 | 3 |
| | Sub Total (7 Holes) | | | | 467.0 m | 45 times |
| Upper Mae Yuam 1 | DR-1 | - | 344.785 | 90° | 50.0 | 1 |
| | DL-1 | - | 330.606 | 90° | 50.0 | - |
| | Sub Total (2 Holes) | | | | 100.0 m | 1 time |
| Upper Mae Yuam 2 | DR-1 | - | 352.332 | 90° | 60.0 | 9 |
| | DR-2 | - | 337.192 | 90° | 50.0 | 8 |
| | DL-1 | - | 354.394 | 90° | 60.0 | 10 |
| | Sub Total (3 Holes) | | | | 170.0 m | 27 times |
| Nam Mae Rit | DR-1 | 1,981,543.079N 394,165.979E | 334.894 | 90° | 49.8 | 4 |
| | DR-2 | 1,981,461.980N 394,246.574E | 237.927 | 90° | 70.0 | 10 |
| | DL-1 | 1,981,408.528N 394,326.509E | 193.697 | 90° | 60.5 | 10 |
| | DL-2 | 1,981,386.919N 394,360.166E | 224.992 | 90° | 70.0 | 10 |
| | DL-3 | 1,981,301.726N 394,462.970E | 299.616 | 90° | 70.0 | 4 |
| | Sub Total (5 Holes) | | | | 320.3 m | 38 times |
| Total (17 Holes) | | | | | 1,057.3 m | 111 times |

## 3.3 Topography and Geology of Project Area

### 3.3.1 Topography

The Yuam river rises from the vicinity of Khun Yuam near 19° north latitude and 98° east longitude, flows south through the Mae Sariang basin for approximately 120 km, eventually changes its course to the west, merges with the Moei river which is a major tributary of the Salawin river, after which it merges with the Salawin river comprising the border between Thailand and Burma.

Meanwhile, the Rit river, which is one of the tributaries of the Yuam river, rises from the vicinity of 18°15' north latitude and 98°15' east longitude, changes its course from south to southwest, and then west, joining the Yuam river after running for about 50 km. As for the Ngao river which is the first of the tributaries of the Yuam river, it flows in the north-northwest direction for approximately 40 km from the vicinity of 17°40' north latitude and 98° east longitude to merge with the Yuam river.

A broad basin is developed along the Yuam river from near its fountainhead to the vicinity of about 25 km south of Mae Sariang, but downstream from this point and along the Ngao river is generally a steep gorge.

The catchment of the Yuam river basin of area approximately 6,000 $km^2$ extends north-south in a slender shape, being approximately 30 to 50 km in width and approximately 160 km in length.

The western boundary of the Yuam river basin consists of a mountainous terrains of around EL. 1,000 m which extends in a straight line southward from Mt. Wi Cho Lo (EL. 1,056 m), while the eastern boundary is the mountainous terrains extending southward at elevations of 1,500 to 1,800 m from Mt. Phate Do (EL. 1,821 m).

### 3.3.2 Geology

The project area, as shown in Fig. 3-1, consists mainly of Paleozoic and Mesozoic sedimentary rocks, and Mesozoic granite.

Paleozoic formations ranging from Cambrian to Carboniferous age may be divided into formations which are mainly non-calcareous rocks and the Ordovician formations which are mainly limestone. The former are widely distributed centered at the southern and eastern parts of the project area, while the latter are distributed in band-form in the north-south direction inside the formations that are mainly non-calcareous rocks.

Paleozoic formations ranging from Carboniferous to Permian age and Triassic formations are both mainly of non-calcareous rocks and are distributed making up most of the northwestern part of the project area.

Granite is intruded in Paleozoic formations at the entire eastern part of the project area and is distributed in the north-south direction as a slender rock body approximately 10 to 20 km in width.

Mesozoic orogenic movements of the two time phases of latest Triassic to Jurassic and Jurassic to Cretaceous have occurred in the northern part of Thailand including this area, the present geologic structure being dominated by this orogenic movement, and structures in the north-south to northwest-southeast directions are prominent. This project area, because of the influence of the above, has strikes of strata, strikes of folds, and strikes of remarkable faults that are chiefly north-south to northwest-southeast.