AN ECONOMIC STUDY OF A PROPOSED HIGH-PRESSURE BOILER AND TURBO-GENERATOR UNIT IN THE CENTRAL HEATING AND POWER PLANT OF THE VIRGINIA POLYTECHNIC INSTITUTE

by

Victor Fontaine Anderson

Thesis submitted to the Graduate Faculty of the
Virginia Polytechnic Institute
in candidacy for the degree of
MASTER OF SCIENCE
in
Power and Fuel Engineering

APPROVED:

Director of Graduate Studies

Dean of Engineering

APPROVED:

Head of Department

Supervisor or Major Professor

June, 1953

Blacksburg, Virginia

TABLE OF CONTENTS

III

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation and thanks to the following associates, whose advice and assistance greatly aided in the completion of this thesis:

C. H. Long, Associate Professor of Power and Fuel Engineering and Mechanical Engineering, for his guidance and support and for serving as chairman of the author's advisory committee;

J. P. Mahaney, Professor of Mechanical Engineering and C. F. DeBusk, Utility Engineer, for serving on the author's advisory committee and for their helpful guidance, suggestions, and criticism;

E. B. Norris, Dean of Engineering; J. B. Jones, Professor of Mechanical Engineering, for freely giving their time and good judgement when called on for advice.

J. B. Jones, Professor of Mechanical Engineering; H. S. Miles, Jr., Associate Professor of Mechanical Engineering, for aiding the author's advisory committee during the absence of C. H. Long and J. P. Mahaney, Professors of Mechanical Engineering.

The following plant personnel for their most willing cooperation: W. M. Broce, Plant Superintendent, H. B. Groseclose, C. E. Martin, J. S. Hamlin, and S. J. Pratt;

J. E. McMurrer, Jr., and A. K. Chatterjee, fellow graduate students, and Betty Lou Anderson, the author's wife, for their interest, cooperation, and moral support.

IV

INTRODUCTION

At present the Central Heating and Power Plant of the Virginia Polytechnic Institute has six (6) boilers with the following rating: Boiler No. 1, Casey Hedges Co., capacity 15,000 # steam per hr. at 165 psig saturated steam; Boiler No. 2, Casey Hedges Co., capacity 15,000 # steam per hr. at 165 psig saturated steam; Boiler No. 3, Hedges-Walsh Weidmer Co., capacity 20,000 # steam per hr. at 165 psig saturated steam; Boiler No. 4, Hedges-Walsh Weidmer Co., capacity 20,000 # steam per hr., 174 psig, temperature 452°F.; Boiler No. 5, E. Keeler Co., capacity 35,000 # steam per hr., at 250-300 psig and 100°F., superheat; Boiler No. 6, Edge Moor, iron works, capacity 60,000 # steam per hr. at 250-300 psig and 100°F., superheat.

The six (6) boilers have a combined maximum capacity of 165,000 # steam per hr.

The power plant is equipped with only two (2) turbo-generator units, which can be operated. These turbo-generators are rated as follows: Allis-Chalmers Co., Turbo-Generator, 1000 Kw at 80% power factor, steam conditions 225 psig and 100°F, superheat at a back pressure of 20 to 35 psig; Westinghouse Co., Turbo-Generator, 750 KVA, steam conditions 160 psig and 75°F., superheat, exhausting to approximately 1"Hg. abs. and bleeding steam at a pressure of 20 to 30 psig.

Tne Central Heating and Power Plant of the Virginia Polytechnic Institute generates steam primarily for the heating of campus buildings

and domestic hot water for use in the laundry, cleaning and pressing shop, dining halls, dairy, hospital, dormitory, and laboratories. All electric energy is generated as a by-product when the low pressure steam is produced by expansion through turbines. This steam is exhausted at approximately 5# gage for use in the heating systems. It can be readily seen that the amount of electric energy produced will vary as the amount of steam required for heating the campus buildings.

The average daily electric load is approximately 1,600 Kw during the heating season, with the peak load at approximately 3,200 Kw. All the electric load in excess of that produced in meeting the requirements of the campus heating system must be purchased from the Appalachian Electric Power Company. This electric load is purchased at the following rate: 12.5 mills per Kw-hr. for the first 50,000 Kw-hrs. per month; 10.0 mills per Kw-hr. for the next 250,000 Kw-hrs. per month; 8.0 mills per Kw-hr. for all energy purchased above 300,000 Kw-hrs. per month.

In recent years there has been an upward trend in both the electric load and steam load. This is partly due to the increase in the growth of Blacksburg. If this upward trend continues the college must either increase the quantity of electric energy purchased from the Appalachian Electric Power Company, or increase the operating efficiency of the Central Heating and Power Plant of the Virginia Polytechnic Institute by installing more modern and efficient electric generating equipment.

This thesis will (1) investigate the trend of the town and campus electric loads as well as the campus steam load, and (2) determine the

economical advantage of a proposed boiler and turbo-generator over the existing power plant facilities.

It is expected that a considerable amount of saving will occur through the operation of a more efficient turbo-generator and boiler unit. This boiler must be able to operate efficiently using the low grade fuel of this area.

Through this thesis evidence will be collected to determine the need of a proposed turbo-generator and boiler unit adequate for future requirements of the campus and the community of Blacksburg.

V

REVIEW OF LITERATURE

With the present increase in power supply and power demand, the ability to obtain equipment for Power Plant uses is becoming more severe. The required time given for minimum date of shipping equipment is two years. This will increase the time from the study of the proposed unit to the actual installation of the unit from two years to two and a half years. Therefore in predicting a unit the element of time must be considered from the time the unit is proposed until it is installed.[3]

In considering the lapse of time a great many things will be studied. The conditions of the world affairs, the expected increase due to the expanding of community industries, and the rate at which the towns growth has increased. The electric energy purchased by the residential customer is steadily increasing each year. This increase in electric energy is due to the scientific development of new and better home equipment, such as hot water heaters, space heating, refrigerators, electric stoves and air conditioning units.[9] "Mr. M. Feaman reported in March 1948 that the sale of hot water heaters was five times that prior to World War II."[10]

"The methods used in predicting the expected load vary from the statistical to analytical forecasting of the load changes of each of the various groups which make the total load, to the simple extension of past behavior into the future for the total load or any of its parts."[11]

" In the statistical and the analytical methods, studies are made among sample load groups to determine the daily load curves for various appliances and applications.[12] Such as average and maximum demands, diversity, load and power factors, and energy consumed and obtained.[11] Load predictions are based on this information and the trends which an analysis of this information may indicate. This type of estimate is more accurate for short periods of time."[7]

Another method involves the study of past load factors,[20] and peak[8] loads. Load factors being defined as, "the ratio of the average load to the maximum peak load of a specified duration occurring during the given period."[5] "The trend of the peak loads and load factors is extended into the future and then the indicated future average loads are obtained from the predicted information."

The extension of the past trends into the future is another method which is used a great deal in predicting a variable quantity. "This applies itself well to the electric loads that are basically residential, because the increasing load curves for this type of load is very smooth and more nearly approaches a straight line than any other type of load growth curve."[13]

The method just discussed was used by the design engineers who planned the recently constructed University of Oklahoma Heating and Power Plant.[21] These engineers made studies of the past and present steam requirements, electric energy requirements and the University's future building program with the expected student growth considered.

"From the information they were able to anticipate the future steam and electric loads required by the school to meet the demands of the near future."

When making a forecast as the one above, one must consider the seasonal effects, past trends, new and expected connected loads, world affairs and the growth of the community.[3] It is very important to have up-to-date records which are reliable and accurate.[17]

The forecaster may use any method he desires, but nothing will increase his accuracy, as that of his experience and good judgement. He must consider all information the records will give him, and from this make the best prediction he can for the future.[17]

INTRODUCTORY SUMMARY

This investigation was conducted to determine the indicated annual saving which could be expected from the proposed installation of a 5000 Kw turbo-generator unit using high-pressure steam at the Virginia Polytechnic Institute Central Heating and Power Plant.

The average electric load curves and the low pressure steam demand curves were determined for the various outdoor degree temperature days for the first half of the heating season of 1951-1952. This data was then projected into the heating seasons of 1956 - 1957, 1957 - 1958, and 1958 - 1959. The three heating seasons considered in this thesis were used because information as to the future building plans of the school are indefinite beyond the year 1958-1959. This information, together with the steam rates for the proposed 5000 Kw turbo-generator having steam conditions at 600 psig and 750°F. and 850 psig and 825°F. were used to project the curves for the expected Kw load. The steam load for 75 psig high-pressure was averaged for the winter season of 1951-1952. This steam load was used to plot the expected Kw loading due to extraction at 100 psig high-pressure steam for the past heating season.

Four curves were plotted for each average outdoor temperature degree day for each of the three heating seasons considered in order to determine the additional kw-hrs that can be produced by the proposed 5000 Kw unit. In connection with the 5000 Kw unit the steam conditions

will be considered at both 600 psig - 750°F. and 850 psig - 825°F. These units will have a back-pressure of 5 psig and will be extracting at 100 psig. The electric load produced by extracting steam at 100 psig will make use of the steam load calculated for the high pressure heating load. This will be plotted as Kw's obtained from extracting high-pressure steam and considered in the final results as to the choice of the unit with or without extraction.

The curves will be used to determine the additional kw which could be generated by a proposed unit of sufficient size to supply the expected future low-pressure steam demand to meet the outdoor temerature degree days per month. These four curves are: Curve No. 1, the expected total electrical load; Curve No. 2, the electric load obtained by extracting steam at 100 psig; Curve No. 3, the electric load of the proposed unit supplying the expected low-pressure steam demand; Curve No. 4, the electric load of the present units in operation in the Virginia Polytechnic Institute Central Heating and Power Plant.

The saving would be the daily saving for the various outdoor temperature degree days for the three heating seasons. This information and the number of days expected in each average outdoor temperature group were used to calculate the total indicated saving for each heating season that would be realized from the installation of the proposed unit.

The area bound by Curve No. 3 and its axes is the expected Kw-hrs produced by the proposed unit except where it crosses Curves No. 1 and 2. Then the curve of the lowest Kw will be considered as the boundary line.

The area bound by Curve No. 2 and its axes and Curve No. 3 is the Kw-hrs expected by use of extracting steam at 100 psig. This is the correct area except where Curve No. 3 crosses Curve No. 1, and then the curve will only follow the line of the expected load. The area under Curve No. 1 and its axes is the total expected kw-hr load for a certain degree-day temperature and heating season. The area under Curve No. 4 and its axes is the total load produced by the units now in operation in the power plant.

The values of these areas were determined by taking the area in square inches and then converting the inches into kw-hrs and multiplying the kw-hrs by a rate cost per kw-hr. The scale constant used to multiply the square inches was 1600 kw hrs per square inch. The constant used to multiply the kw-hrs by was $0.00728 per kw-hr for steam conditions at 600 psig - 750°F. and $0.0073 per kw-hr. for steam conditions at 850 psig - 825°F. The resulting figures represented the daily saving for the various average outdoor temperature degree days for the three heating seasons at either 600 psig - 750°F. or 850 psig - 825°F., with or without extraction. This information and the number of days expected in each average outdoor temperature group were used to calculate the total indicated saving that would be realized from the installation of the proposed unit.

The savings at steam conditions 600 psig and 750°F. without extraction were $34,190.00 for 1956-1957, $37,730.00 for 1957-1958, and $41,860.00 for 1958-1959. Savings in addition to that of non-extraction at same initial steam conditions with extraction at 100 psig

were $1,498.70 for 1956-1957, $2,505.50 for 1957-1958, and $3,239.60 for 1958-1959. At steam conditions 850 psig and 825°F. the savings at no extraction were $35,605.00 for 1956-1957, $39,370.00 for 1957-1958, and $46,590.00 for 1958-1959. At this same initial steam condition with extraction occurring at 100 psig the additional savings were $986.00 for 1956-1957, $1,703.90 for 1957-1958, and $2,933.00 for 1958-1959. For total saving at the extraction condition, the savings of both non-extraction and extraction must be added together. This would give the following savings at steam condition 600 psig- 750°F: $35,688.70 for 1956-1957, $40,235.50 for 1957-1958, and $45,099.60 for 1958-1959. For the total saving at steam condition 850 psig- 825°F.: $36,591.00 for 1956-1957, $41,073.90 for 1957-1958, and $49,523.00 for 1958-1959.

VII

THE INVESTIGATION

A. Object

The object of this investigation is to determine the economical advantage of a proposed high-pressure generator and boiler unit in the Central Heating and Power Plant of the Virginia Polytechnic Institute.

B. Proposed Procedure

The material for this investigation will consist of the existing records of the low pressure of 5 psig steam and of the electric load for both the non-heating and heating seasons. This procedure will assume the records for the heating year of 1951-1952 as an average year and make use of the number of degree days as an operating basis. Load curves will be plotted for the steam and electric load of the year 1951-1952, the future estimated electric load for the community of Blacksburg, and the growth of the college in the immediate future.

It will be necessary to calculate the maximum amount of electric energy which can be generated with the present equipment in the Central Heating and Power Plant of the Virginia Polytechnic Institute.

The above material will be summarized for use in determining the proposed installation of a high-pressure boiler and turbo-generator unit for the Central Heating and Power Plant of the Virginia Polytechnic Institute.

C. Procedure Followed

This study consisted of the collection and projection into the future of the information relative to the low-pressure steam and electric loads of the Virginia Polytechnic Institute Central Heating and Power Plant and was made to determine the saving that might be realized by the installation of a new 5000 Kw back pressure turbo-generator unit.

It was known that the electric load varied with the outdoor temperature. It was, therefore, decided to base the investigation on the average outdoor temperature, and plant records used for the period studied were collected into groups having outdoor temperatures of 20°F, 25°F, 30°F, 35°F, 40°F, 45°F, 50°F, 55°F, and 60°F, plus or minus 2.5°F. The daily steam loads for the Westinghouse and Allis-Chalmers Turbines were collected into their known outdoor temperature groups by use of the daily outdoor temperature records. From each temperature group the average hourly steam load was calculated for the Westinghouse and Allis-Chalmers Turbines. Then the steam load for both units was totaled. The daily kilowatt output for the Westinghouse and Allis-Chalmers Turbines was collected into their outdoor temperature groups. The total hourly load was obtained for each unit. Then the daily kilowatt output for both units was totaled.

The first half of the heating season of 1951-1952, October 15, 1951, to January 15, 1952, was taken as the basic period for which the average electric load curves and average low-pressure steam demand curves were determined and projected into the future. The information obtained was used uncorrected because it was current and because it was noted that

the various monthly average outdoor temperatures were very close to the 1951 year monthly average outdoor temperature.[6] It was an average heating year.

The heating seasons of 1956-1957, 1957-1958, and 1958-1959 were chosen as the heating seasons to be studied because it was decided that the proposed unit could not be installed before the year of 1958 and reliable information concerning the heating requirements of the campus beyond 1958-1959 was not available.

The average hourly kilowatt load on the plant was determined for each outdoor temperature group from the plant log sheets. These average hourly kilowatt loads were then projected into the future and the heating seasons studied, using a yearly increase of eight per cent. A yearly increase of eight per cent was decided upon after a discussion with the College Utility Engineer and a study of the loads, national and the expected national load increases as discussed in current engineering magazines.

The average hourly low-pressure steam demand was determined from the steam flow charts for the Allis-Chalmers and Westinghouse Turbines. There are no meters in the plant that directly measure the low-pressure steam demand. Here the assumption is made that the Westinghouse Turbine operated with the bleeder fully open, the condenser loading was negligible, and that no steam passed through the reducing valve. The average hourly low-pressure steam load thus determined was projected into the future heating seasons studied, assuming that the expected increase in the low-pressure steam demand would be proportional to the expected increase in

building radiation. The expected increase in the building radiation was obtained from the Campus Planning Engineer.

It was decided upon by the Westinghouse Planning Engineer and Campus Utility Engineer that the most feasible temperature and pressure to use for a unit of the 5000 Kw size for such an installation as the Virginia Polytechnic Institute Central Heating and Power Plant would be as follows: 600 psig-750°F., 850 psig-825°F., and 600 psig-825°F. With these values the Willans Line was drawn for all three conditions. From this, information was taken to find the steam rates for each of the units. All these data were then converted into kw-hrs and plotted.

After all the data had been used to plot curves, the information from the curves was taken in order to determine the indicated annual saving which could be expected from the proposed installation of a 5000 Kw turbo-generator unit in the Virginia Polytechnic Institute Central Heating and Power Plant. This was done by plotting four curves for each average outdoor temperature for the heating seasons considered. The curves were: Curve No. 1, the expected total electric load, Curve No. 2, the electric load obtained by extracting steam at 100 psig, Curve No. 3, the electric load of the proposed unit supplying the expected low-pressure steam demand, and Curve No. 4, the electric load for the present units in operation at the power plant.

To obtain the information to plot the curve for the electric load that could be carried by the present turbo-generator units, tests were conducted on both units to determine the Willans Line. The area under Curve

No. 3 and its axes represents the kw-hrs that the proposed unit can produce. The area between Curve No. 2 and Curve No. 3 and its axes is the kw-hrs that can be produced when the extraction is carried out. The area bound by the above curves and their axes is correct in all cases, except where the expected electric load is less than the proposed load, in which case the turbine would not operate at full load. The economical value of these areas was obtained by multiplying the areas by the scale constant, 1600 kw-hrs per square inch and by $0.00728 for steam condition at 600 psig - 750°F, and $0.0073 for steam condition at 850 psig - 825°F, the saving per kw-hr realized by generating electric energy in the plant instead of purchasing it from the local utility. The values obtained are the savings that could be expected for the operation of the proposed turbo-generator unit for the various average outdoor temperature degree days for the three heating seasons considered.

Assuming the distribution of outdoor temperature days to be the same for the heating season of 1951-1952 and the three heating seasons considered, the total indicated savings for each year that could be expected from the operation of the proposed turbo-generator unit were calculated.

D. Results

Amount Saved For Each Heating Season
Based On Number Of Days At The Average Outdoor Temperature
With No Extraction And Steam Conditions 850 Psig - 825°F

Average Outdoor Temperature Degrees F	No. Of Days Expected At Outdoor Temperature	Saving Per Heating Season In Dollars		
		1956-1957	1957-1958	1958-1959
20	12	2,080.00	2,140.00	2,740.00
25	20	3,840.00	4,025.00	5,250.00
30	26	5,650.00	6,320.00	6,660.00
35	28	5,700.00	6,300.00	6,640.00
40	28	5,175.00	6,525.00	7,850.00
45	14	2,640.00	3,220.00	3,330.00
50	20	3,940.00	4,350.00	5,700.00
55	18	3,650.00	3,920.00	4,960.00
60	18	2,930.00	2,570.00	3,460.00

Total Indicated Saving Per
Heating Season

Heating Season	1956-1957	1957-1958	1958-1959
Saving	$35,605.00	$39,370.00	$46,590.00

Additional Amount Saved For Each Heating Season
Based On Number Of Days At The Average Outdoor Temperature
When Extracting And Steam Condition 850 Psig - 825° F

Average Outdoor Temperature Degrees F	No. Of Days Expected At Outdoor Temperature	Saving Per Heating Season In Dollars		
		1956-1957	1957-1958	1958-1959
20	12	00.00	99.00	21.00
25	20	14.00	23.30	93.00
30	26	24.20	75.60	257.00
35	28	32.60	114.00	147.00
40	28	35.90	85.00	179.00
45	14	58.80	294.00	350.00
50	20	95.50	210.00	512.00
55	18	116.00	267.00	545.00
60	18	609.00	640.00	829.00

Total Indicated Saving Per
Heating Season

Heating Season	1956-1957	1957-1958	1958-1959
Saving	$986.00	$1,703.90	$2,933.00

Amount Saved For Each Heating Season
Based On Number Of Days At The Average Outdoor Temperature
With No Extraction And Steam Condition 600 Psig - 750°F

Average Outdoor Temperature Degrees F	No. Of Days Expected At Outdoor Temperature	Saving Per Heating Season In Dollars		
		1956-1957	1957-1958	1958-1959
20	12	2,080.00	2,450.00	2,870.00
25	20	3,680.00	4,440.00	5,170.00
30	26	5,100.00	5,950.00	6,720.00
35	28	5,250.00	5,620.00	6,960.00
40	28	6,000.00	6,460.00	5,000.00
45	14	2,490.00	2,620.00	3,680.00
50	20	3,820.00	3,970.00	4,970.00
55	18	3,360.00	3,630.00	3,740.00
60	18	2,410.00	2,590.00	2,750.00

Total Indicated Saving Per
Heating Season

Heating Season	1956-1957	1957-1958	1958-1959
Saving	$34,190.00	$37,730.00	$41,860.00

Additional Amount Saved For Each Heating Season
Based On Number Of Days At The Average Outdoor Temperature
When Extracting And Steam Condition 600 Psig - 750°F

Average Outdoor Temperature Degrees F	No. Of Days Expected At Outdoor Temperature	Saving Per Heating Season In Dollars		
		1956-1957	1957-1958	1958-1959
20	12	.0	14.00	28.10
25	20	93.50	70.00	163.50
30	26	43.20	273.00	273.00
35	28	68.50	146.50	261.00
40	28	98.00	228.00	720.00
45	14	179.00	325.00	229.00
50	20	187.00	397.00	535.00
55	18	252.00	442.00	420.00
60	18	577.50	610.00	610.00

Total Indicated Saving Per
Heating Season

Heating Season	1956-1957	1957-1958	1958-1959
Saving	$1,498.70	$2,505.50	$3,239.60

CURVE CHART

Curve Number	Curve Line	Meaning of Curve
1.	— — — — — — — —	Expected total electric load for the heating season.
2.	————————	Electric load of the proposed extraction unit which was obtained when extracting steam at 100 psig, supplying expected high pressure steam demand.
3.	——— — ———	Electric load of the proposed unit supplying the expected low pressure steam demand no extraction.
4.	————————	Electric load of the present units in operation at the power plant.

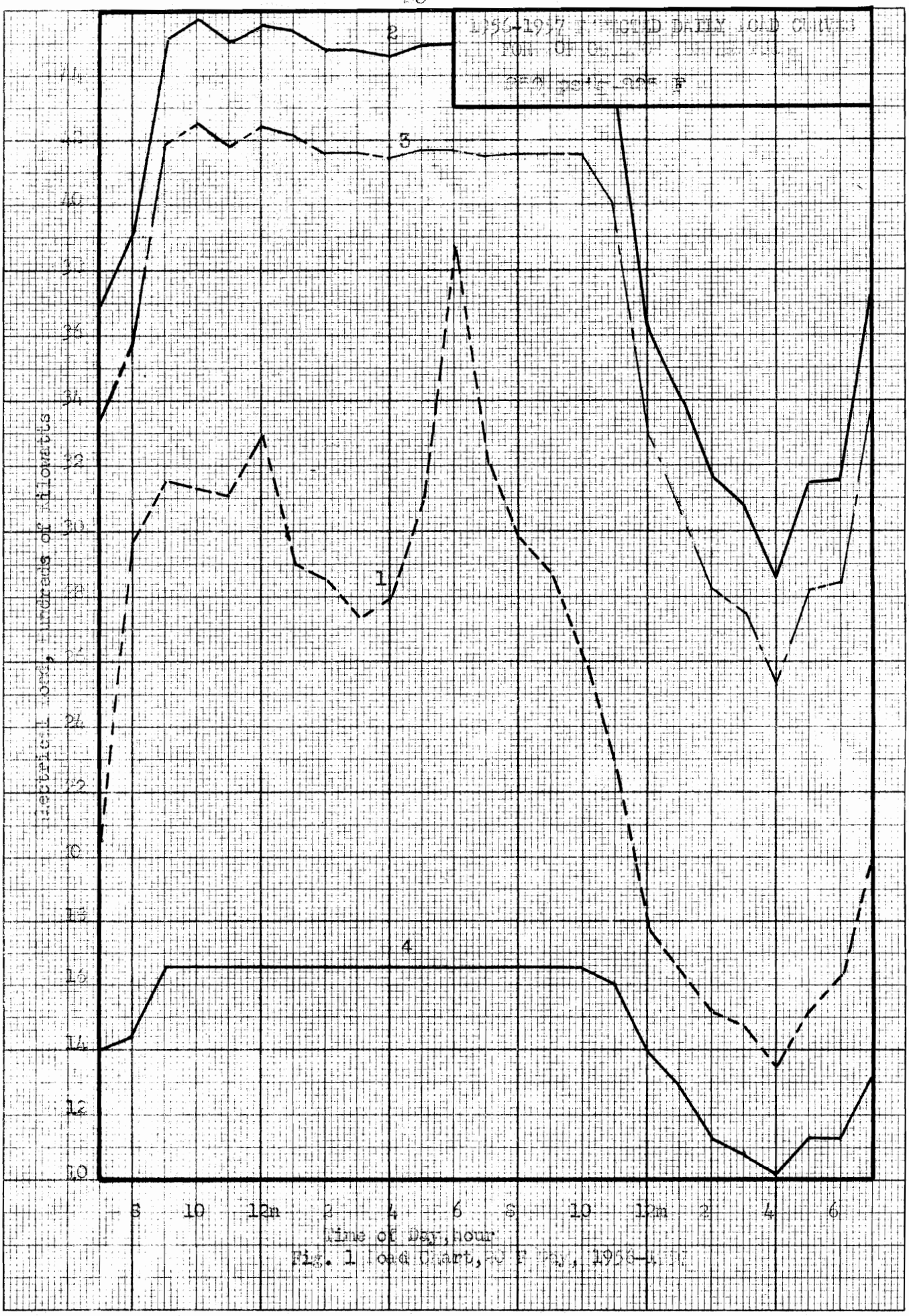


Fig. 1 Load Chart, [illegible], 1956-1957

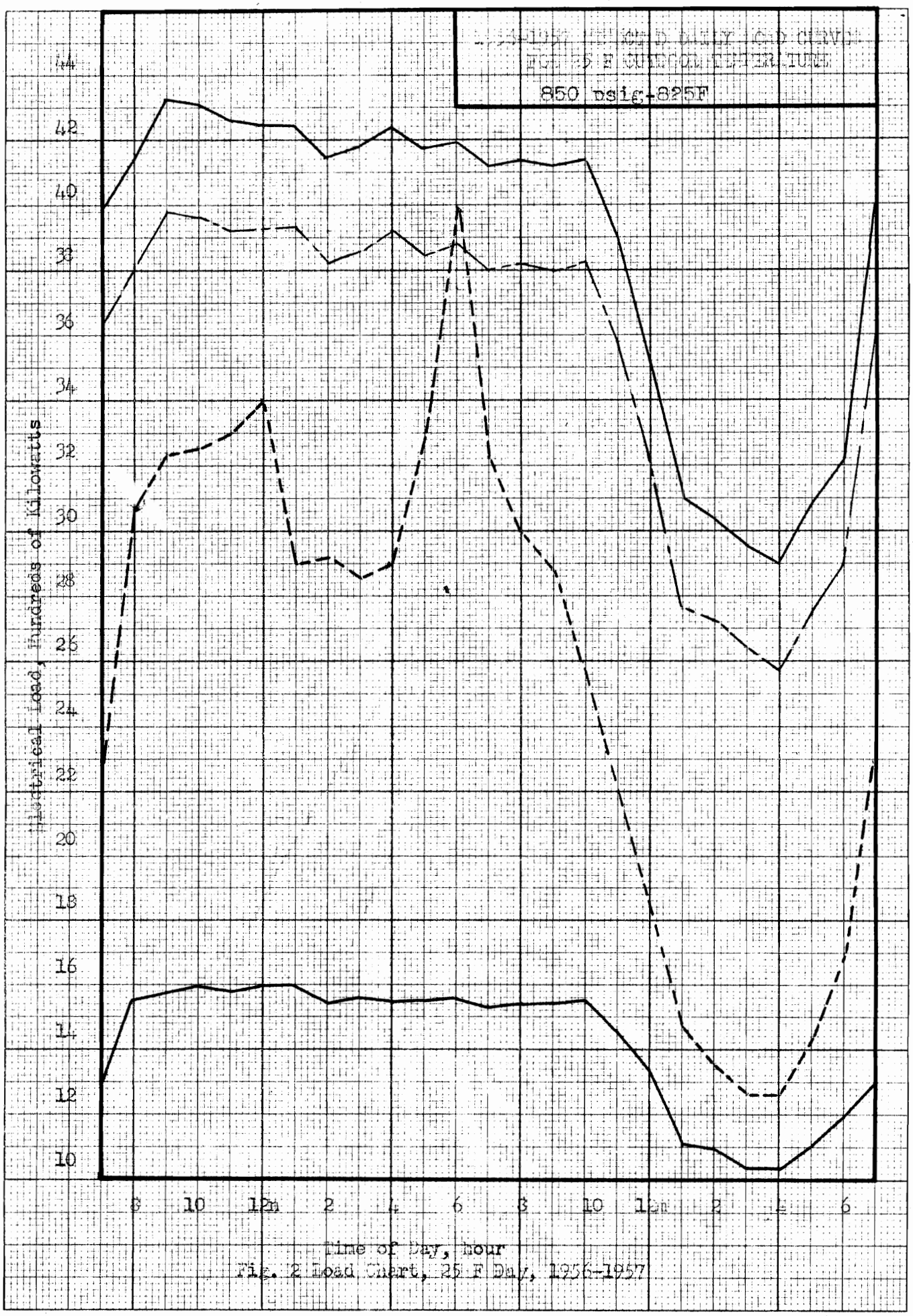


Fig. 2 Load Chart, 25 F Day, 1956-1957

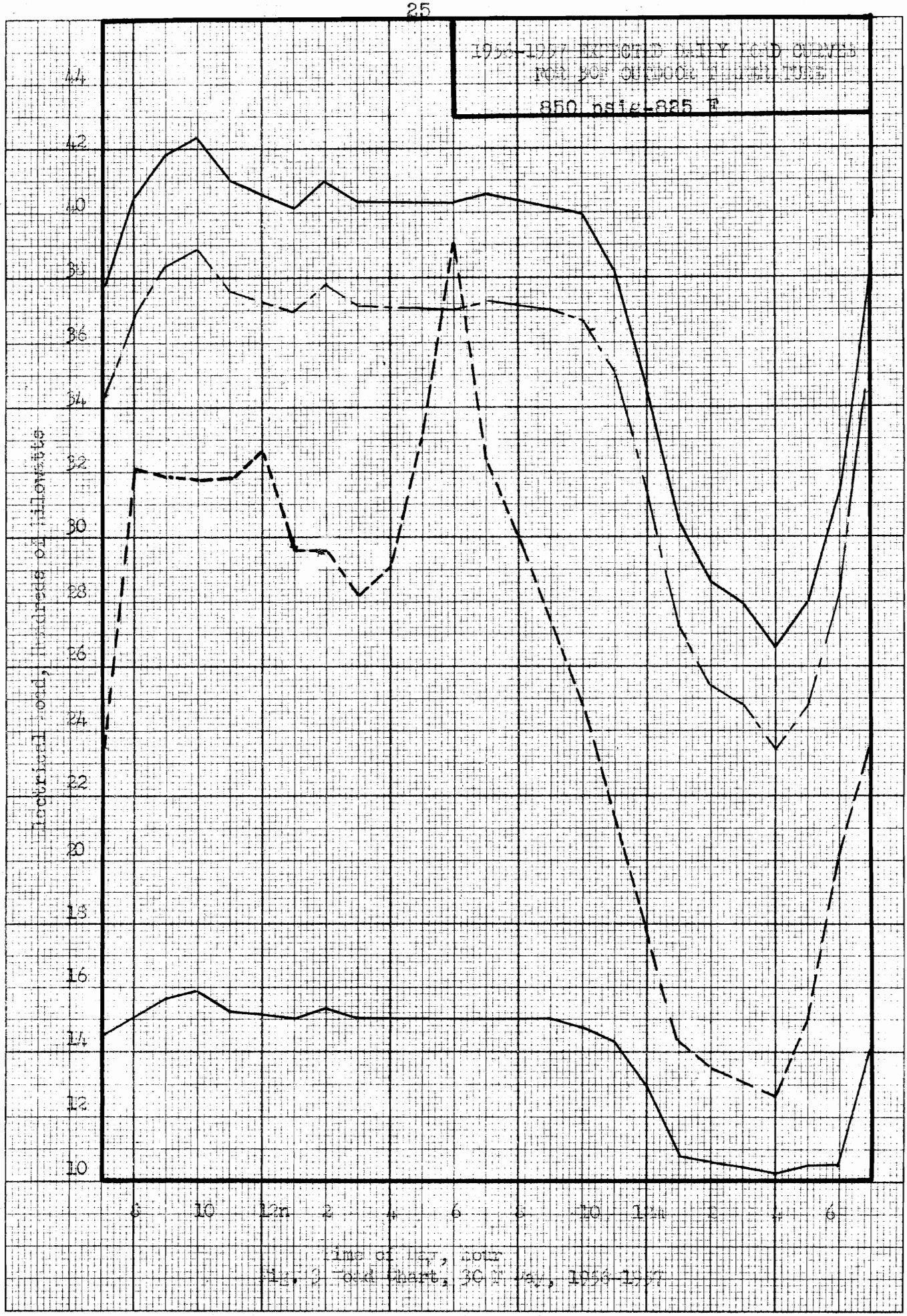

1956-1957 EXTENDED DAILY LOAD CURVES
FOR 30° SATURDAY TEMPERATURE
850 psig-825 F
Hundreds of Kilowatts
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
6
10
12n
2
4
6
8
10
12
2
4
6
Time of Day, CST
41, 2 Load Chart, 30 F Sat., 1956-1957

Fig. A Load Chart, 35 F Day, 1956-1957

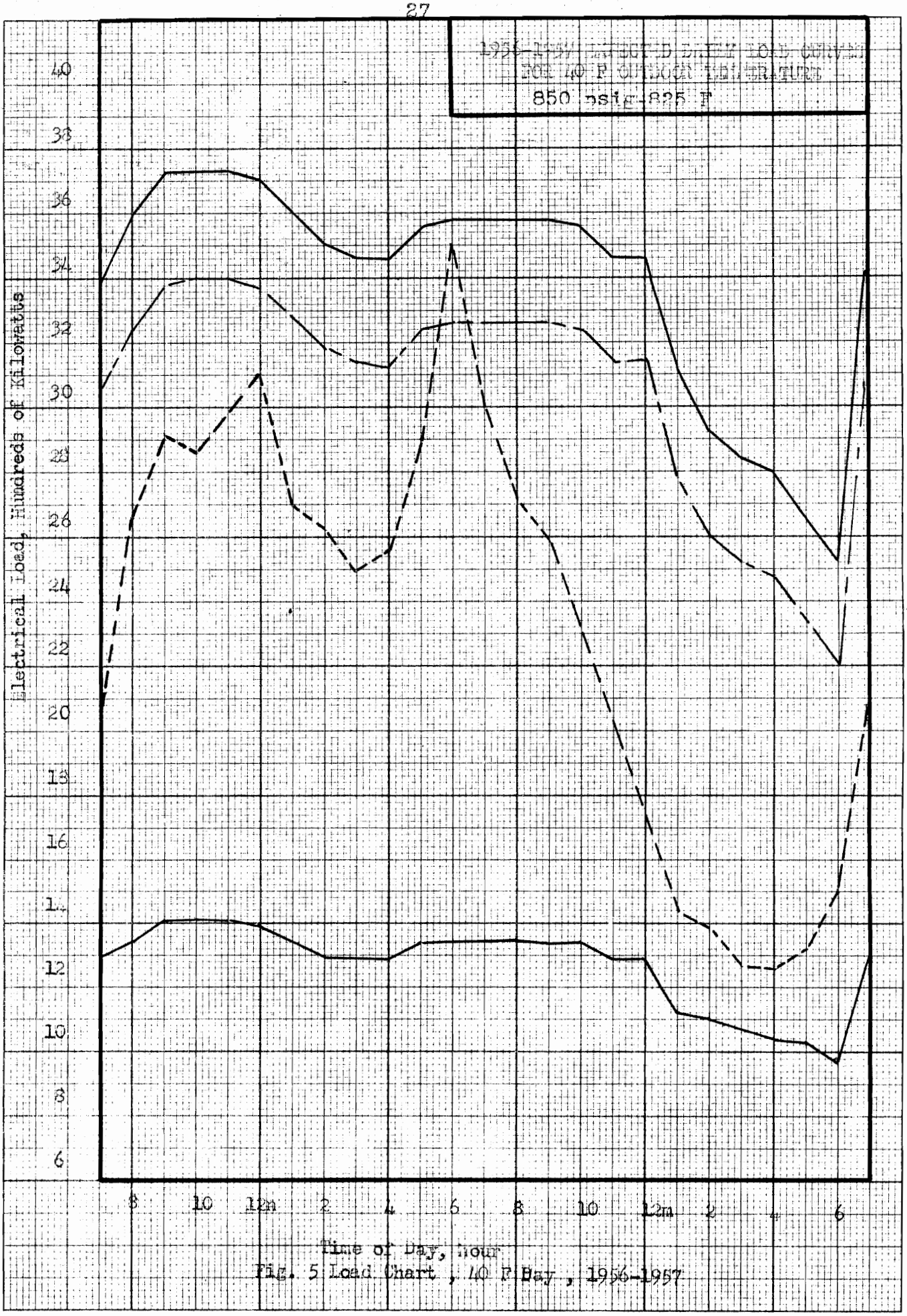


Fig. 5 Load Chart , 40 F Day , 1956-1957

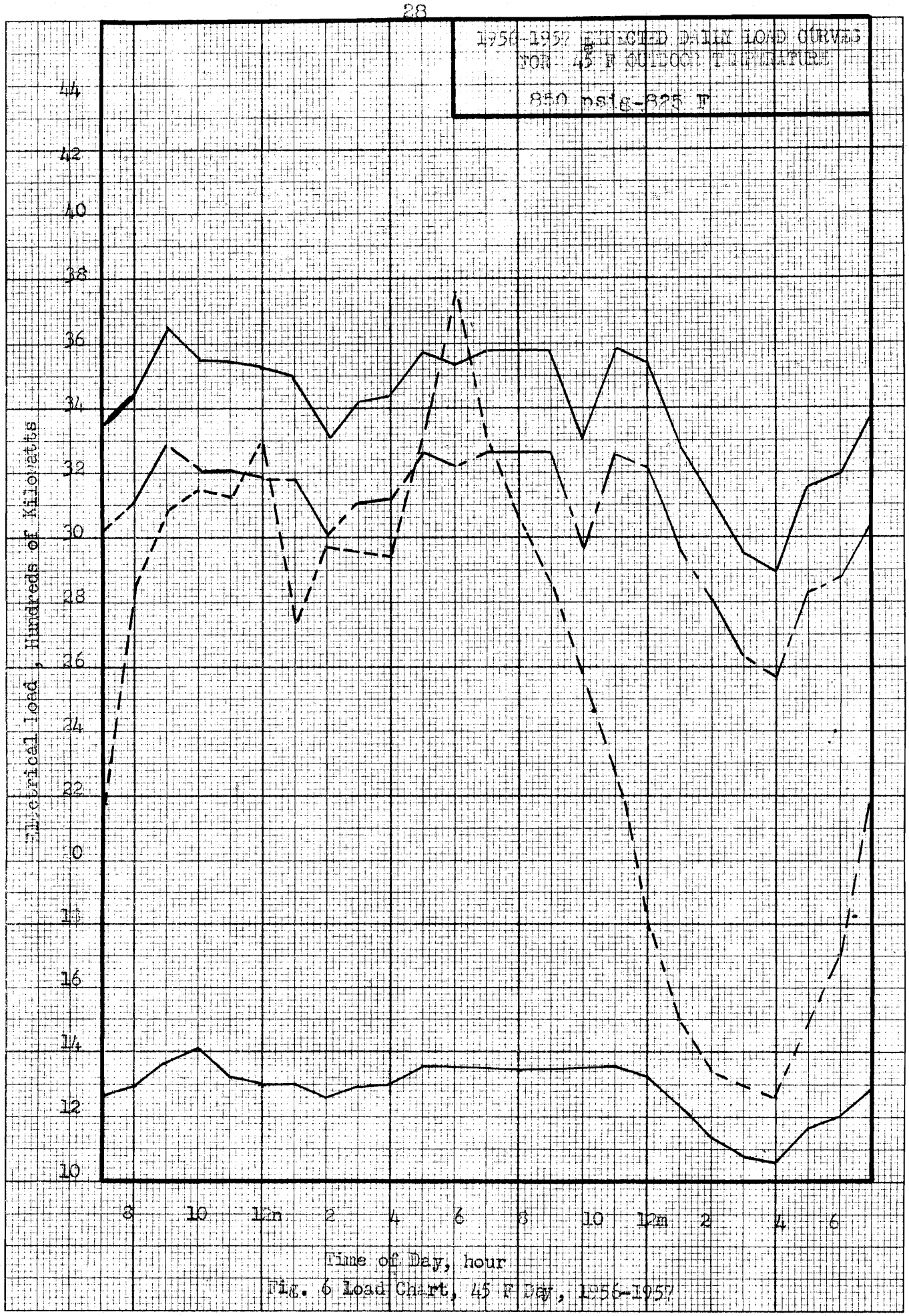


Fig. 6 Load Chart, 45 F Day, 1956-1957

Fig. 7 Load Chart, 50 F Day, 1956-1957

Figs Load Chart, 55 F Day, 1956-1957

Fig. 9 Load Chart, 60 F May, 1956-1957

Fig, 10 Load Chart, 20 F Day, 1957-1958

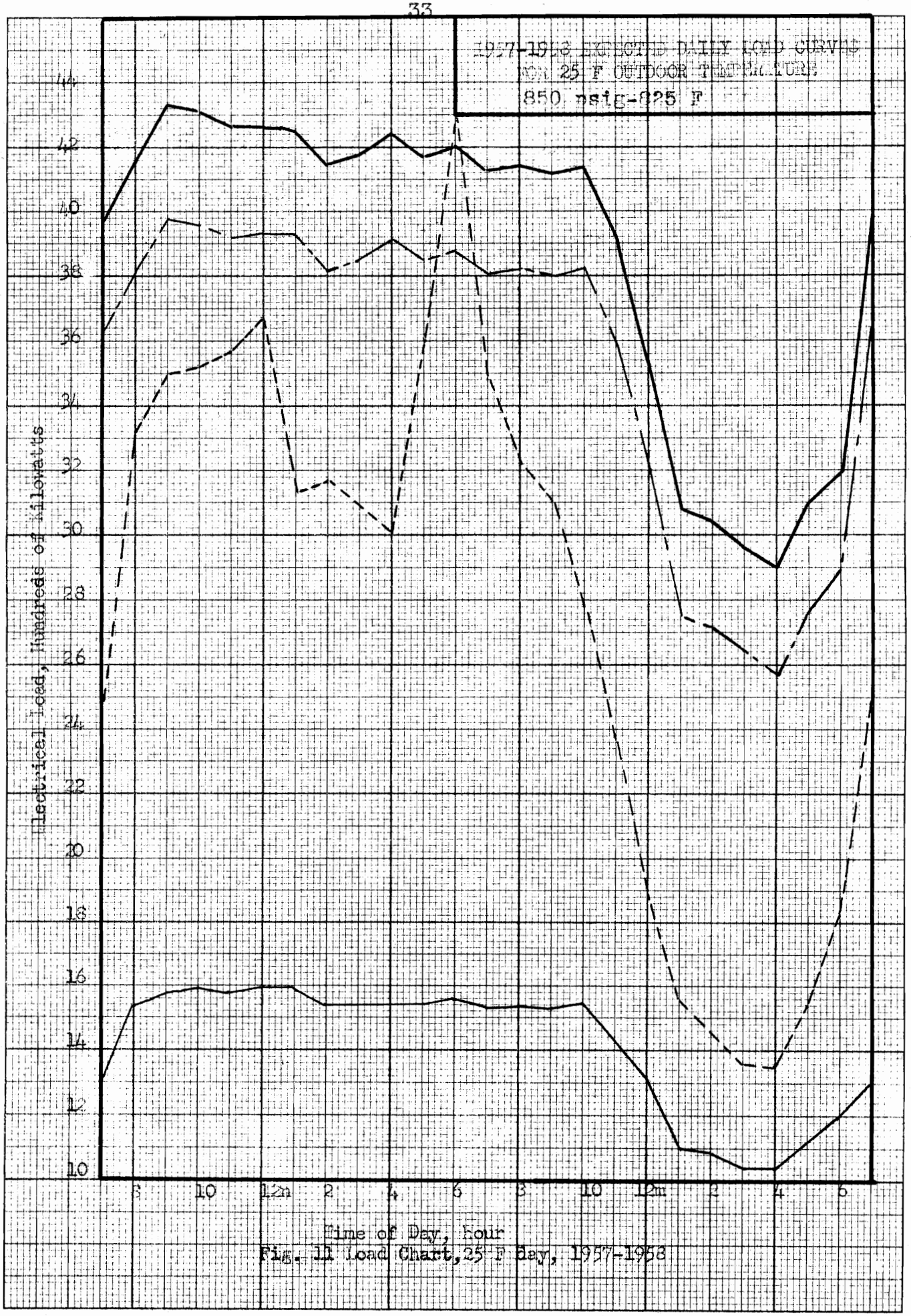


Fig. 11 Load Chart, 25 F Day, 1957-1958

Fig. 14 Load Chart, 30 F Day, 1957-1958

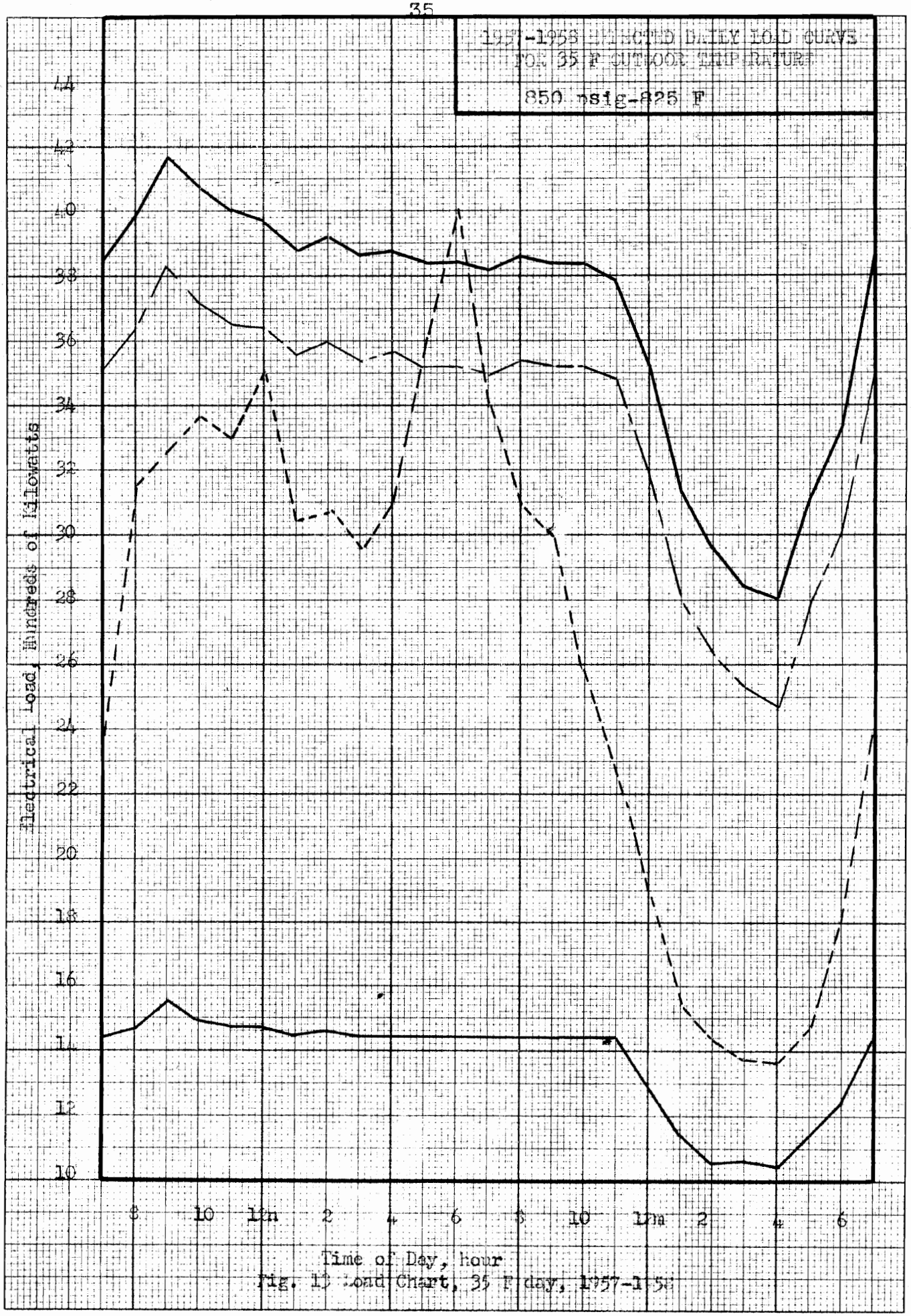


Fig. 13 Load Chart, 35 F day, 1957-1958

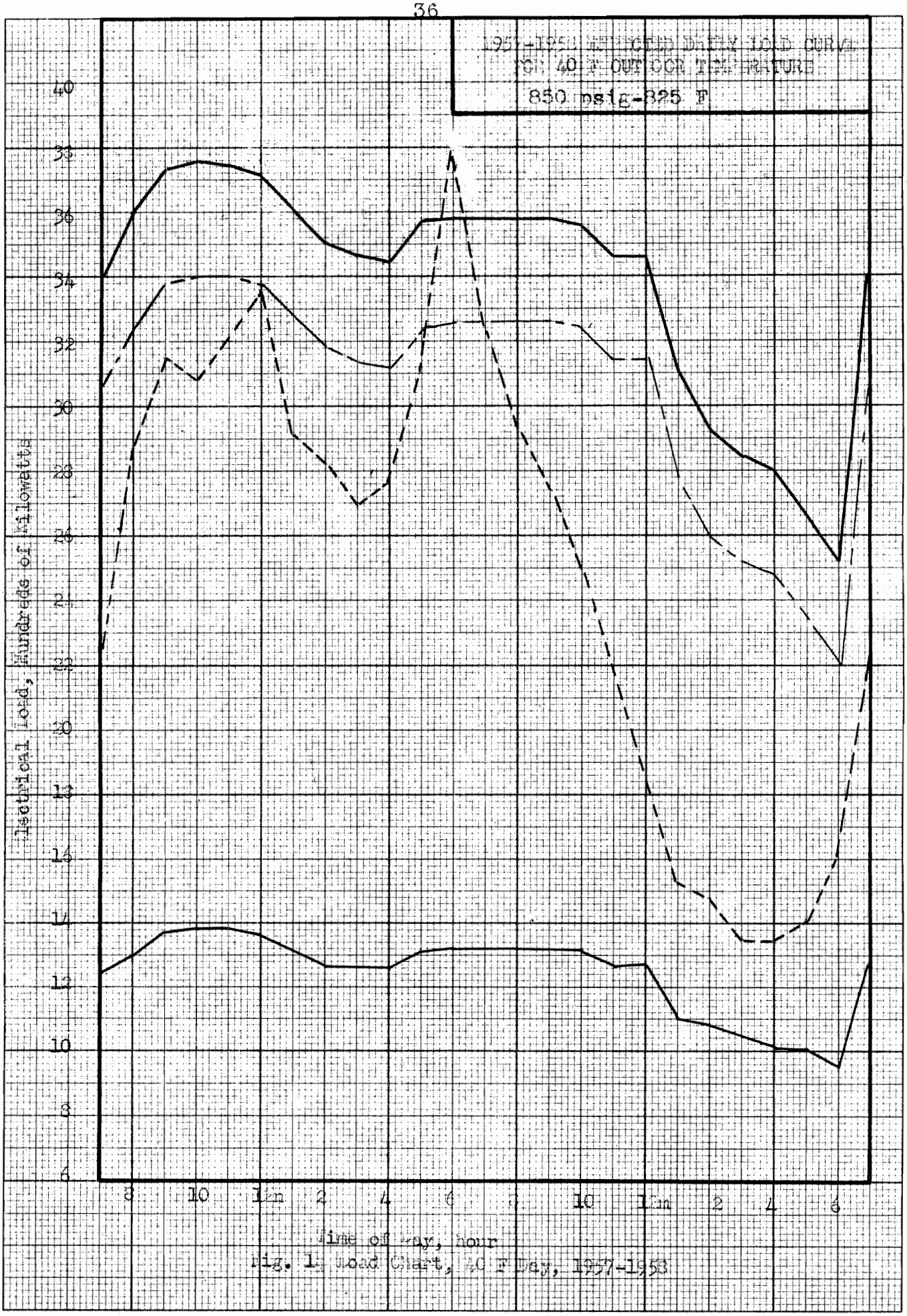


Fig. 1 Load Chart, 40 F Day, 1957-1958

Fig. 15 Load Chart, 45 F Day, 1957-1958

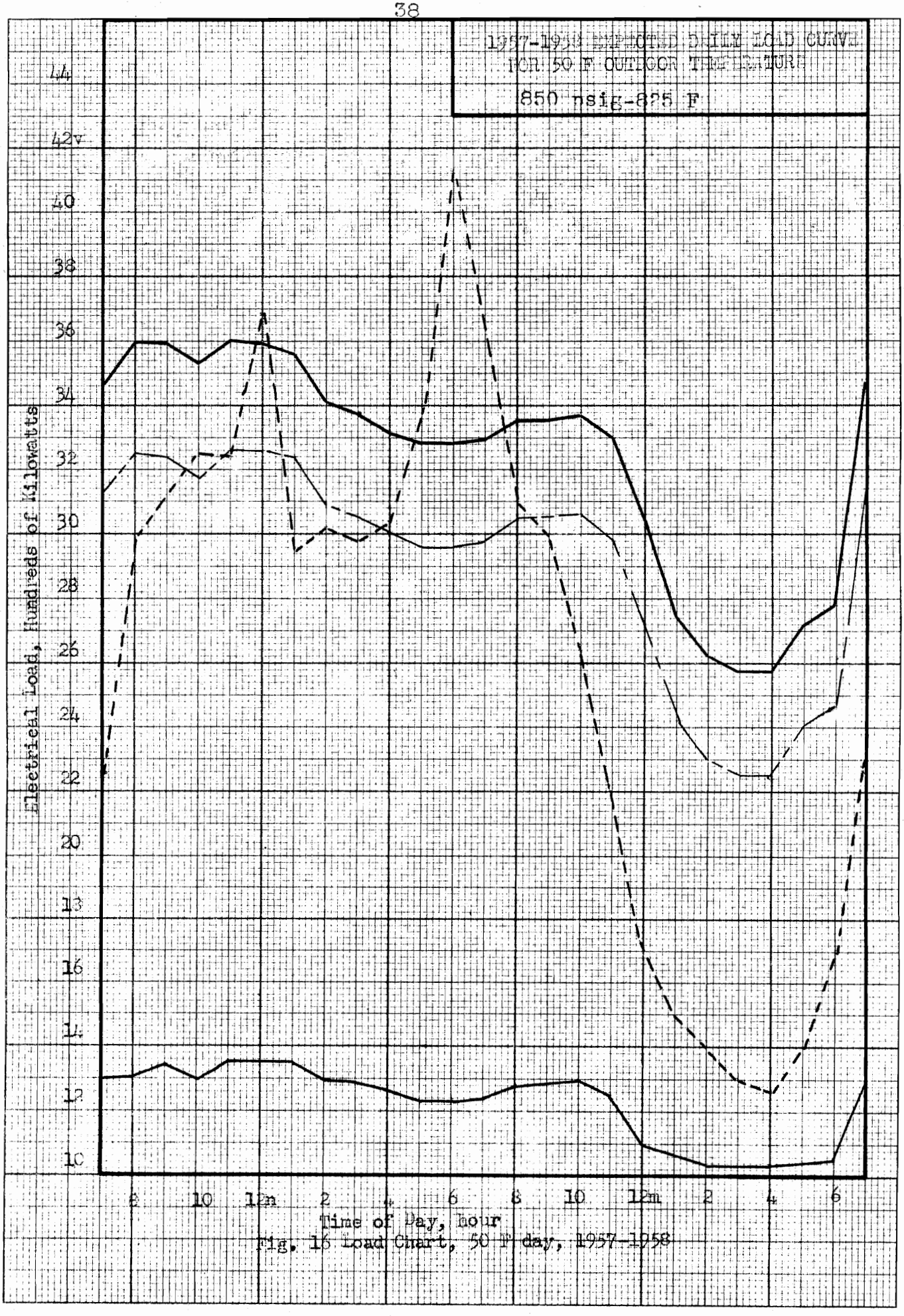


Fig. 16 Load Chart, 50 F day, 1957-1958

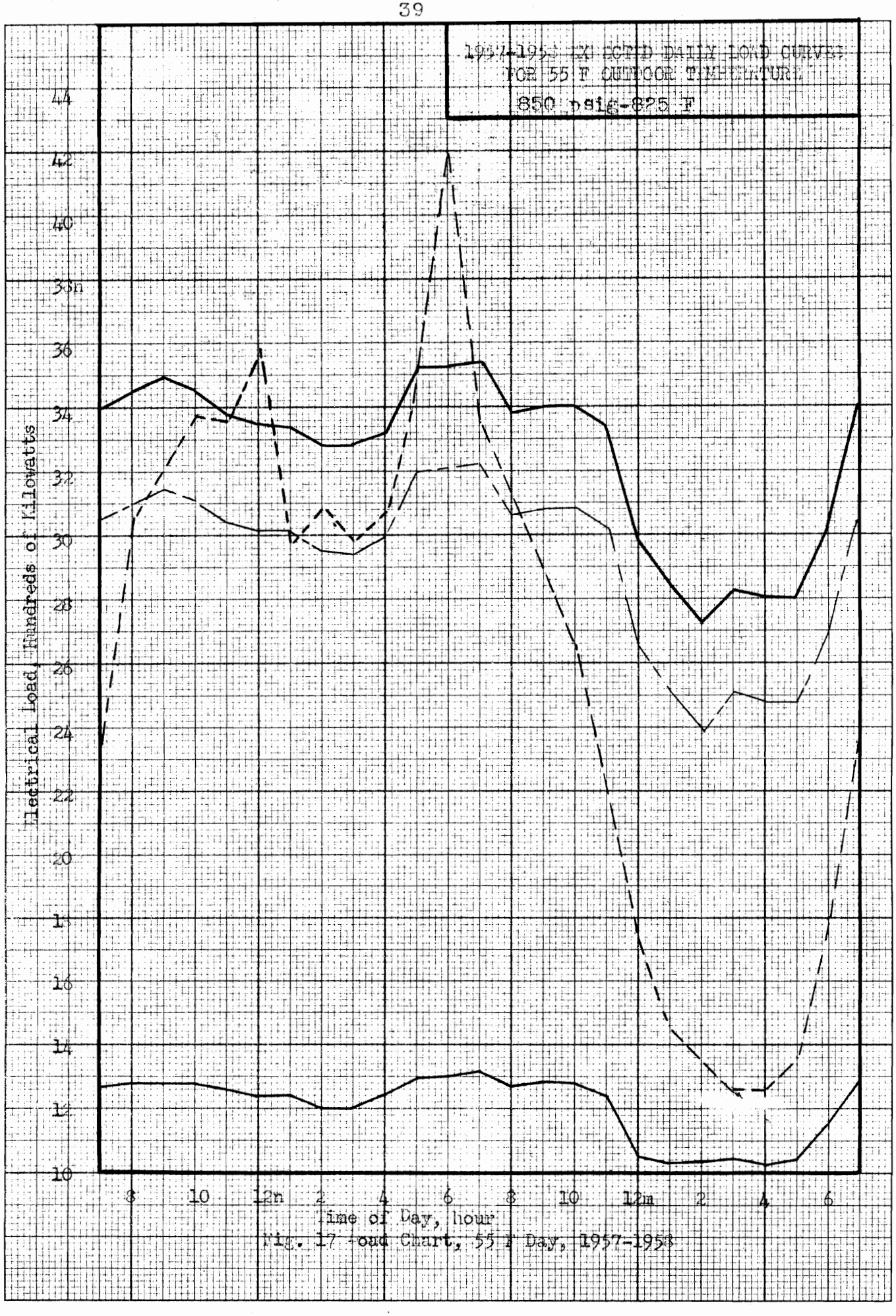


Fig. 17 Load Chart, 55 F Day, 1957-1958

Fig. 18 Load Chart, 60 F Day, 1957-1958

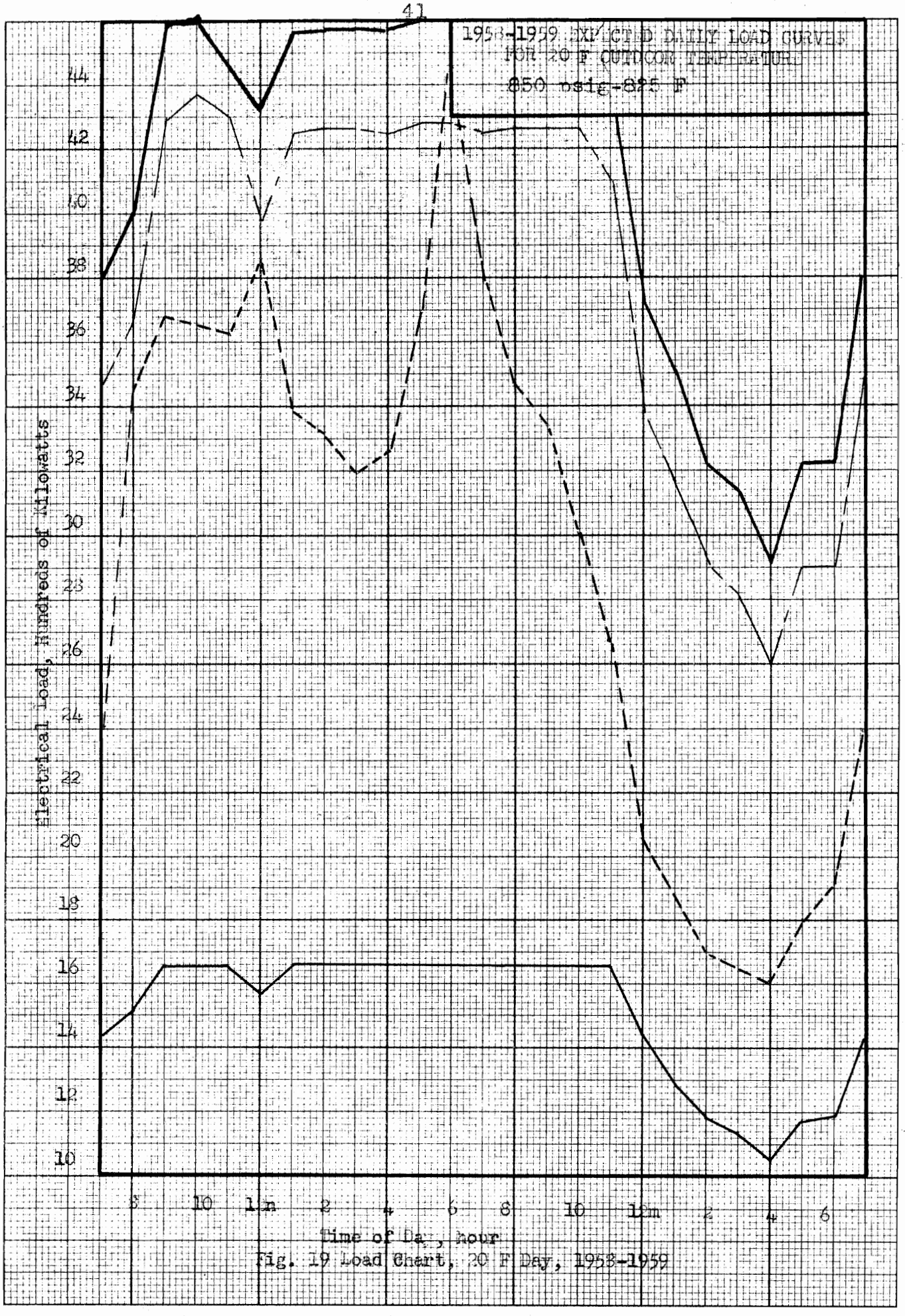
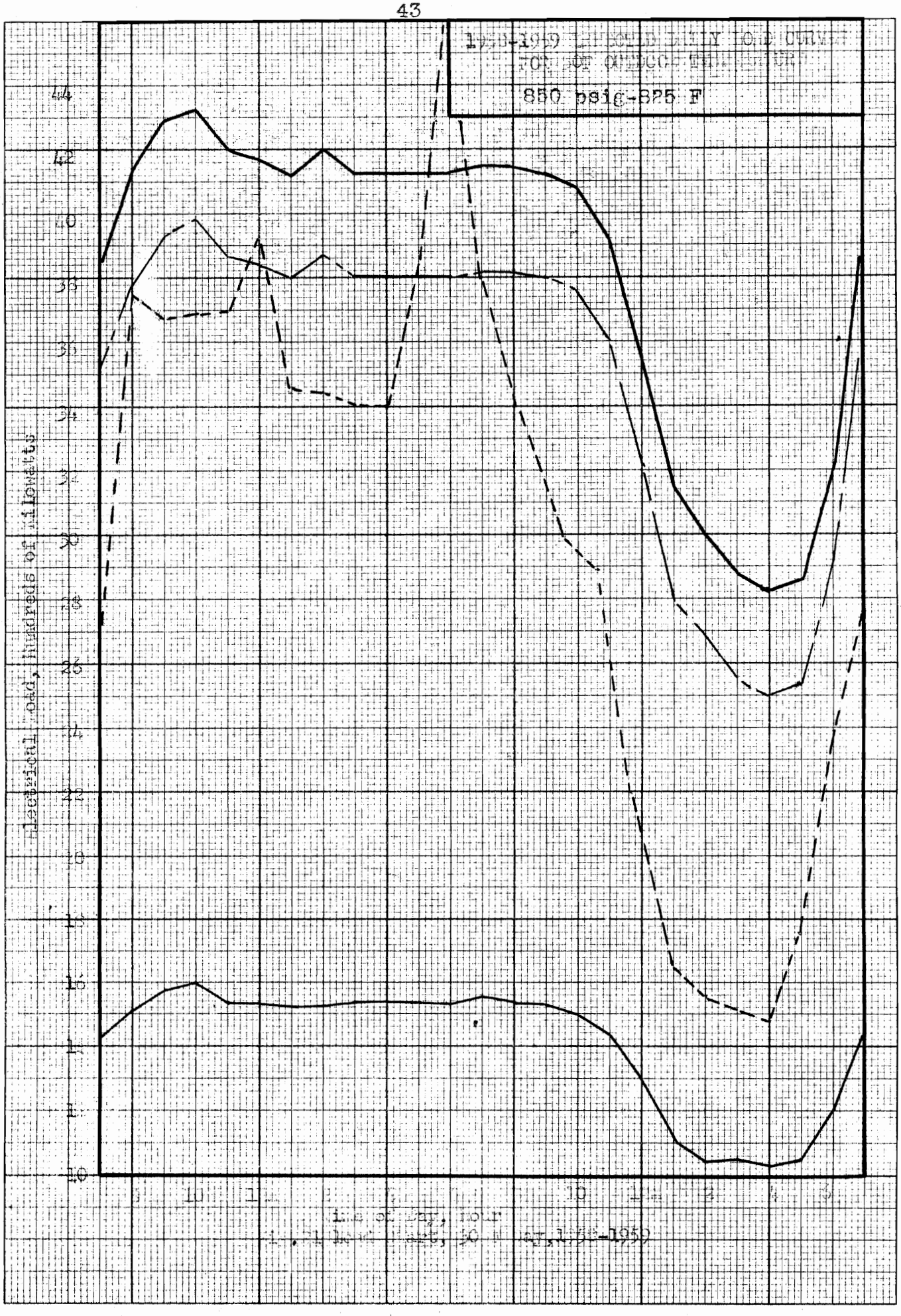


Fig. 19 Load Chart, 20 F Day, 1958-1959

Fig. 20 Load Chart, 25 F Day, 1958-1959


850 psig-825 F
Electrical load, hundreds of kilowatts

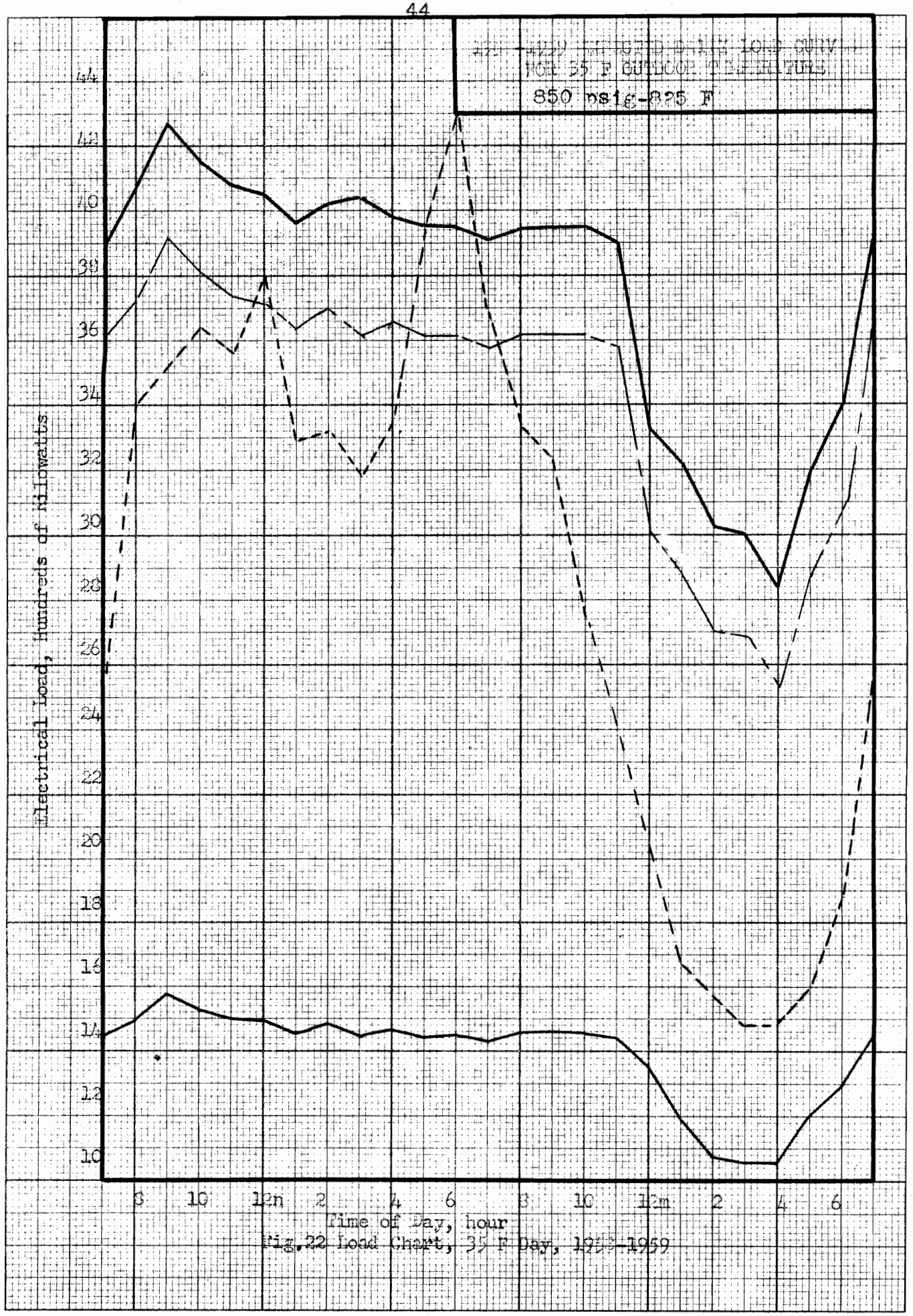


Fig. 22 Load Chart, 35 F Day, 1958-1959

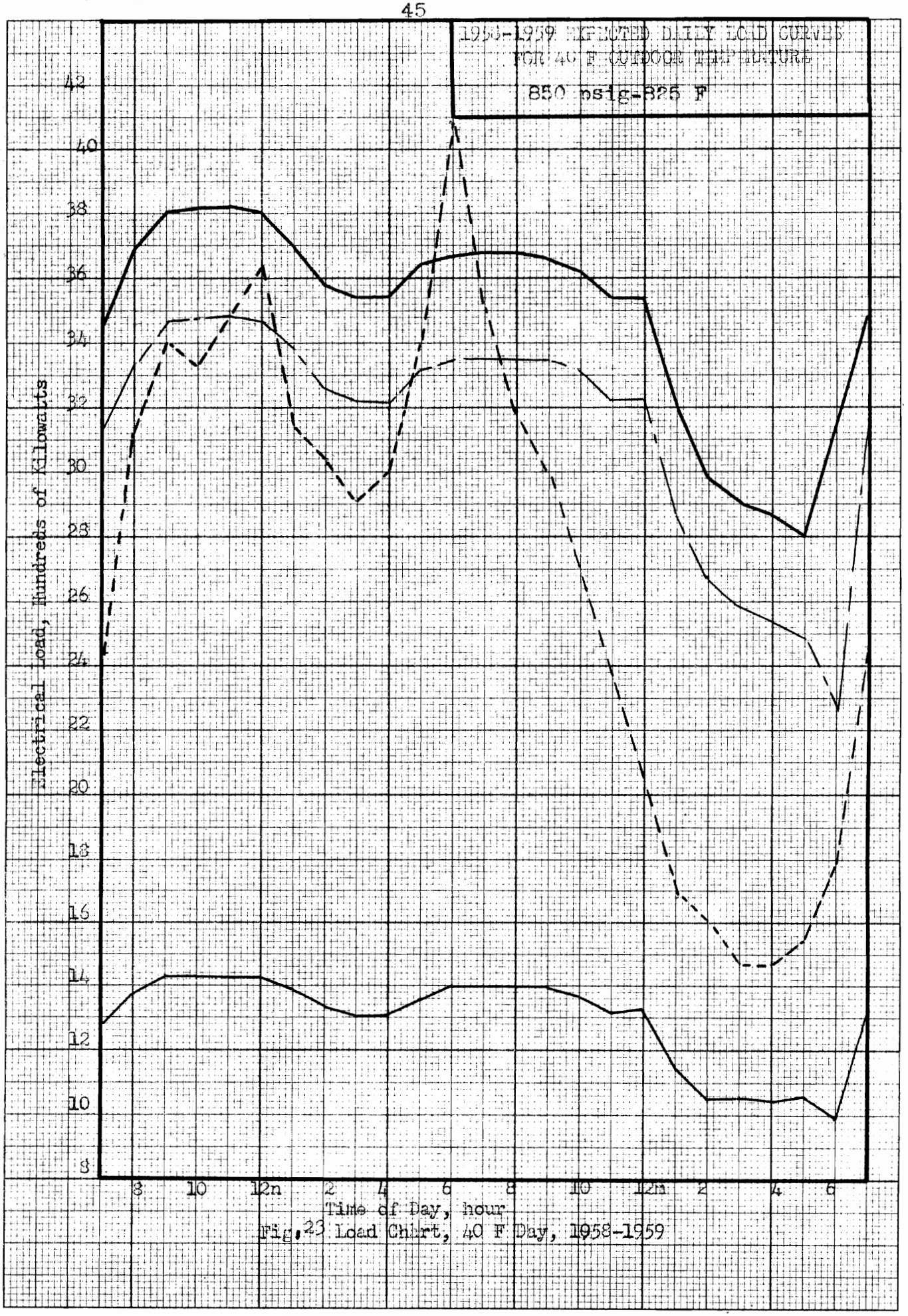


Fig. 23 Load Chart, 40 F Day, 1958-1959

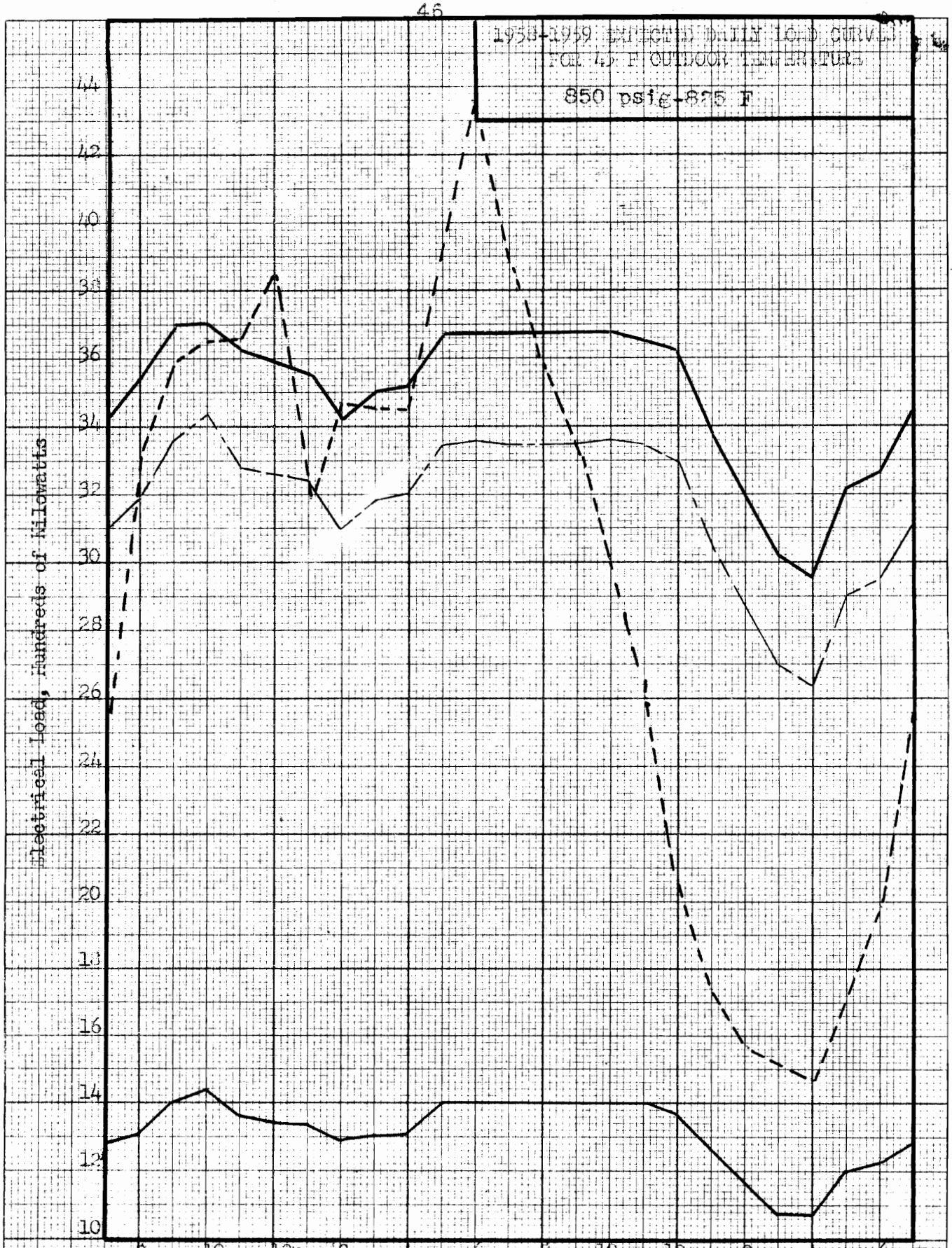


Fig. 24 Load Chart, 45 F Day, 1958-1959

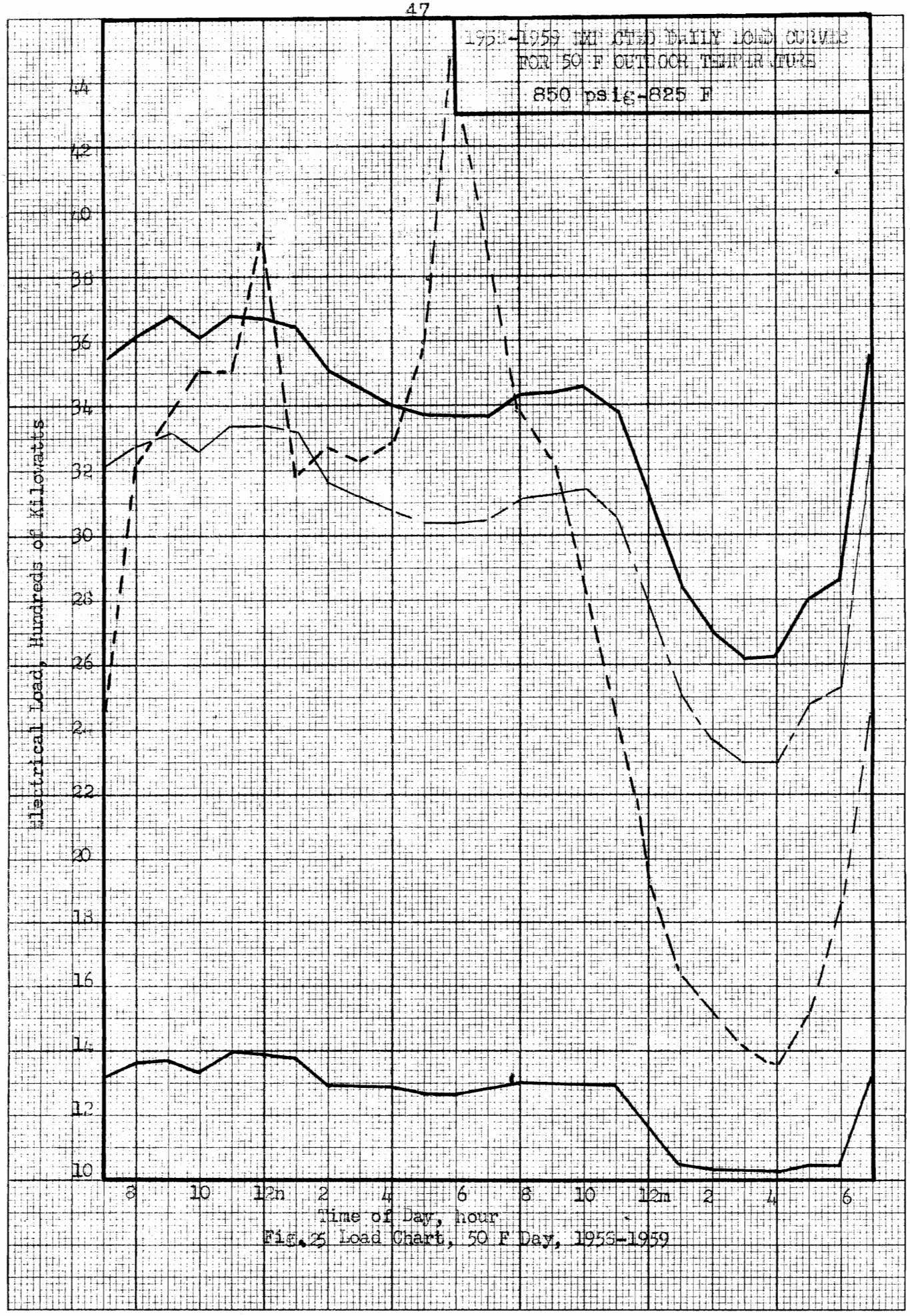


Fig. 25 Load Chart, 50 F Day, 1958-1959

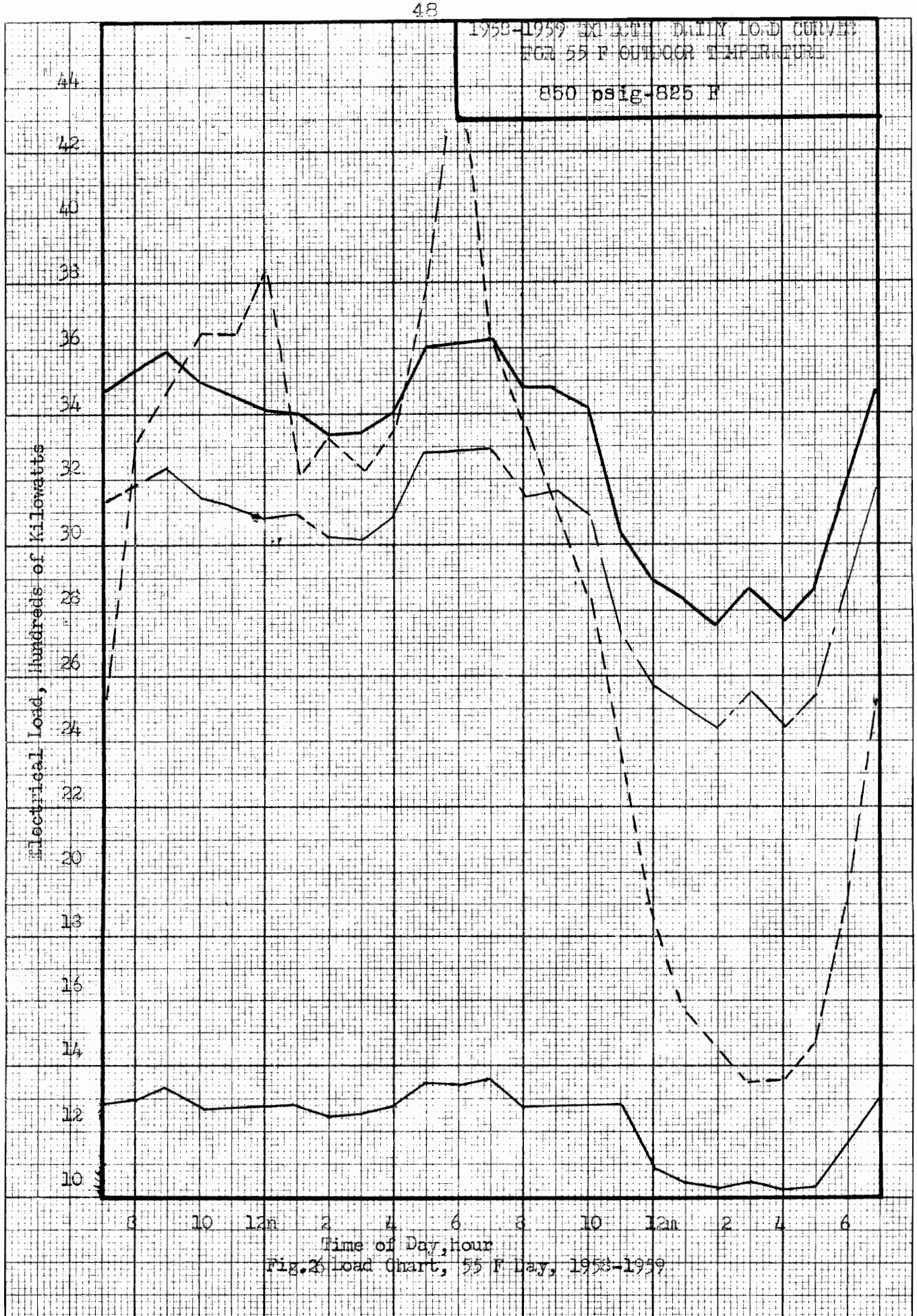


Fig. 2 Load Chart, 55 F Day, 1958-1959

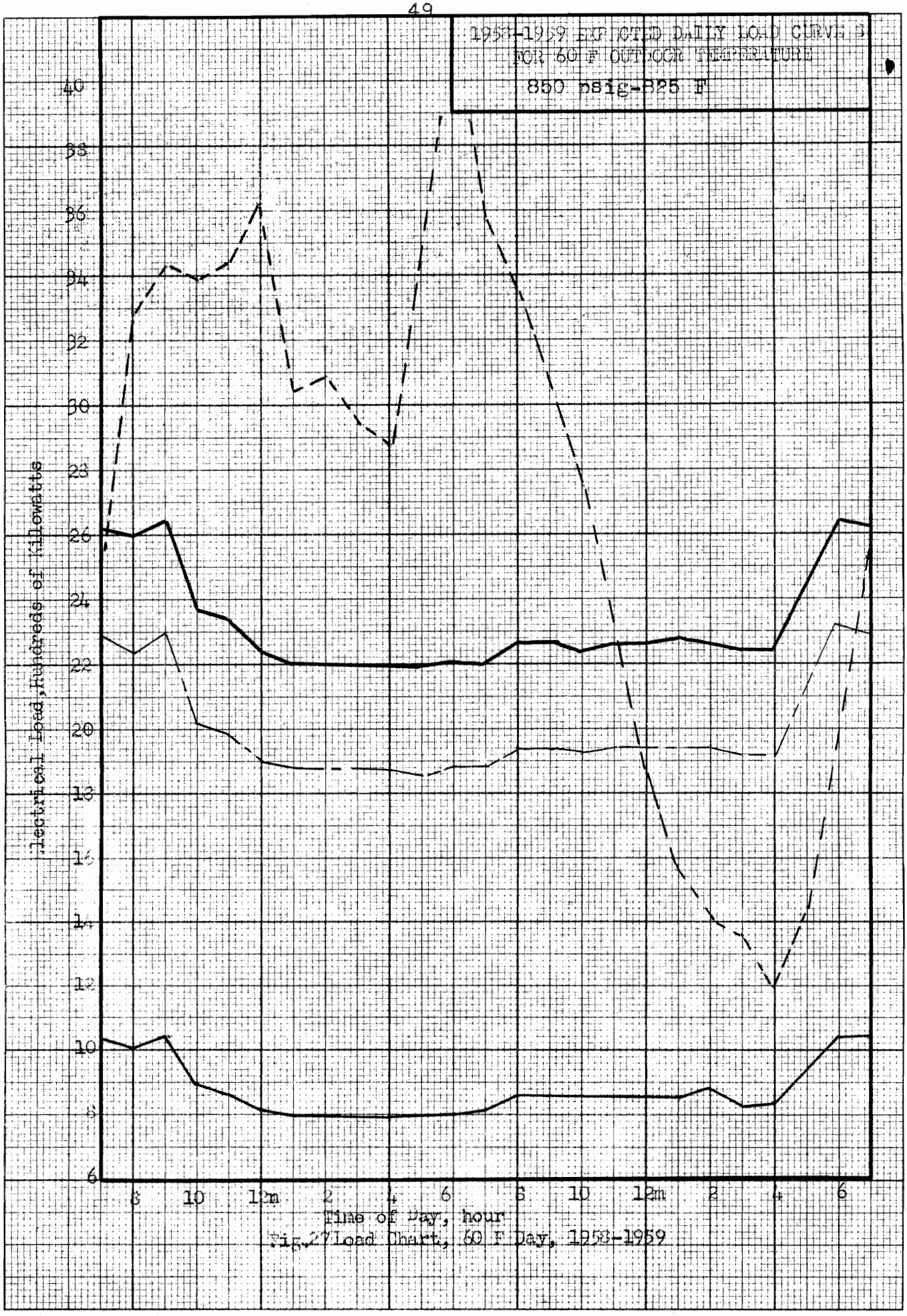


Fig. 27 Load Chart, 60 F Day, 1958-1959

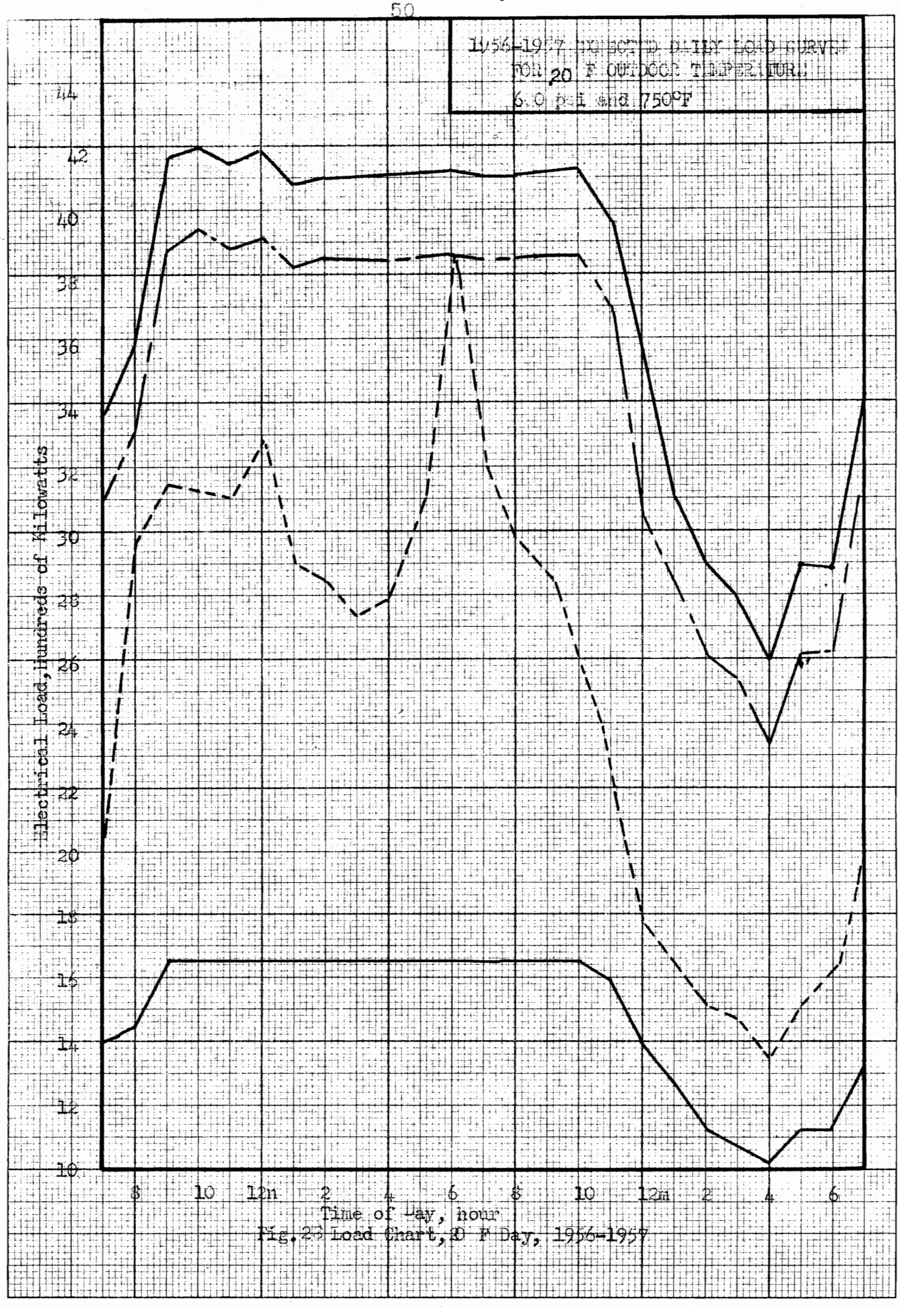


Fig. 23 Load Chart, 0 F Day, 1956-1957

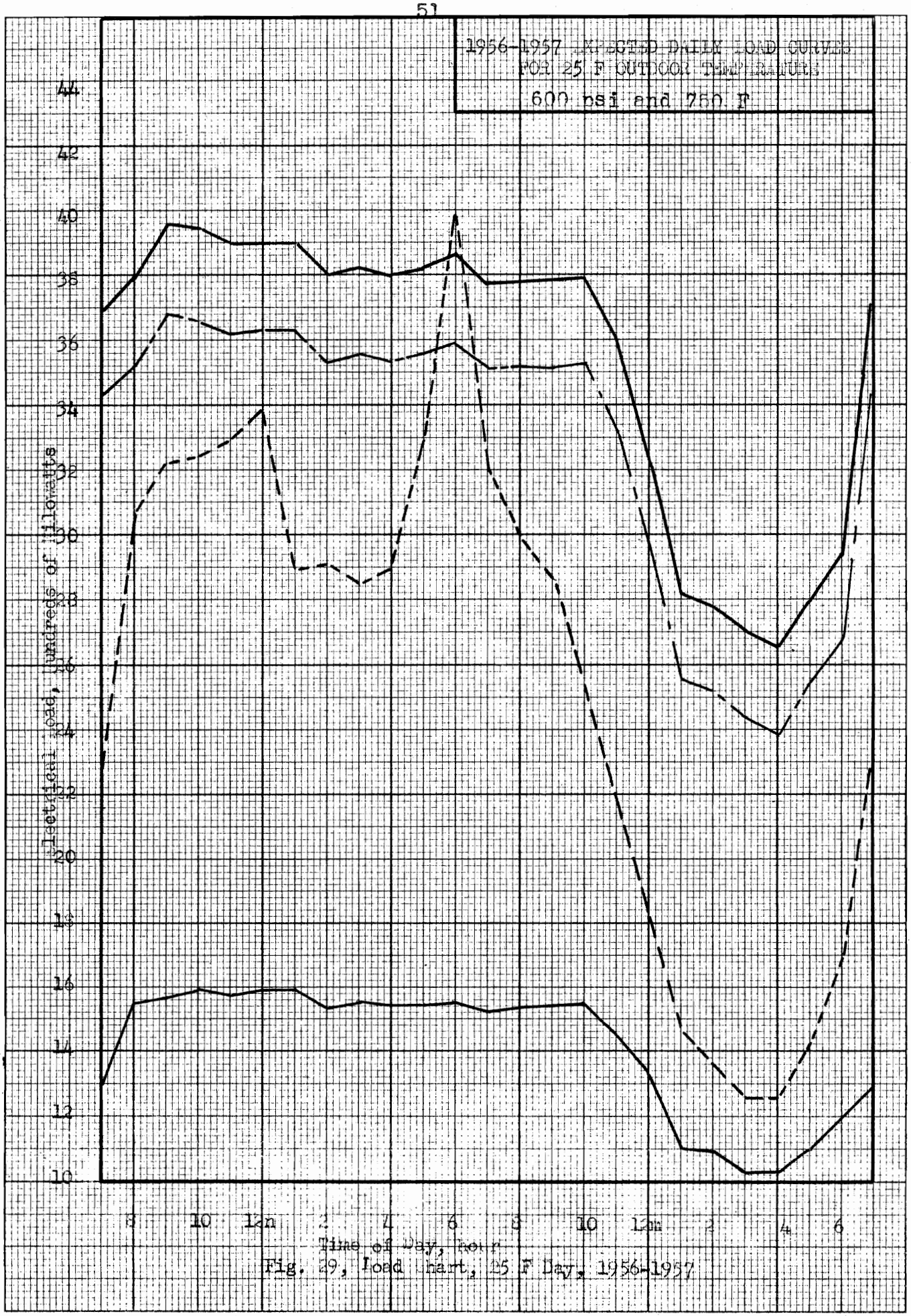


Fig. 29, Load Chart, 25 F Day, 1956-1957

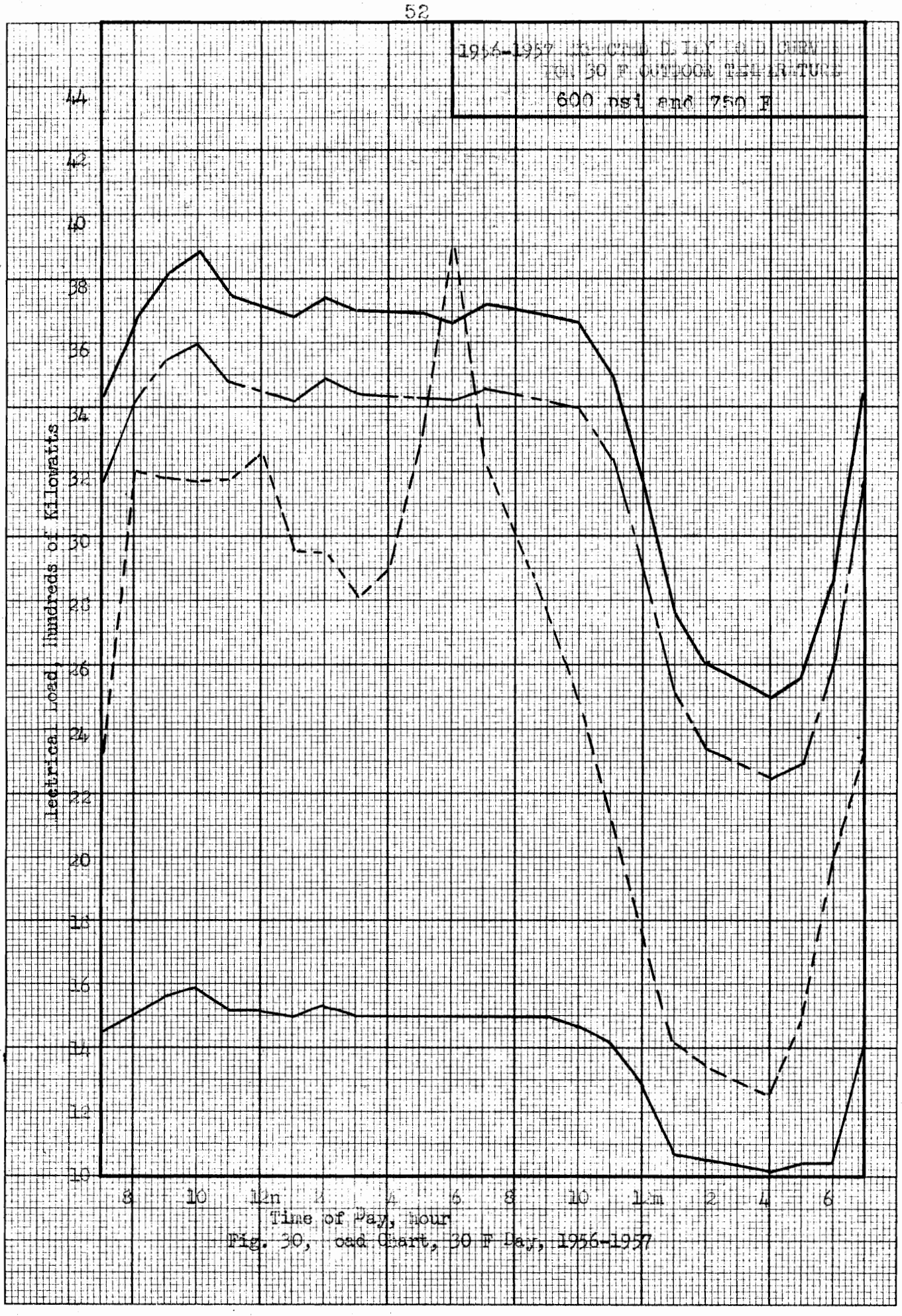


Fig. 30, Load Chart, 30 F Day, 1956-1957

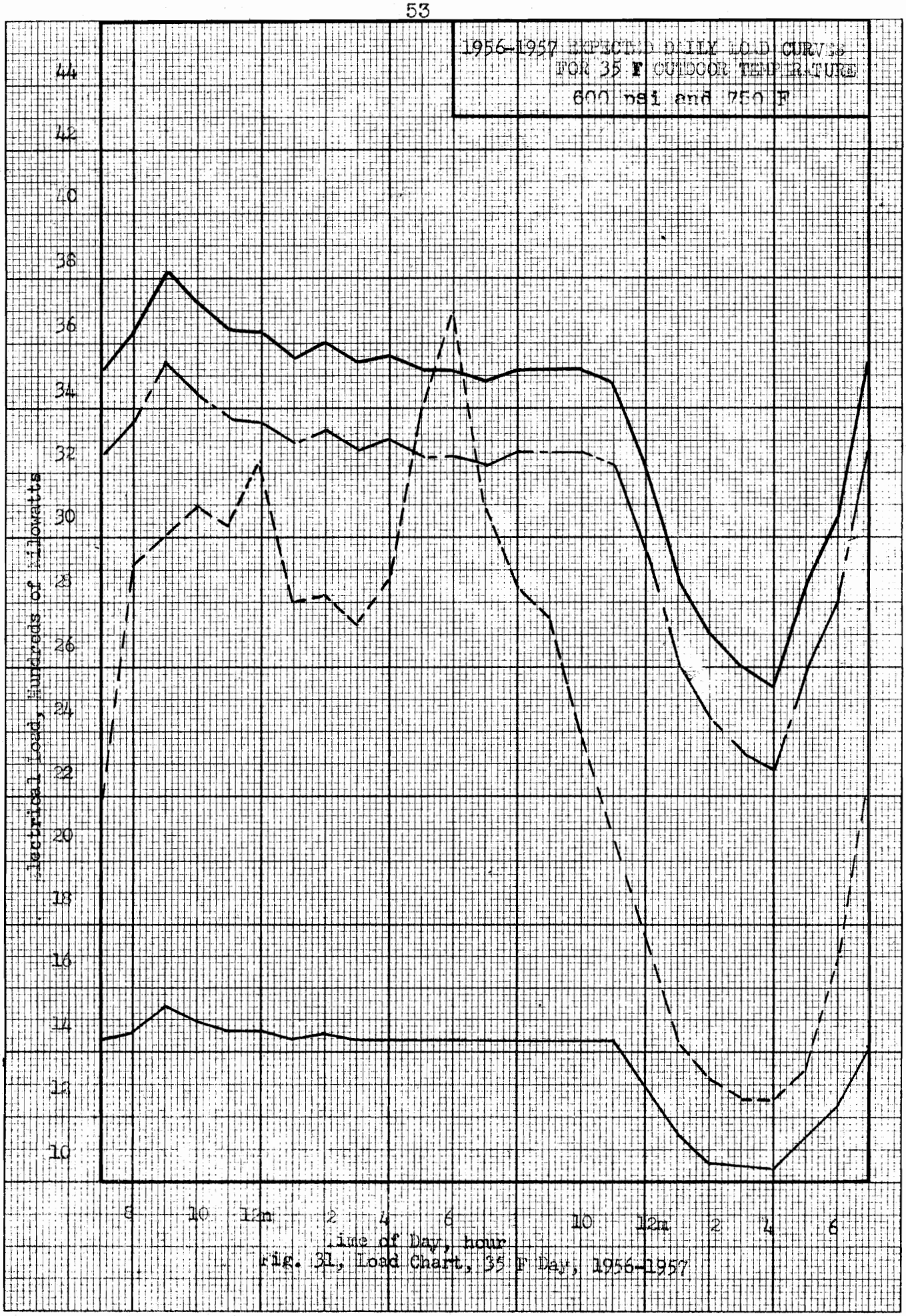


Fig. 31, Load Chart, 35 F Day, 1956-1957

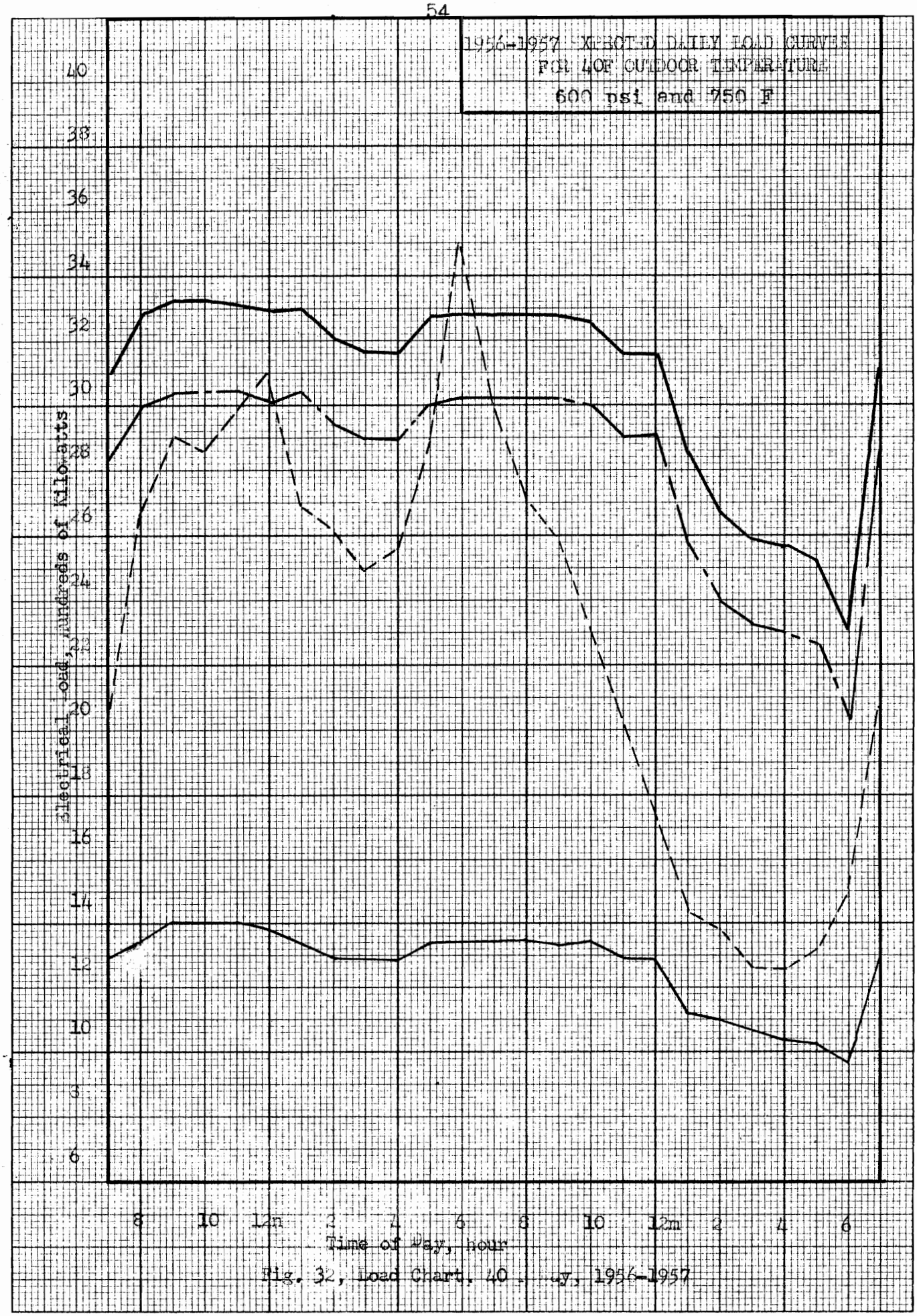


Fig. 32, Load Chart, 40 . . .y, 1956-1957

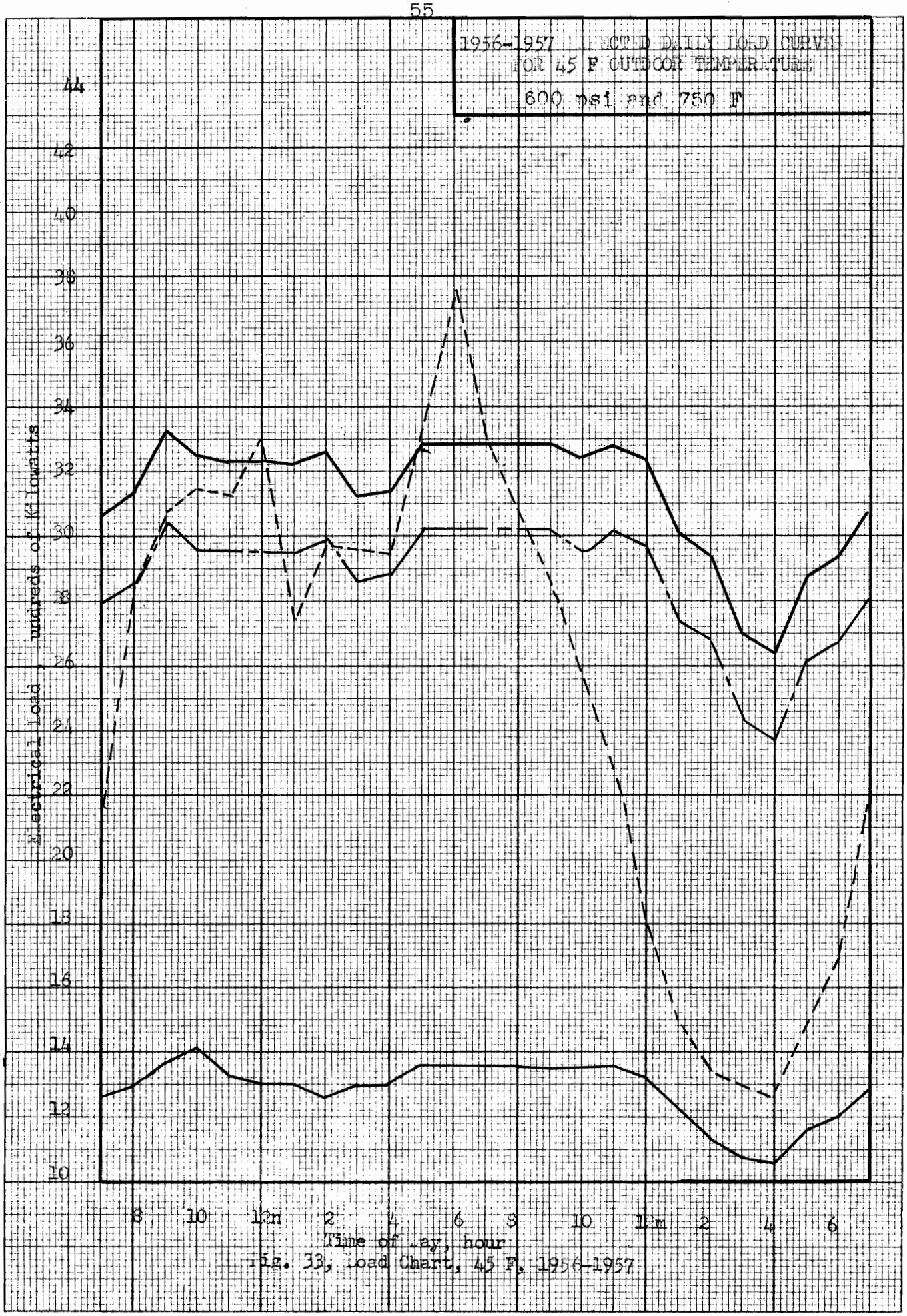


Fig. 33, Load Chart, 45 F, 1956-1957

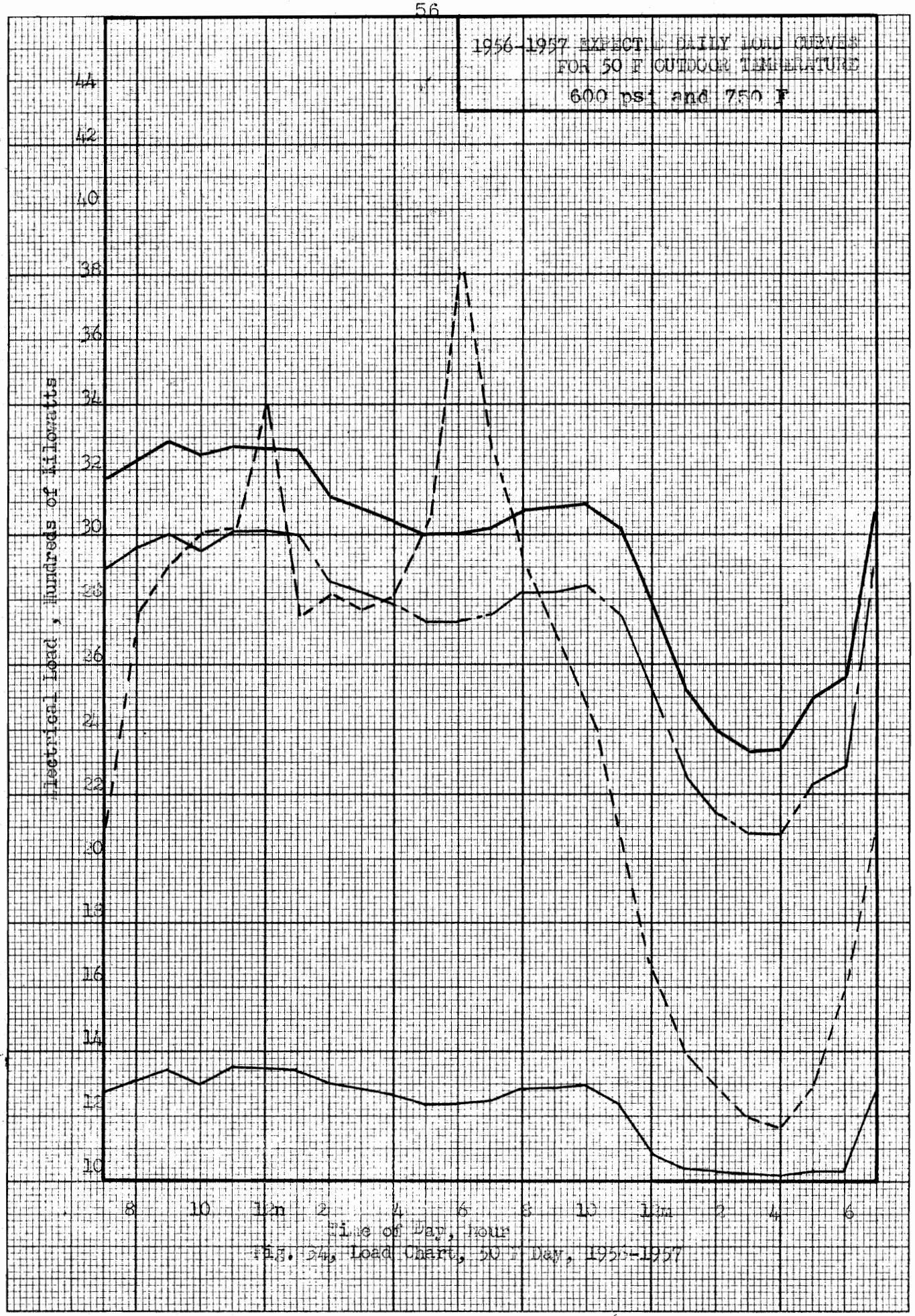


Fig. 24, Load Chart, 50 F Day, 1956-1957

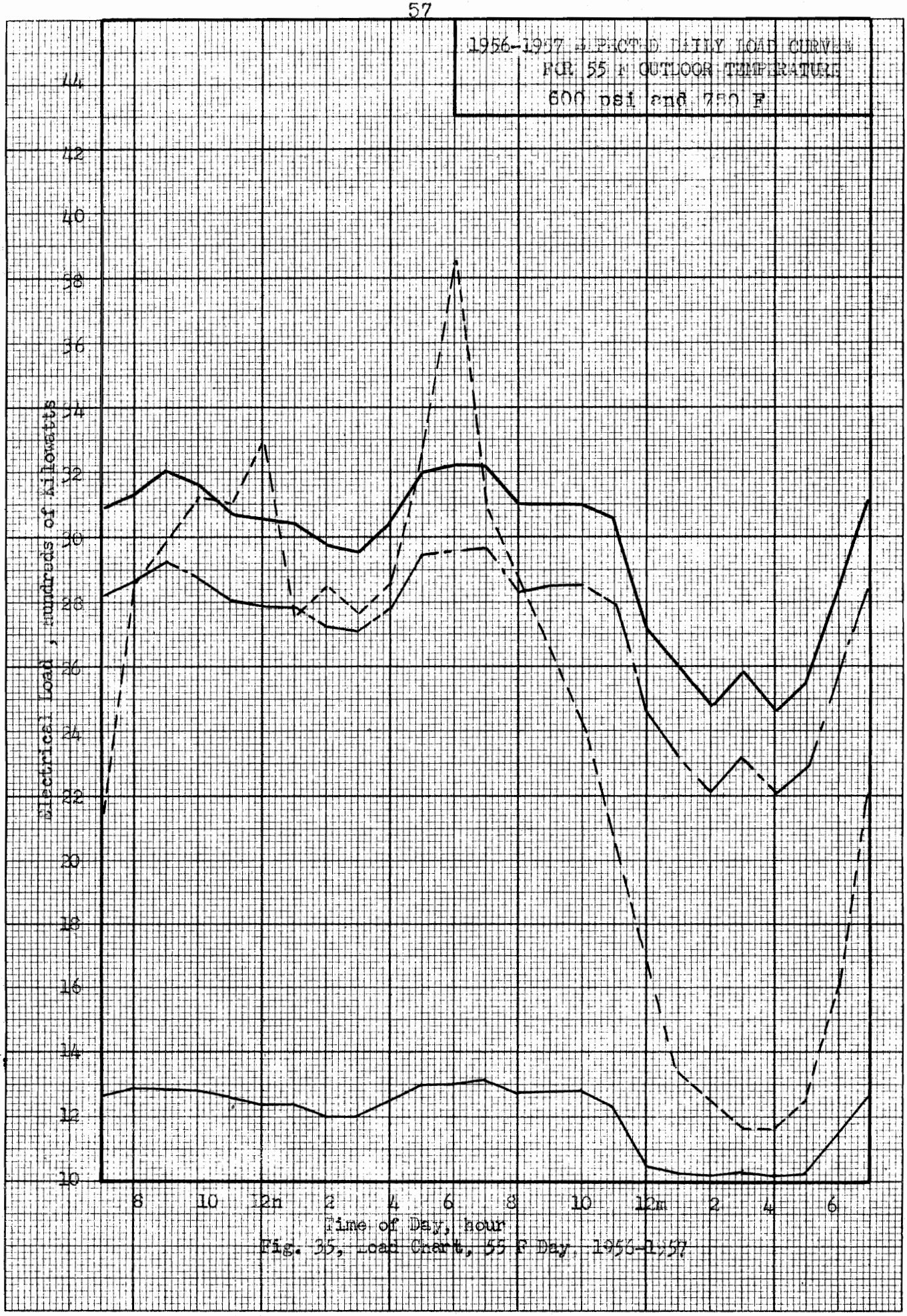


Fig. 35, Load Chart, 55 F Day, 1956-1957

Fig. 36, Load Chart, 10 - Day, 1956-1957

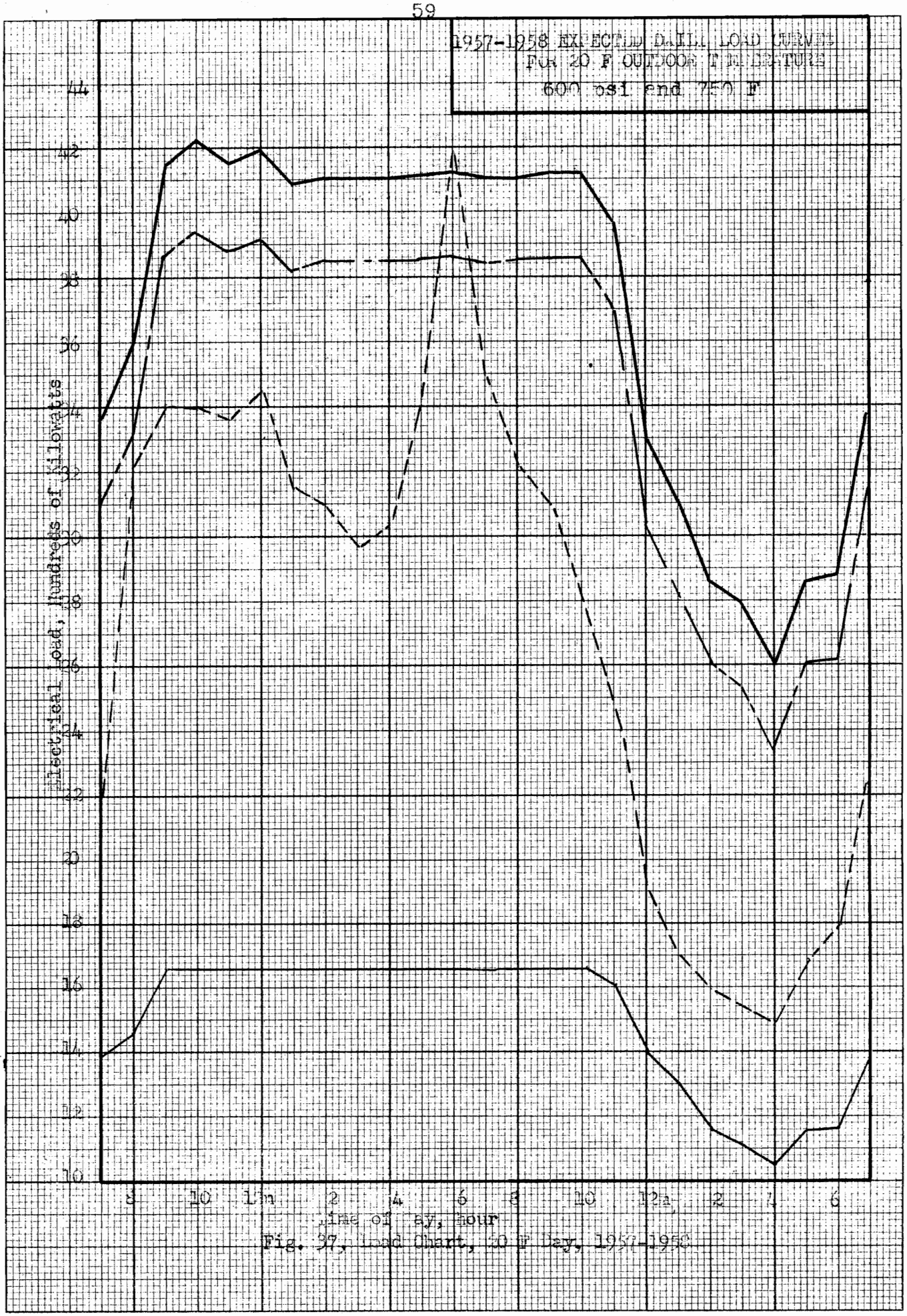


Fig. 37, Load Chart, 20 F Day, 1957-1958

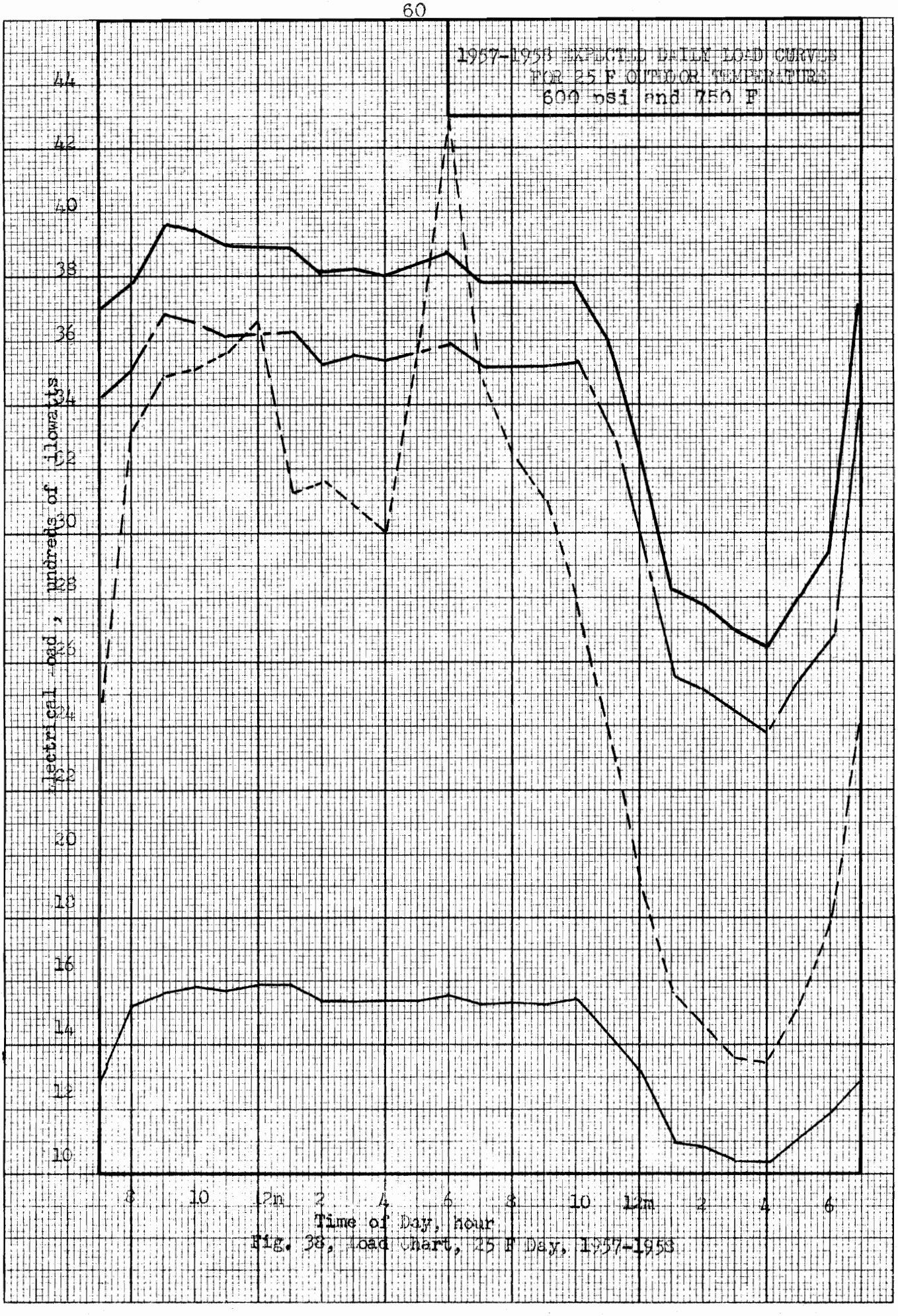


Fig. 38, Load Chart, 25 F Day, 1957-1958

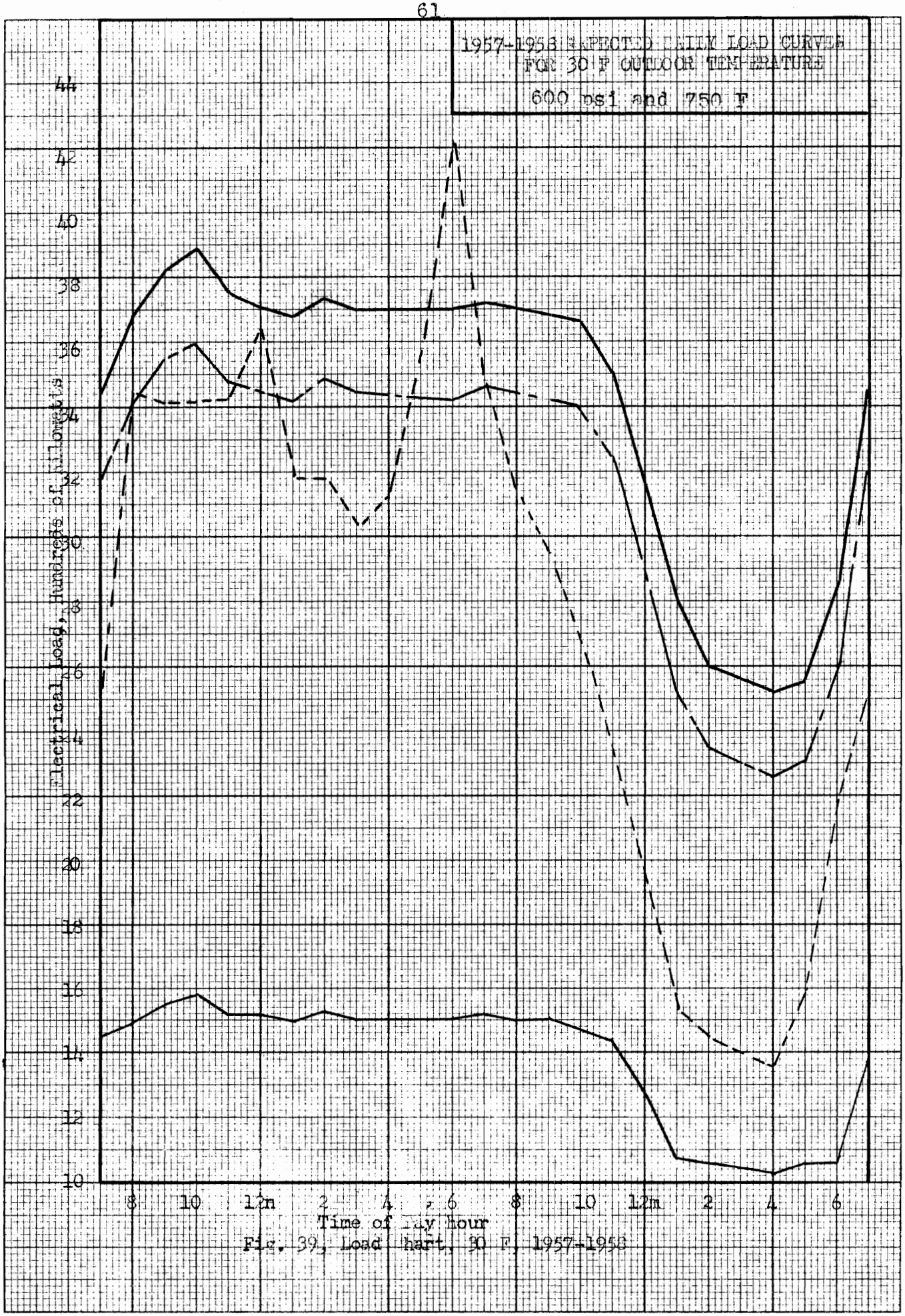


Fig. 39, Load chart, 30 F, 1957-1958

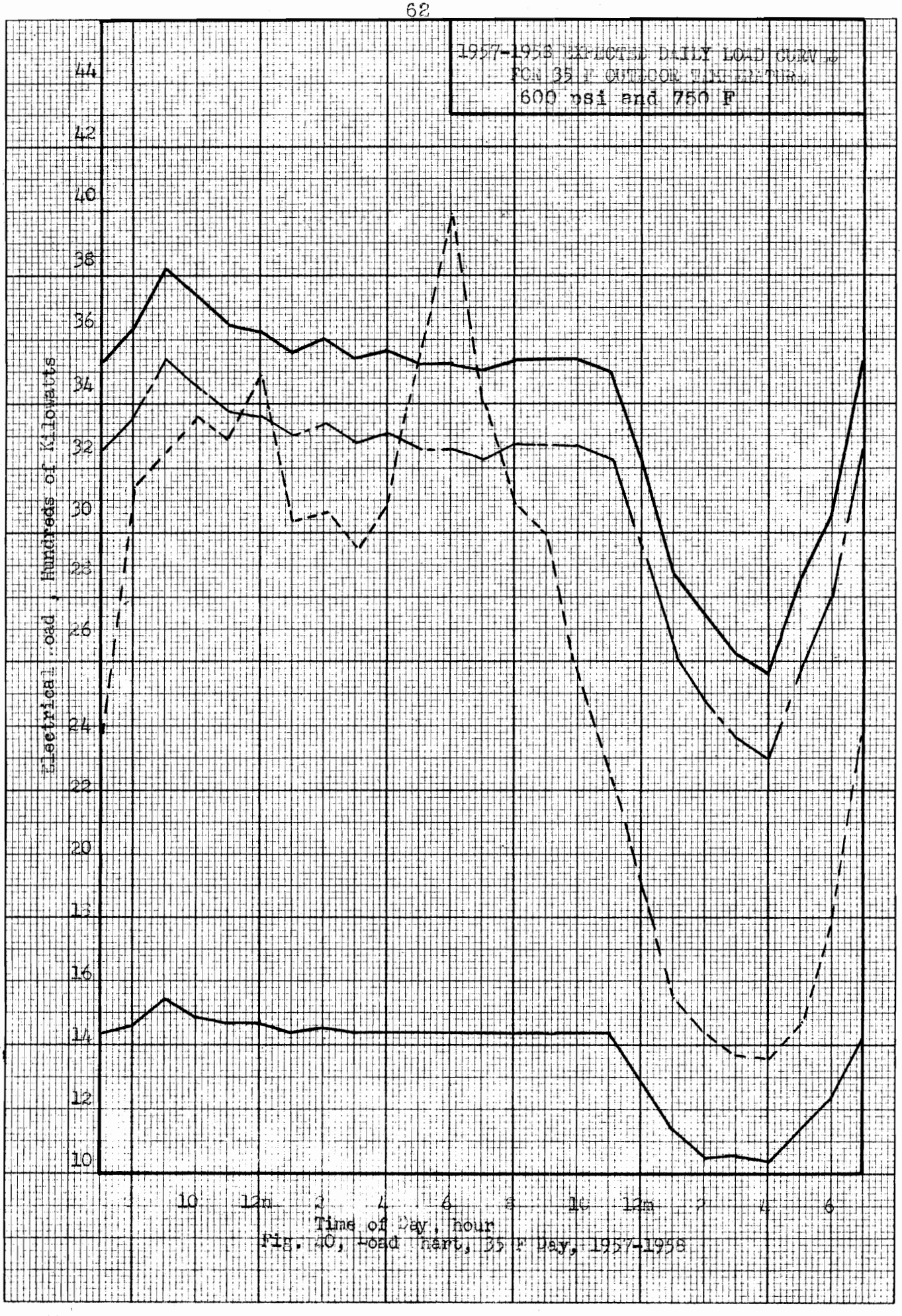


Fig. 40, Load Chart, 35° F Day, 1957-1958

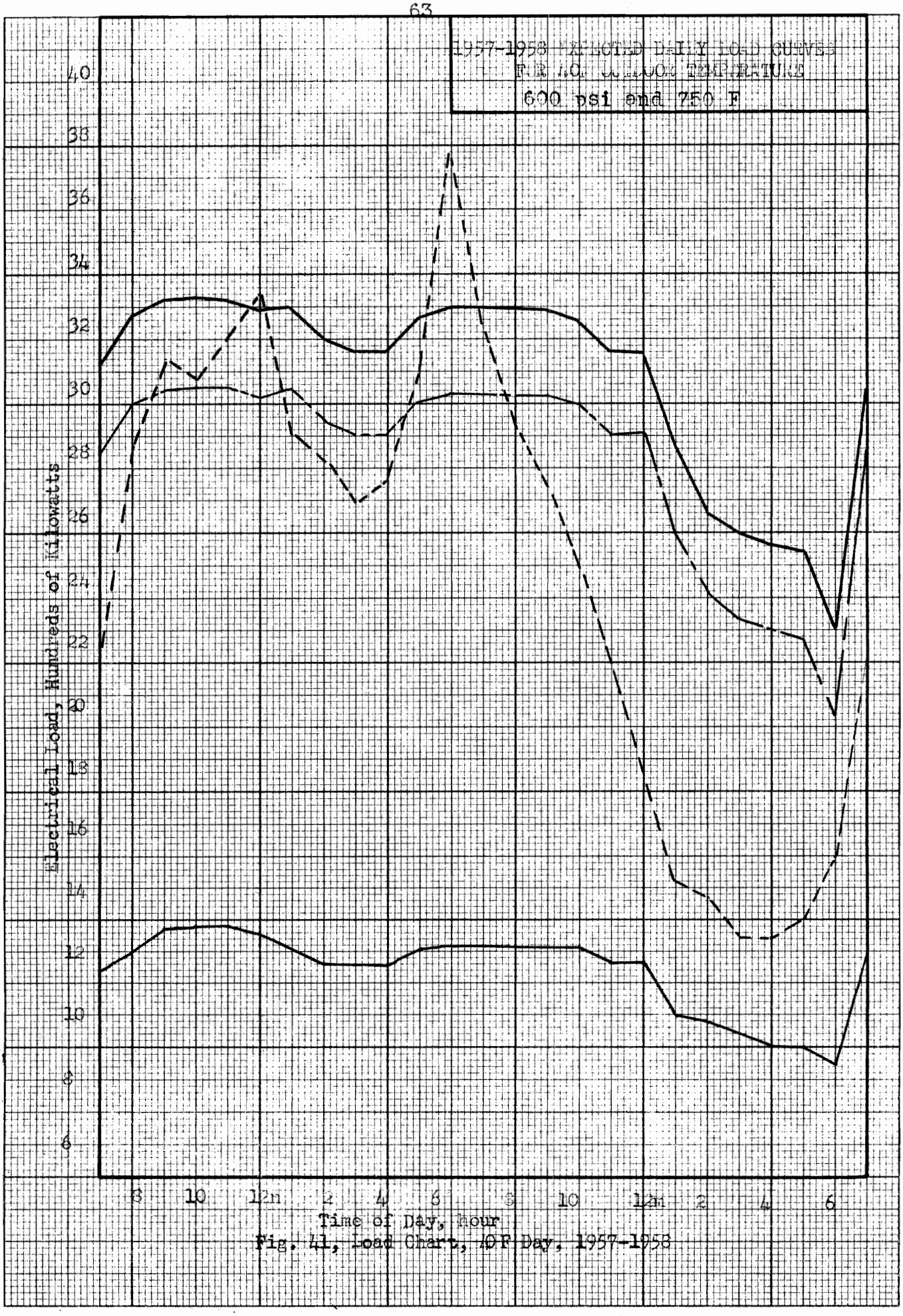


Fig. 41, Load Chart, 40 F Day, 1957-1958

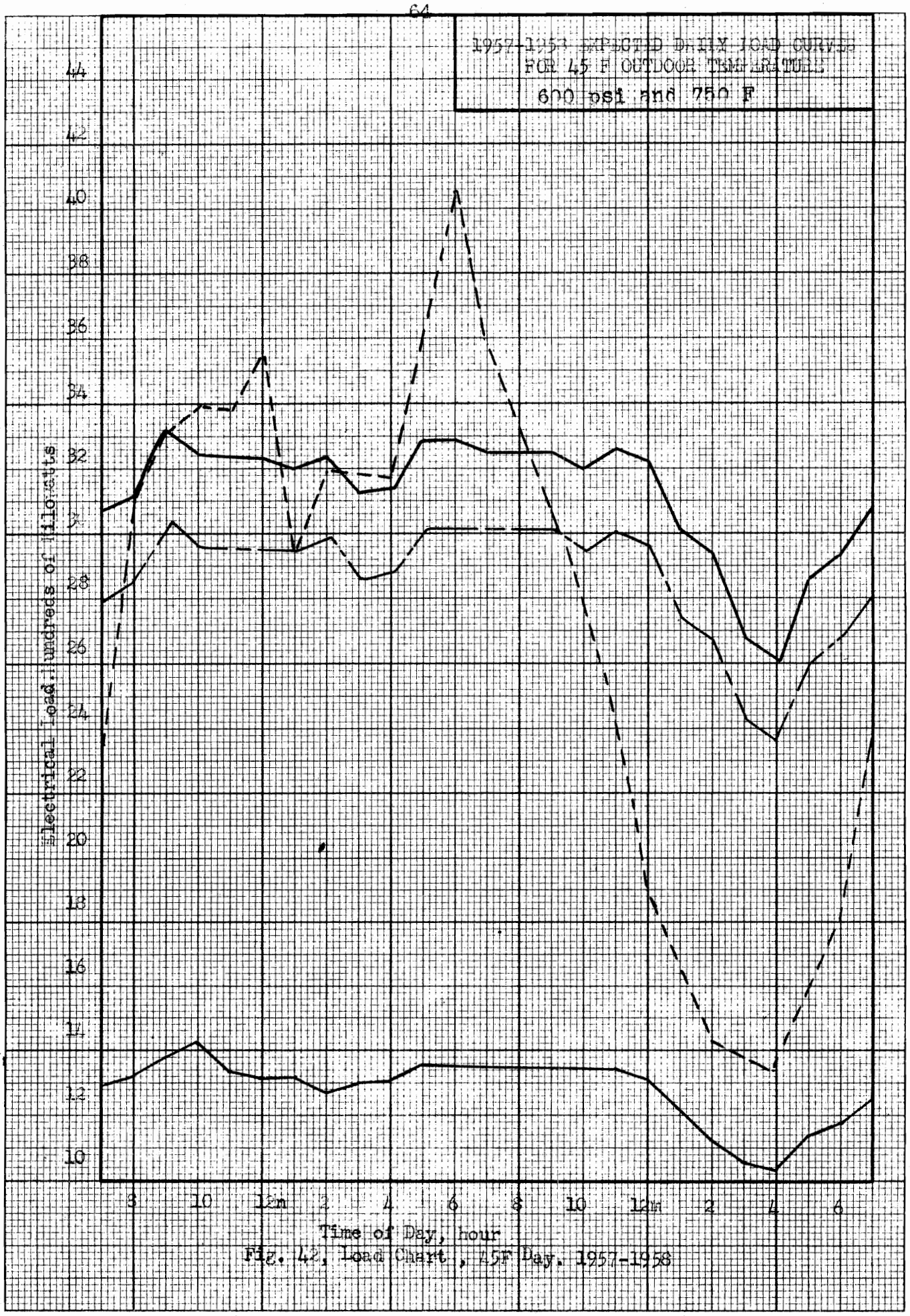


Fig. 42, Load Chart, 45F Day, 1957-1958

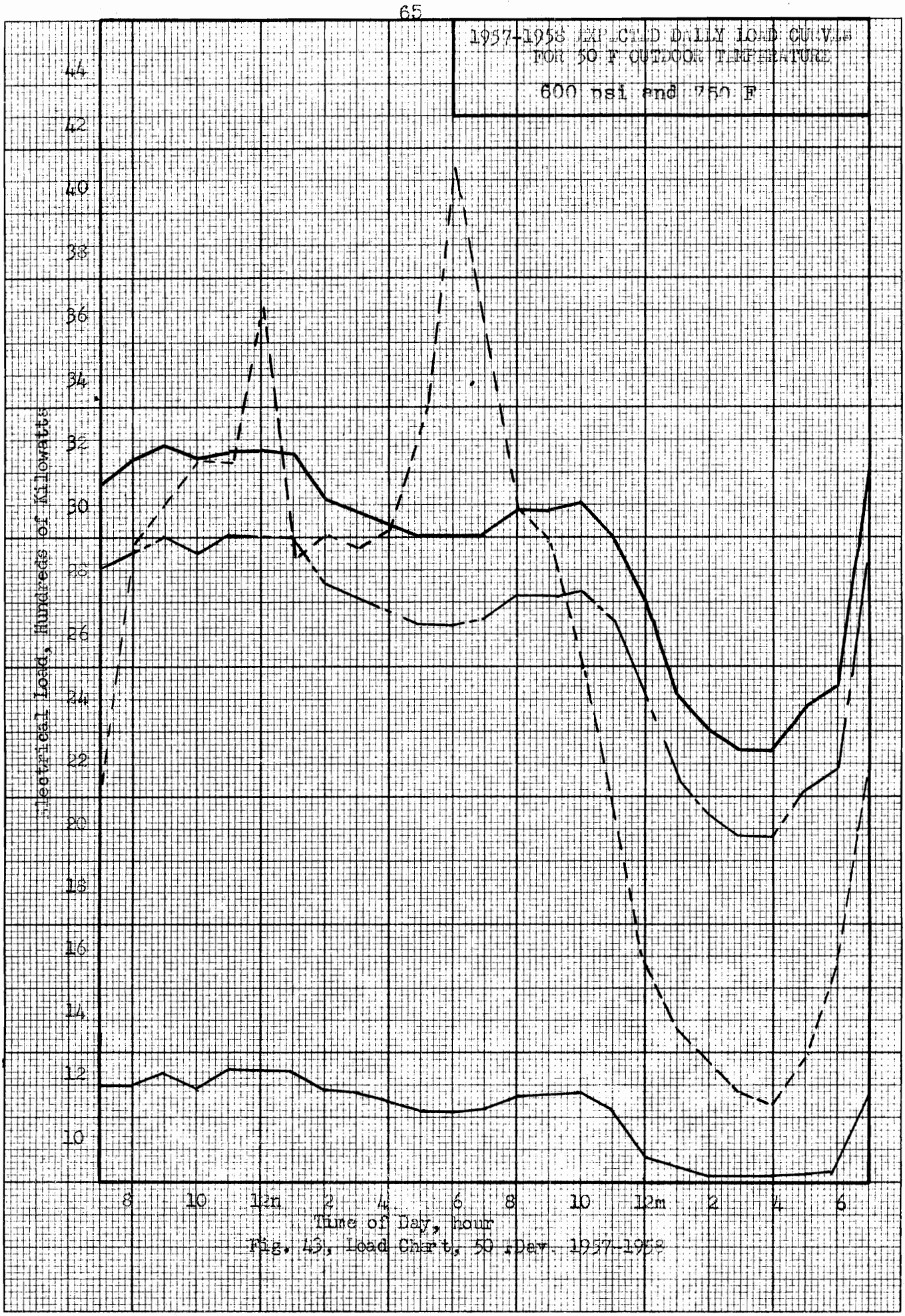


Fig. 43, Load Chart, 50 Dev. 1957-1958

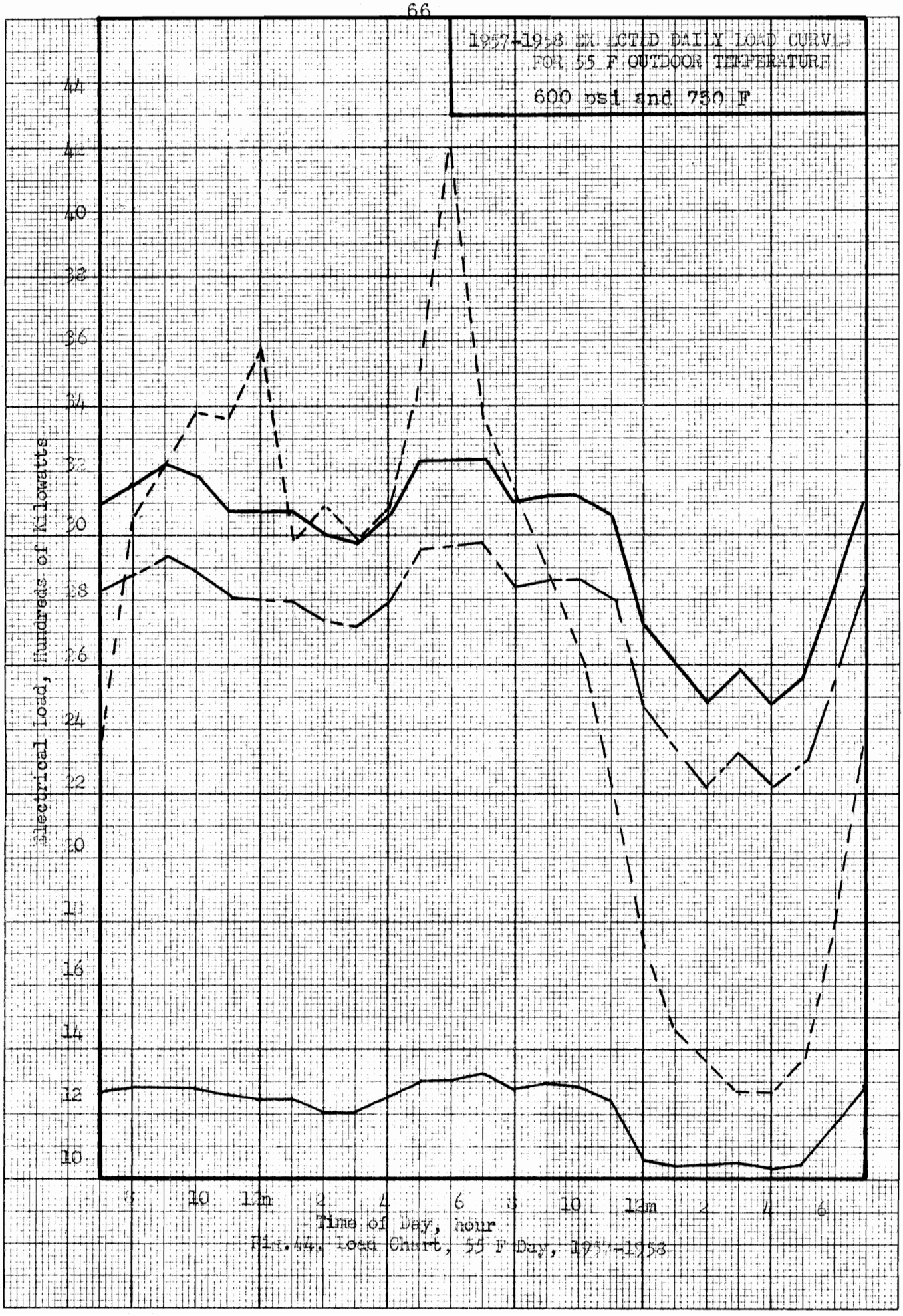


Fig.44. Load Chart, 55 F Day, 1957-1958

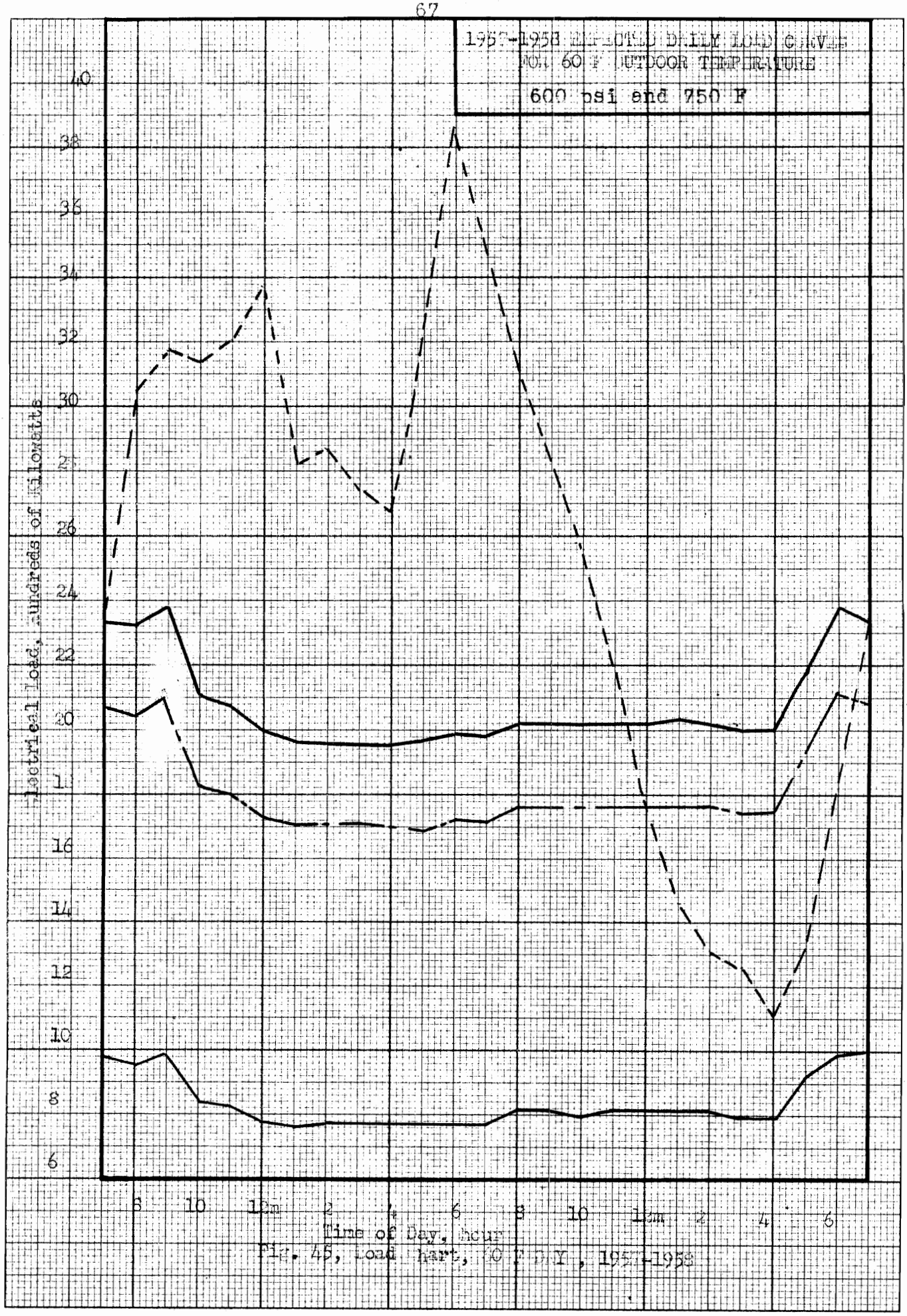


Fig. 45, Load Chart, NOV., 1957-1958

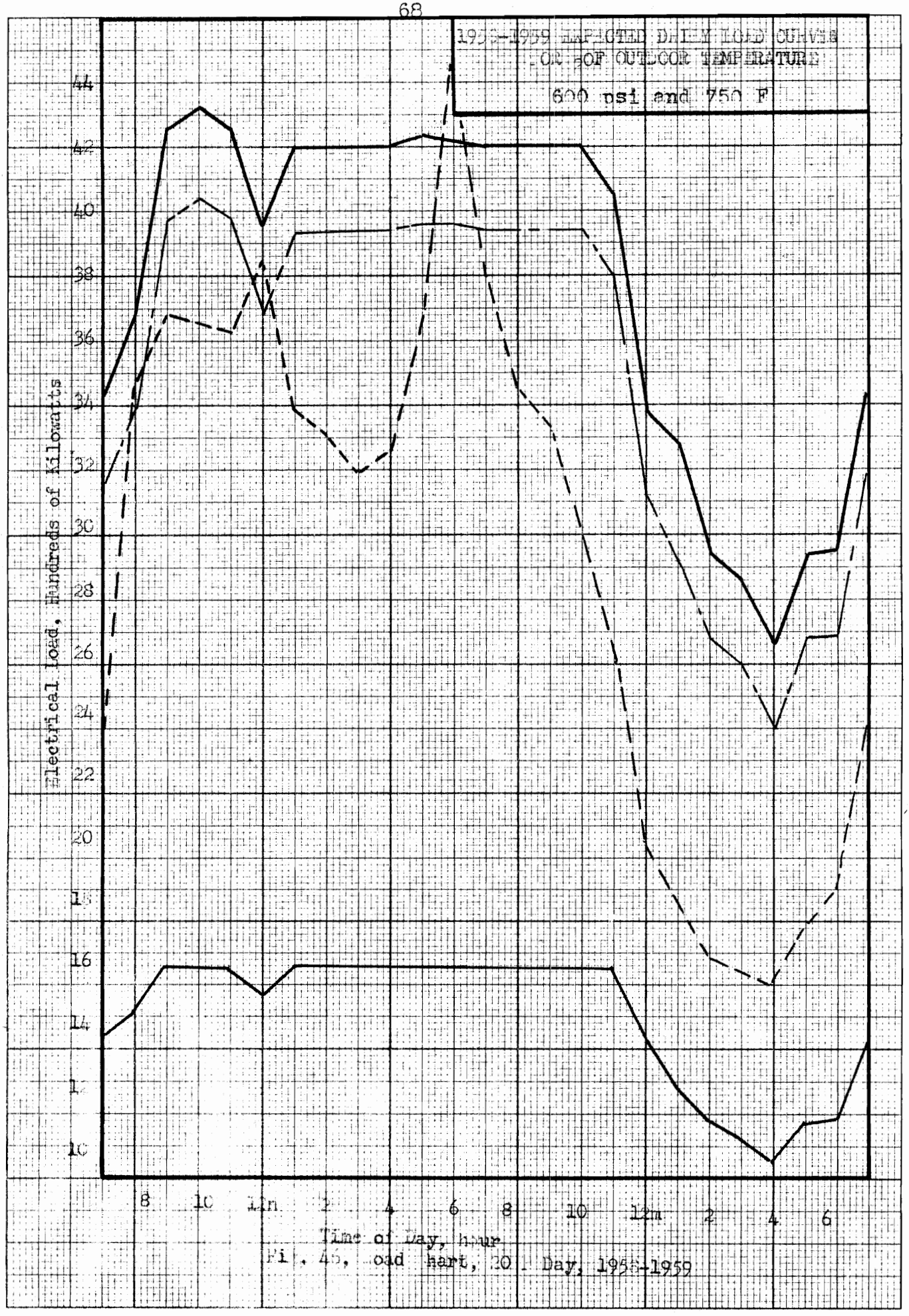


Fig. 45, Load Chart, 20 Day, 1955-1959

Fig. 47, Load Chart, 25F Day, 1958-1959

Fig. 43, Load Chart, 30 F Day, 1958-1959

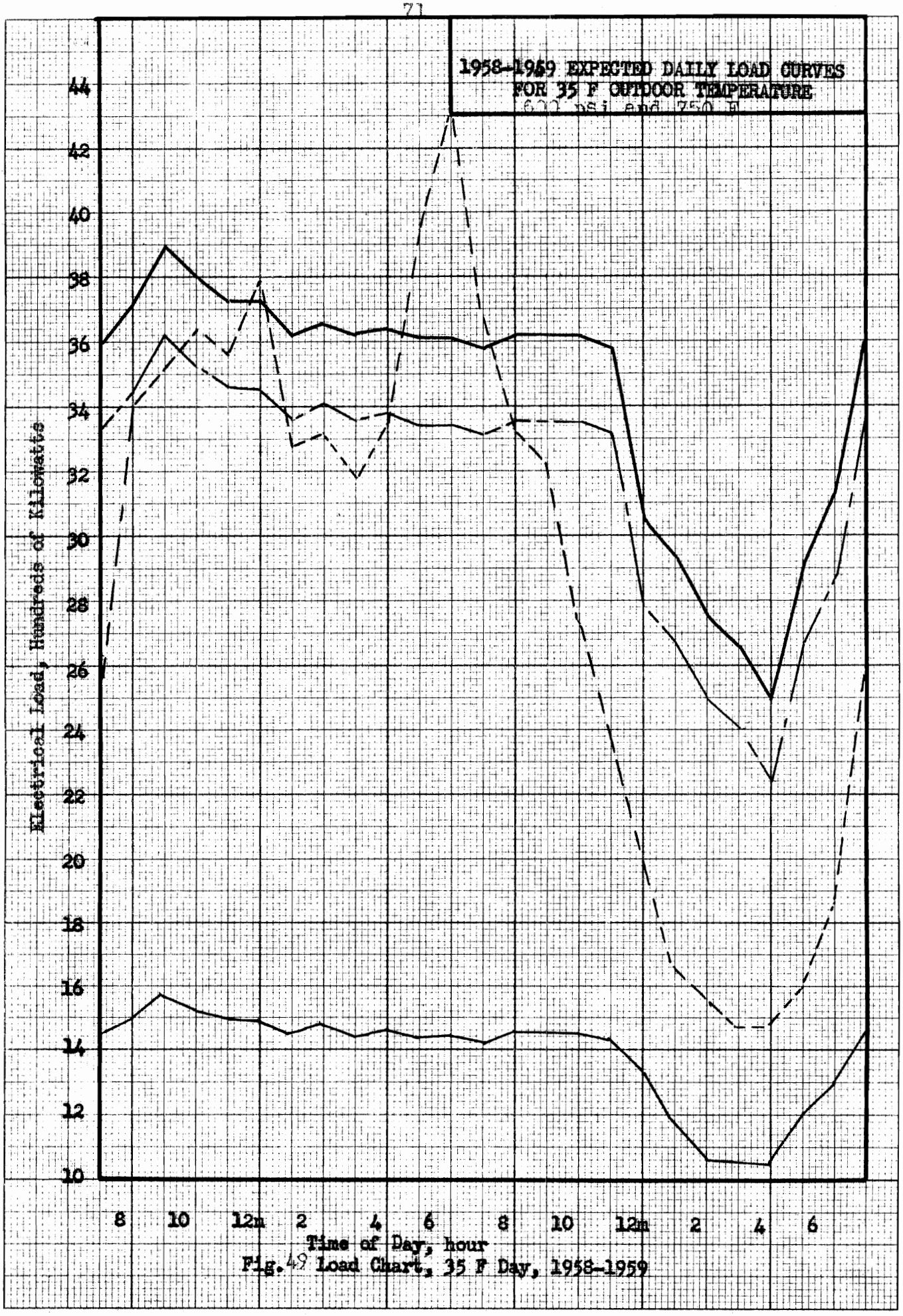


Fig. 49 Load Chart, 35 F Day, 1958-1959

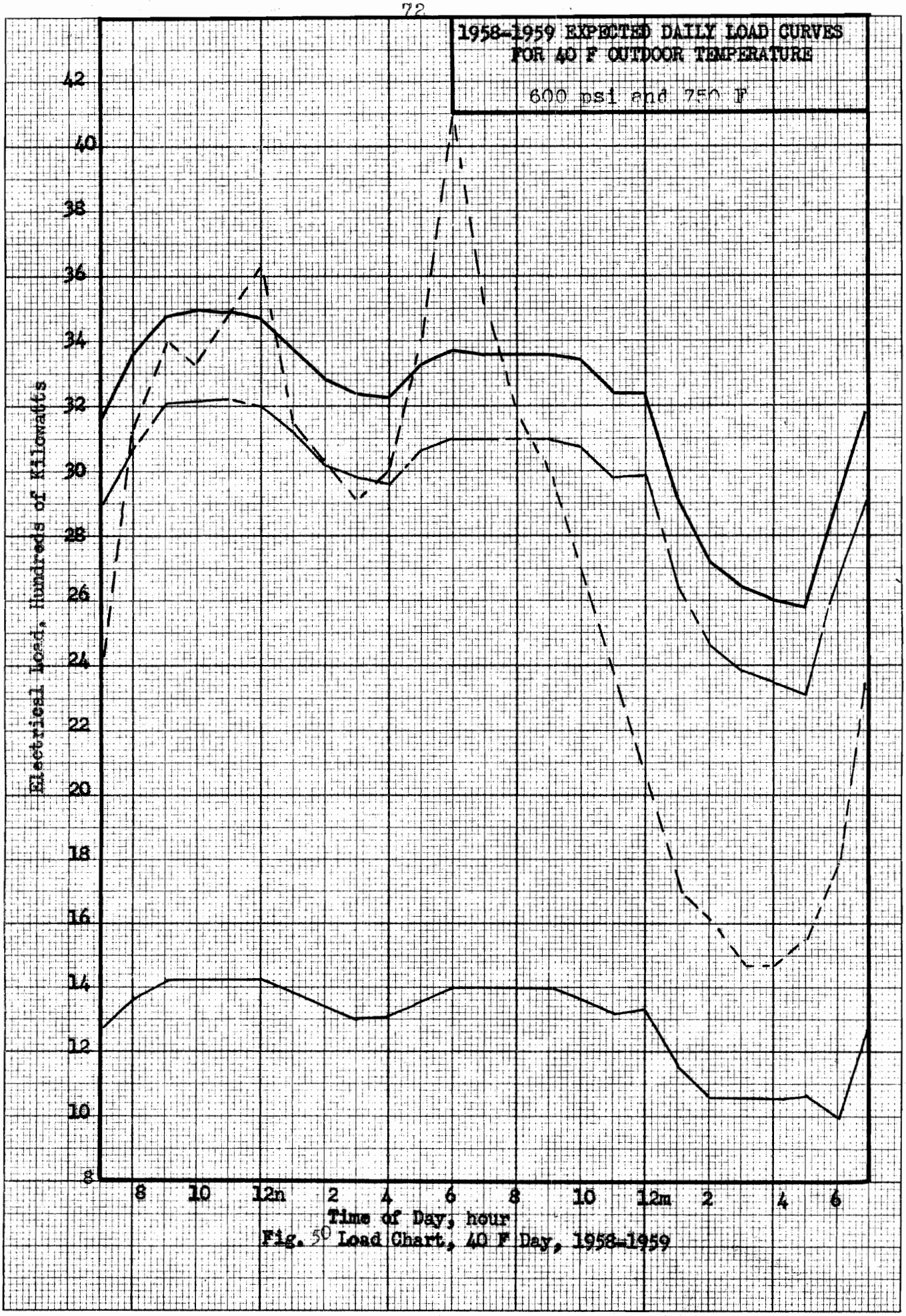


Fig. 50 Load Chart, 40 F Day, 1958-1959

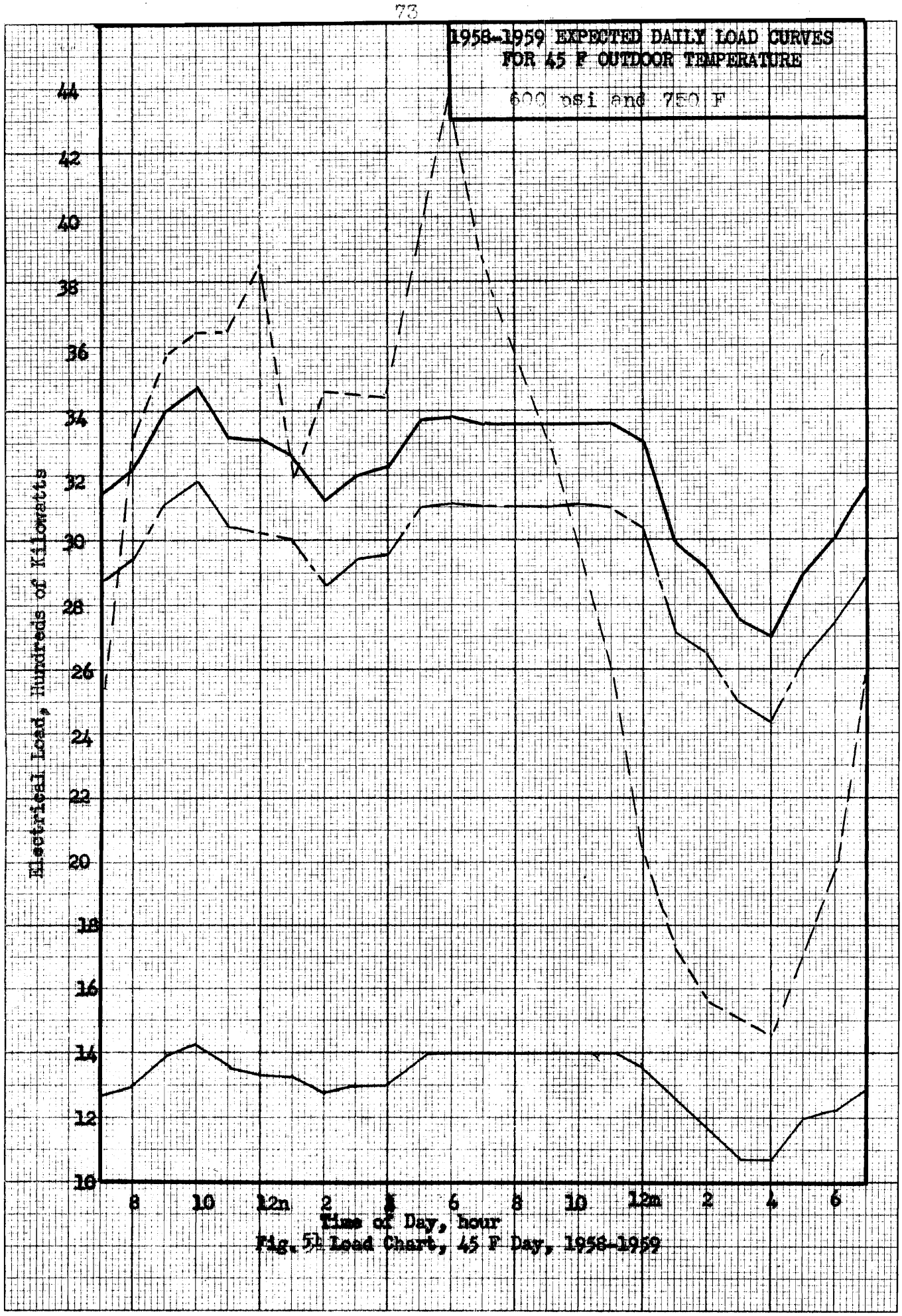


Fig. 5h Load Chart, 45 F Day, 1958-1959

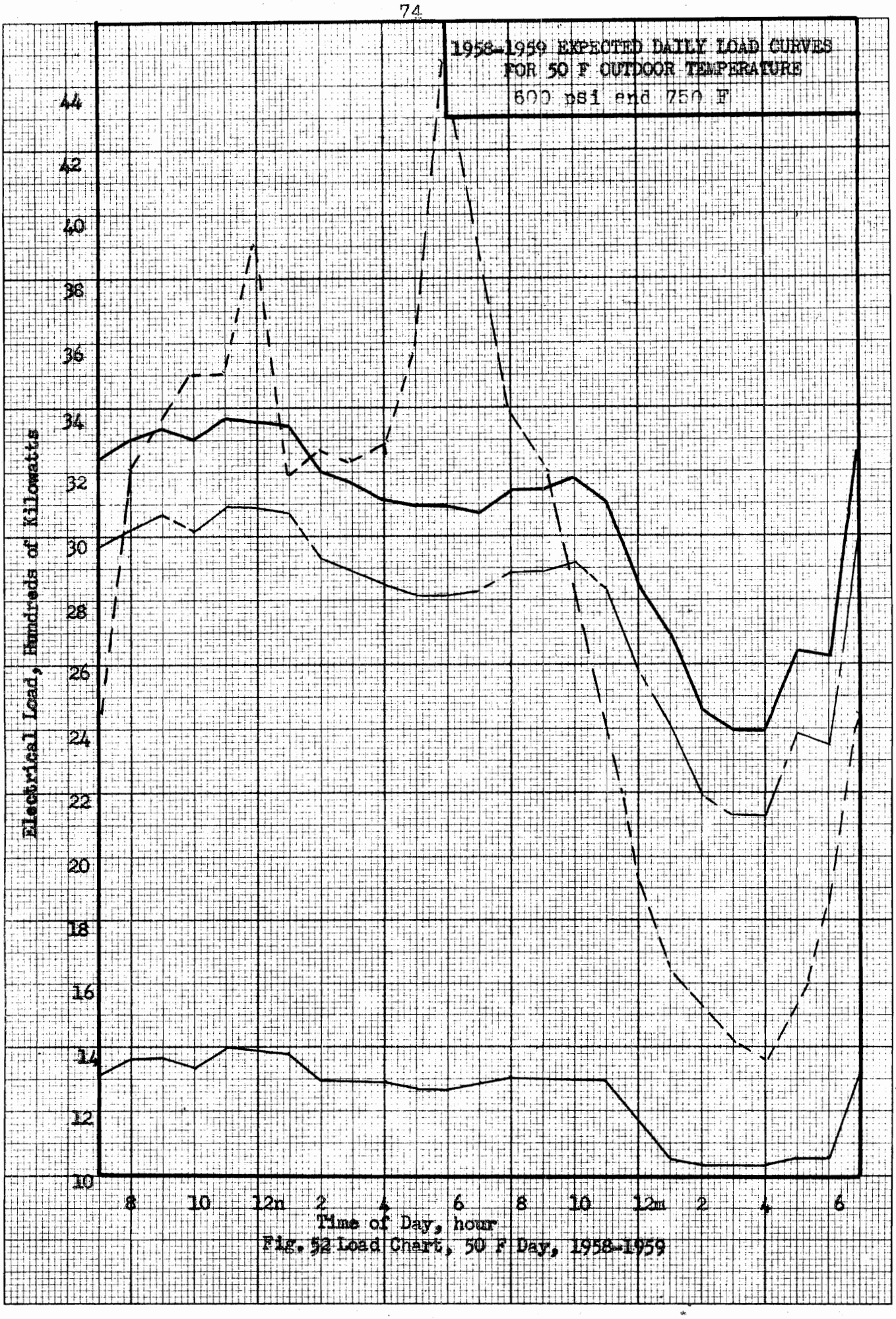


Fig. 52 Load Chart, 50 F Day, 1958-1959

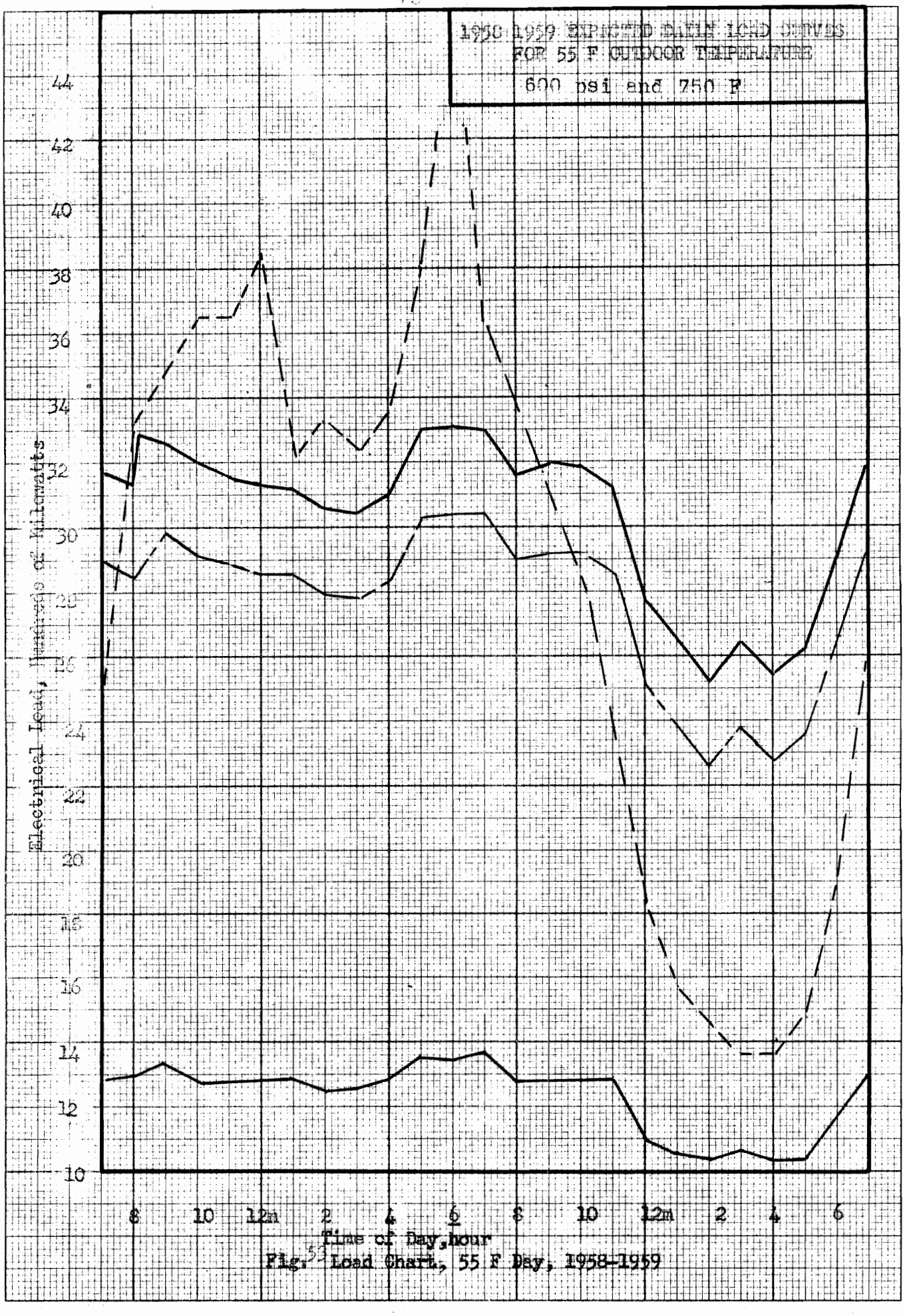


Fig. 53 Load Chart, 55 F Day, 1958-1959

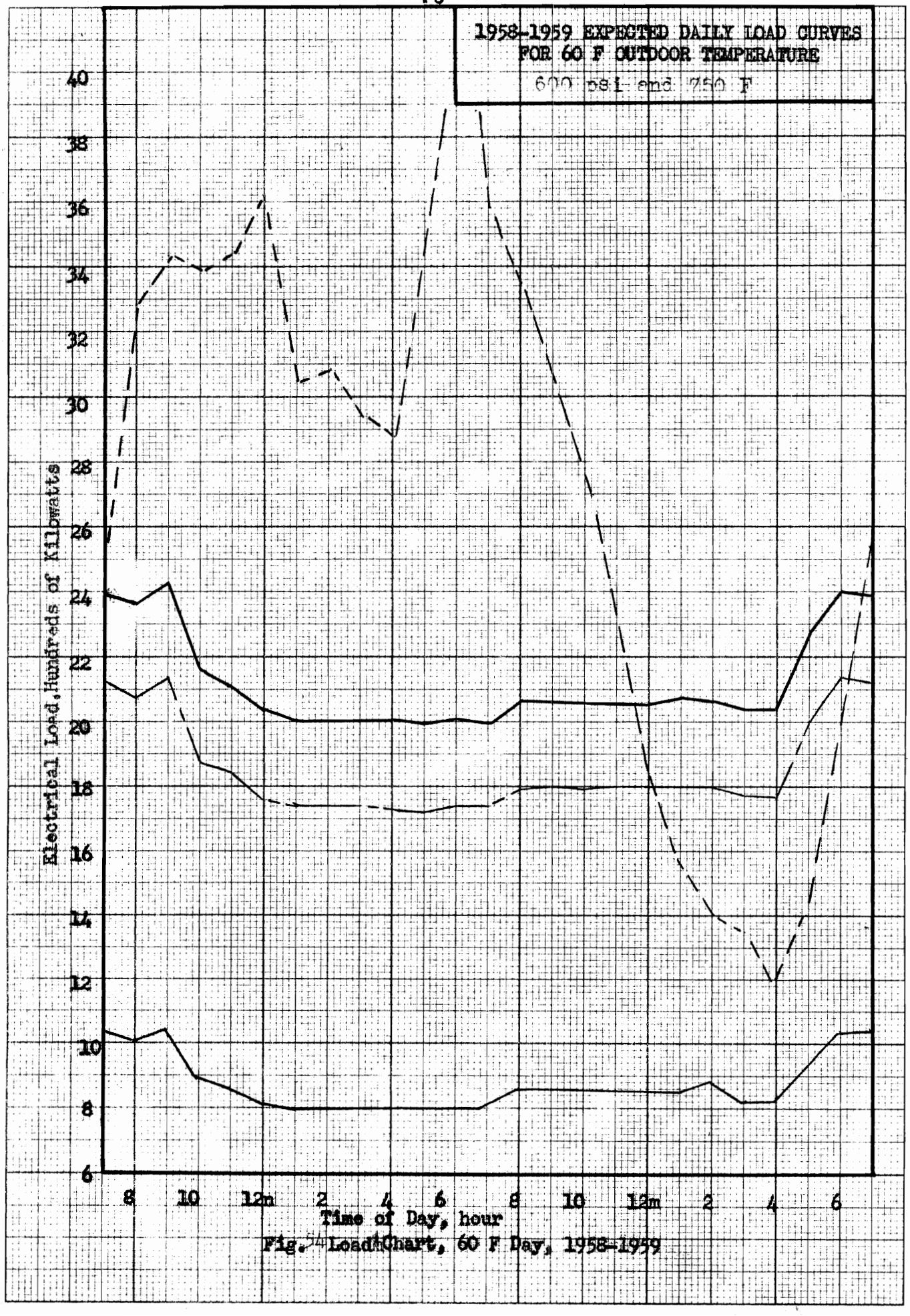


Fig. 14 Load Chart, 60 F Day, 1958-1959

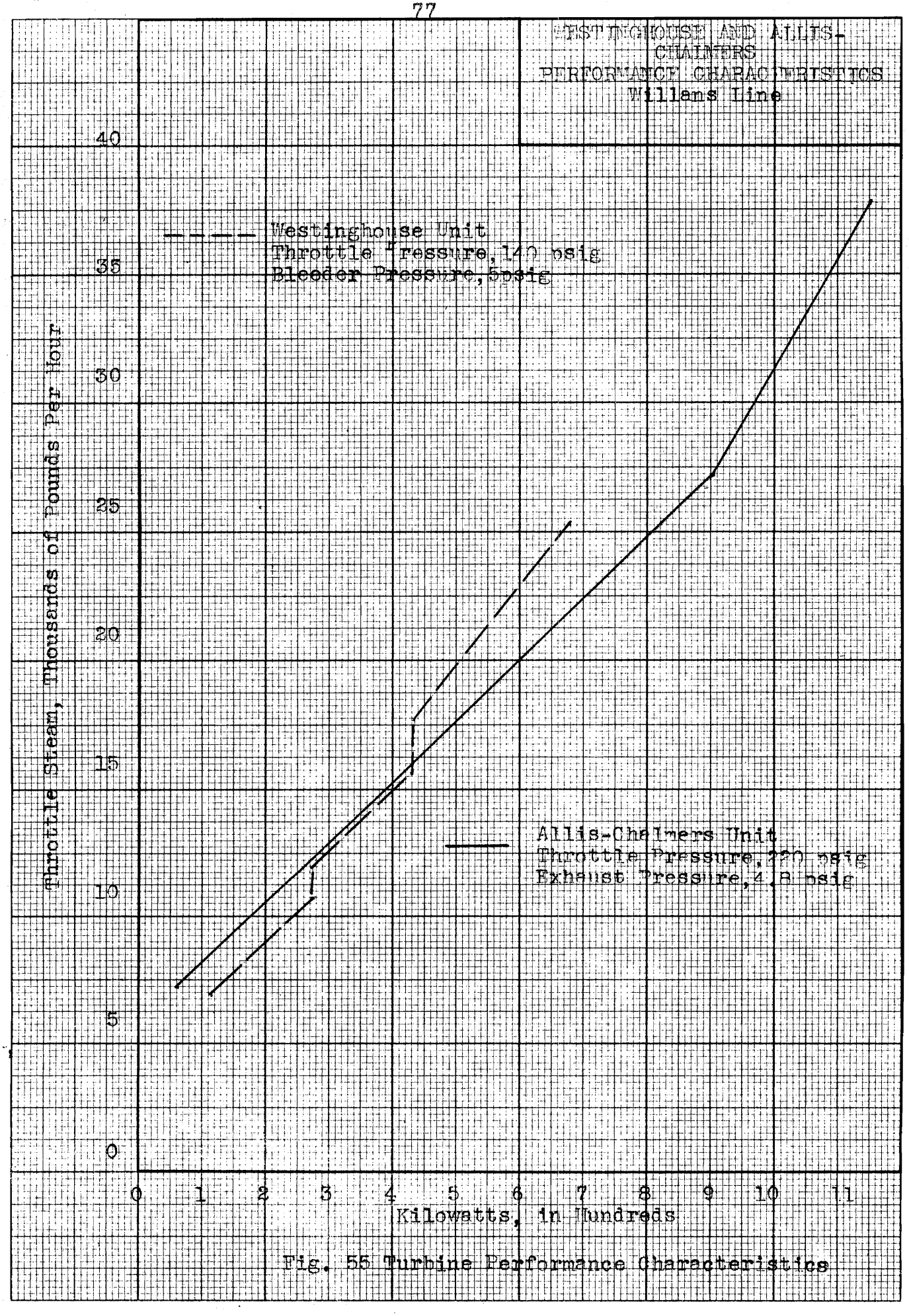


Fig. 55 Turbine Performance Characteristics

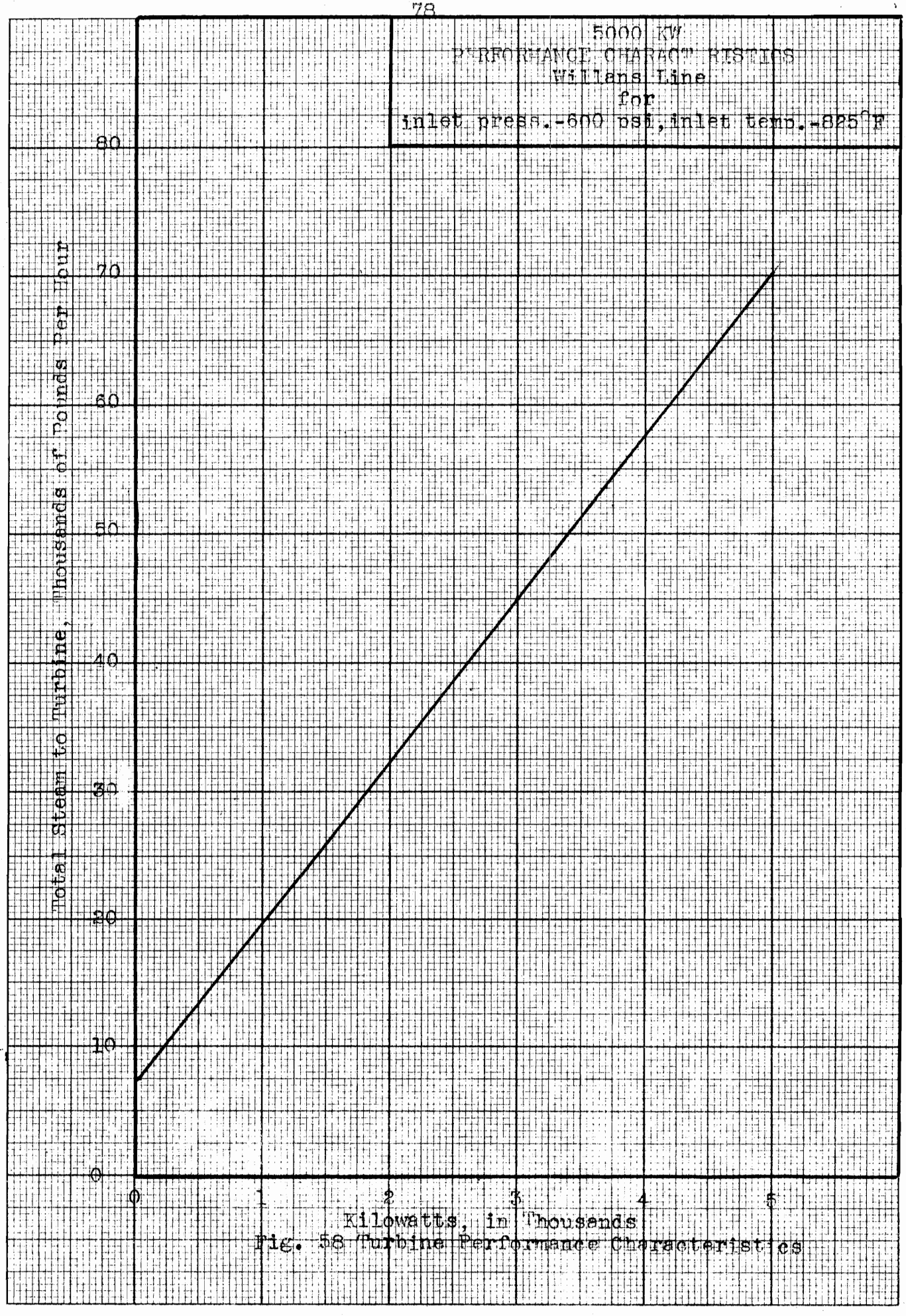


Fig. 58 Turbine Performance Characteristics

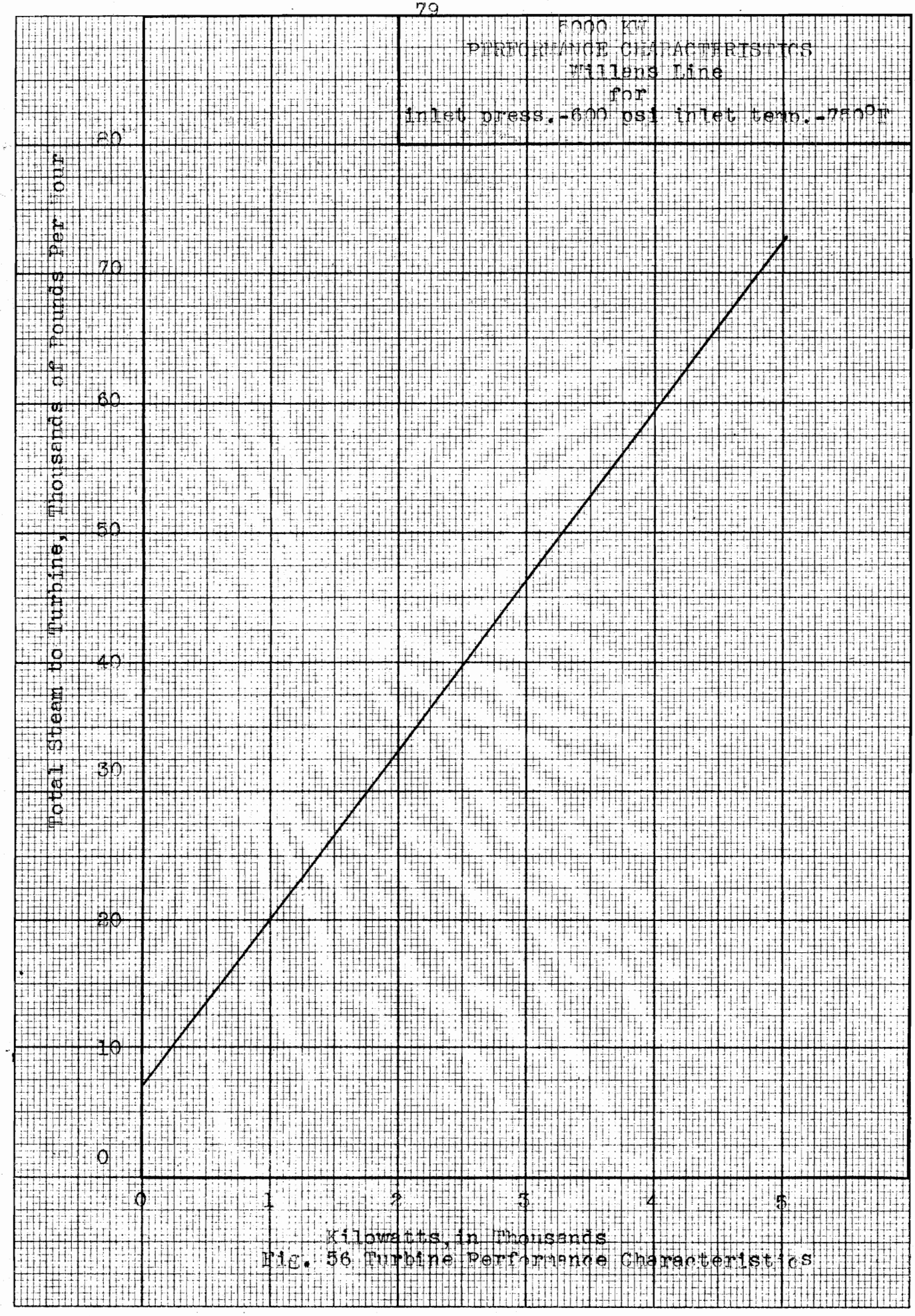


Fig. 56 Turbine Performance Characteristics

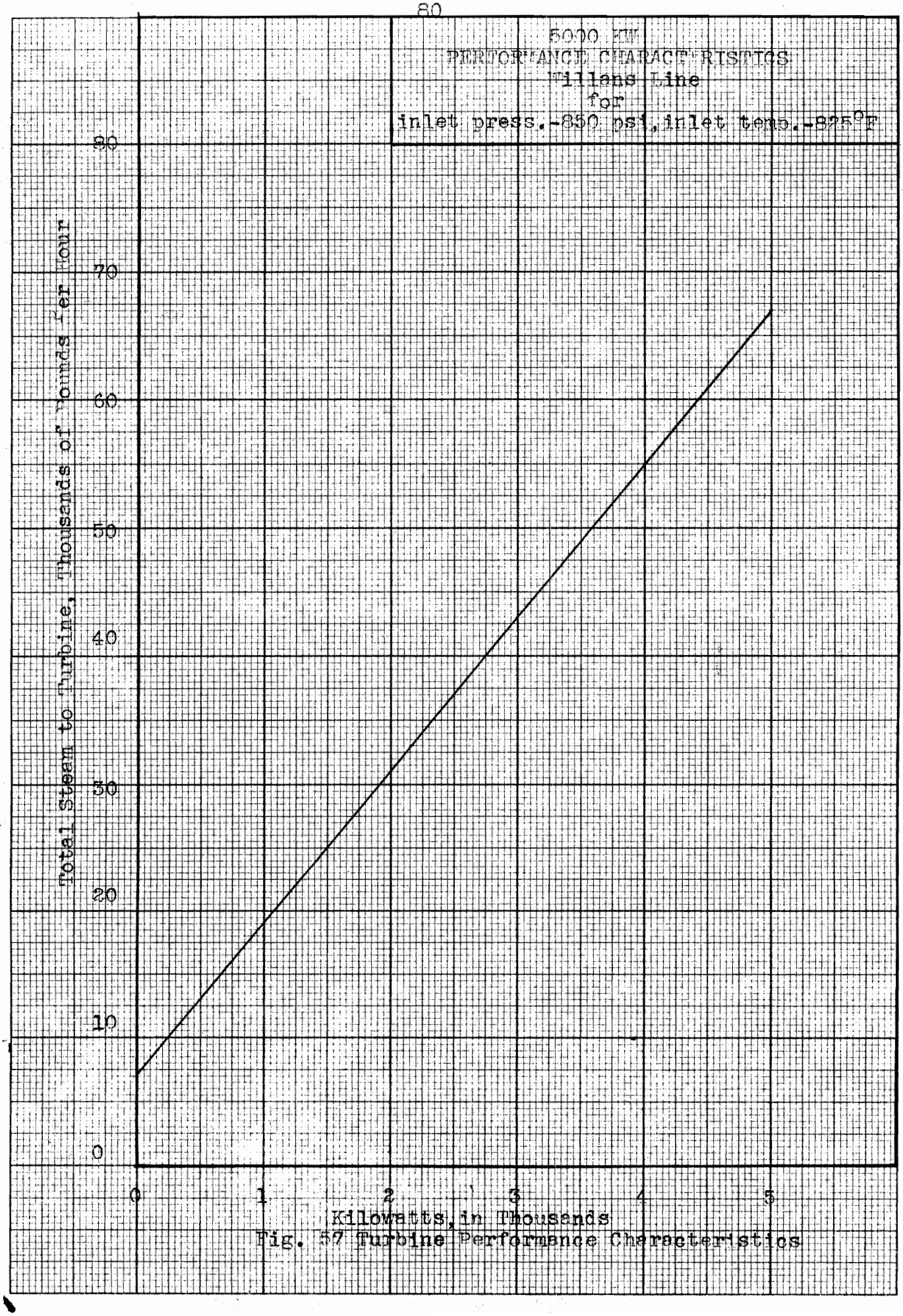
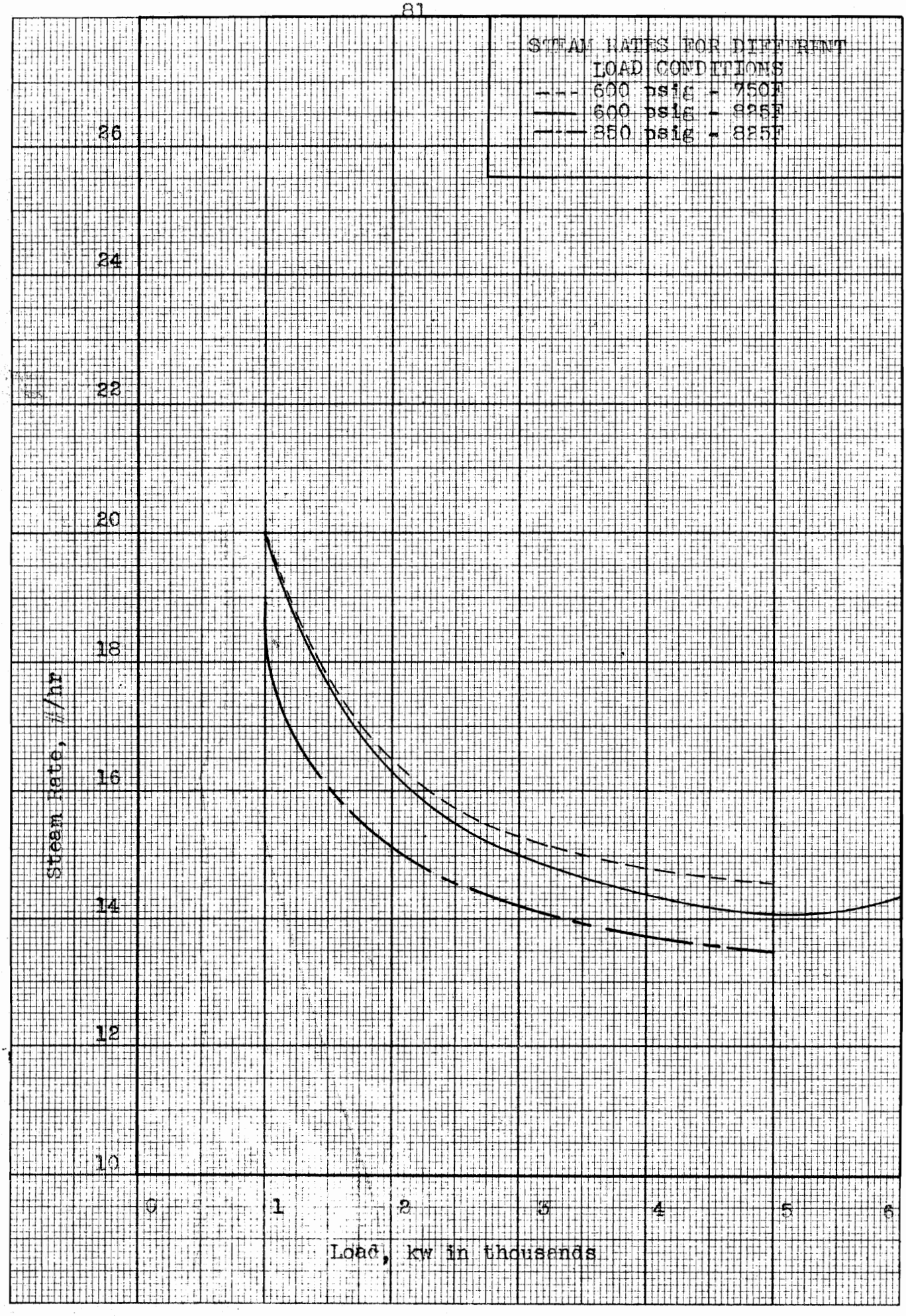


Fig. 57 Turbine Performance Characteristics


STEAM RATES FOR DIFFERENT LOAD CONDITIONS
600 psig - 750F
600 psig - 825F
850 psig - 825F
26
24
22
20
18
16
14
12
10
Steam Rate, #/hr
0
1
2
3
4
5
6
Load, kw in thousands

VIII

DISCUSSION OF RESULTS

The results of this investigation indicate that the installation of a new 5000-kw turbo-generator unit operating at one of the following steam conditions, 600 psig-750°F. or 850 psig-825°F., having a back pressure of 5 psig for both steam conditions, in the Virginia Polytechnic Institute Central Heating and Power Plant would result in the following savings for the first three years of operation if the unit were installed by the fall of 1956: $34,190.00 for the heating season of 1956-1957 at steam conditions 600 psig-750°F., $37,730.00 for the heating season 1957-1958 at steam conditions 600 psig-750°F., $41,860.00 for the heating season of 1958-1959 at steam condition 600 psig-750°F., $35,605.00 for the heating season 1956-1957 at steam condition 850 psig-825°F., $39,370.00 for the heating season of 1957-1958 at steam condition 850 psig-825°F., and $46,590.00 for the heating season of 1958-1959 at steam condition 850 psig-825°F. These savings would probably be larger if the cost of fuel is reduced from the present rate.

This investigation also included a study of the above units operating with extraction at 100 psig. This extraction would be used as a means of obtaining the needed high pressure steam required on the campus. This resulted in the following savings for the first three years: $1,498.70 for the heating season of 1956-1957 at the initial steam condition of 600 psig-750°F., $2,505.05 for the heating season of 1957-1958 at the initial steam condition of 600 psig-750°F., $3,239.60 for the heating

season of 1958-1959 at the initial steam condition of 600 psig-750°F., $986.00 for the heating season of 1956-1957 at the initial steam condition of 850 psig-825°F., $1,703.90 for the heating season of 1957-1958 at the initial steam condition of 850 psig-825°F., and $2,933.00 for the heating season of 1958-1959 at the initial steam condition of 850 psig-825°F.

If the unit discussed is to use extraction, the savings made by the addition of extracting high pressure steam at 100 psig would be added to the saving of the unit operating without extraction.

In the type turbines considered in this thesis the extraction unit can be had at no extra cost up to 15 per cent of the total steam load. Therefore, extraction load could increase up to approximately 10,900 #'s/hr. at steam condition 600 psig-750°F., and 10,100 #'s/hr. at steam condition 850 psig-825°F without extra cost to the unit. The large increase in extraction would only come with an increase in the present high-pressure steam demand. The average high-pressure steam demand is approximately 8,300 #'s/hr. at present condition.

A study of the curves showed the following information:

1. The most important curves were those which represented the electric output of the present proposed units with and without extraction. The curve for the proposed electric load of the 5000 kw turbo-generator fell above the electric load expected for all heating seasons at all degree days except the 20°F. day. "Here the curve fell below the expected electric load. In most cases the proposed electric load was above the expected electric load except at the time of day from 10:00 A.M. - 1:00 P.M.,

and 4:00 P. M. - 8:00 P. M."

2. "It was noted that the peak outputs which could be obtained with both the present proposed units with and without extraction would occur between 7:00 A.M. and 11:00 A.M. when the maximum low pressure steam demand would occur. Minimum output of the units would occur early in the morning, between 1:00 A.M. and 6:00 A.M., when the minimum low pressure steam would occur."

3. It was noted that the proposed units when supplying the low pressure steam demand would be able to operate between half load and over load conditions. From this basis the units proposed in this thesis would satisfy the operating conditions of the power plant.

4. It should be noted here that in considering the steam rates for the given units in this thesis the writer chose a steam rate at full load for both conditions. The reason for this assumption was that the turbine when operating between 4,000 kw and 6,000 kw has only a two tenths per cent variation in its steam rate. This means that the turbine steam rate would be effected very little to run at varying loads from three-quarters load to overload, Figure 59. This assumption will also show the turbine operating at its highest efficiency.

For a more accurate procedure in estimating the electrical load as it varies with the steam demand, use of the Willans Lines would be more correct. Even with this the error of the human eye comes into the picture from two points of view, plotting the curve and reading the points.

The writer of this thesis is in error of approximately one per cent. This error will be used to show its effect on the conclusions.

"It was noted from a study of the areas that represent the additional kw-hrs which could be generated with the proposed unit that for a given heating season the areas decreased as the outdoor temperature increased, and that for a given temperature the areas increased every year. This was to be expected."

Several assumptions were made in this investigation and must be kept in mind when interpreting the information presented in this thesis. The assumptions were as follows:

1. The growth of the community of Blacksburg continues the same as it has in the past years: there will be no sudden enlargements in the town due to varying conditions.

2. The growth of the college will be as predicted due to the expected student enrollment.

3. The Westinghouse and Allis-Chalmers turbo-generators remain in operation for the next six years at their present operating conditions.

4. The total electric load for the community of Blacksburg, including the college, will increase at a rate of eight per cent per year.

5. The college low pressure steam demand increase will be proportional to the increase in building radiation.

6. The distribution of outdoor temperature days for the future heating seasons considered will be the same as for the heating season of 1951-1952.

In conclusion it will be noted for a more accurate study of this material, the data should be set up for a complete year. The study should be only for the year which the unit could be installed and the years after installation.

This thesis runs parallel with the thesis, "An Economic Study of a Proposed 2000-kw Turbo-Generator Unit In The Virginia Polytechnic Institute Central Heating And Power Plant" which was written by James E. McMurrer, Jr. This thesis was calculated in the same manner as the reference thesis.

No actual choice can be made definitely from the data compiled in this thesis as to the unit best suited for the Virginia Polytechnic Institute Central Heating and Power Plant. The object of this thesis was a study of the savings involved, as to what can be expected from each unit savings and not a final choice of a unit.

Many more factors would have to be considered beyond what this study has obtained, in order to make a definite choice of a unit. Such factors as feed water treatment and the ability of present personnel to operate proposed equipment would have to be considered as well as many more factors.

The actual saving in comparison to the two units considered will not be too great when you consider the extraction savings plus the non-extraction savings. As a comparison of the results of these units, 1958-1959 is used only because this is the only year that can have any possible meaning. That is the first year that the unit could be installed and the results show only a loss in savings of $4,423.40 by the use of

the unit using steam at 600 psig-750°F. with extraction at 100 psig as compared to the 850 psig-825°F. with extraction.

The extraction would eliminate another unit producing steam at the high pressure condition of 100 psig. With the use of the needed quantity of high pressure steam extra kw's can be produced as well as obtaining the needed high-pressure steam load, by use of one boiler and one turbine.

In all cases, the extraction adds extra kw's to the expected load at 1958-1959. If the expected load continues to increase as is predicted the extraction will become of more importance in the future.

It can be seen that with the savings (From Saving Chart) of the first two heating seasons remain almost the same with extraction at steam conditions 600 psig-750°F., whereas you get almost double the saving the second year at the same conditions but without extraction. It can then be seen that in the expected future load this will have a more severe effect on the saving than the present expected trend will show. It is possible to have as much as $100,000.00 saving by the heating season 1963-1964.

Of course, these savings will be even more pronounced with steam conditions at 850 psig-825°F., with extraction.

In either case of the two proposed units the yearly savings justify the installation of the unit. Before either of these units should be considered finally a very accurate study should be made on the Power Plant as to its location, fuel supply, operating space, insurance, and depreciation. All of these factors would effect the over-all savings and must be considered in the final analysis.

SAVINGS CHART

Savings for the 1956-1957 Heating Season

600 psig-750°F. without extraction	$34,190.00	850 psig-825°F. without extraction	$35,605.00
600 psig-750°F. added due to extraction	$ 1,498.70	850 psig-825°F. added due to extraction	$ 986.00
600 psig-750°F. total with extraction	$35,688.70	850 psig-825°F. total with extraction	$36,591.00
Effect of 1% error	$ 356.89	Effect of 1% error	$ 365.91

Savings for the 1957-1958 Heating Season

600 psig-750°F without extraction	$37,730.00	850 psig-825°F. without extraction	$39,370.00
600 psig-750°F. added due to extraction	$ 2,505.50	850 psig-825°F added due to extraction	$ 1,703.90
600 psig-750°F. total with extraction	$40,235.50	850 psig-825°F. total with extraction	$41,073.90
Effect of 1% error	$ 402.35	Effect of 1% error	$ 410.74

Savings for the 1958-1959 Heating Season

600 psig-750°F. without extraction	$41.860.60	850 psig-825°F. without extraction	$46,590.00
600 psig-750°F. added due to extraction	$ 3,239.00	850 psig-825°F. added due to extraction	$ 2,933.00
600 psig-750°F. total with extraction	$45,099.60	850 psig-825°F. total with extraction	$49,523.00
Effect of 1% error	$ 451.00	Effect of 1% error	$ 495.23

IX

RECOMMENDATIONS

1. A complete economic investigation should be made concerning the installation of a 5000 Kw turbo-generator, of the type considered in this thesis, for the Virginia Polytechnic Institute Central Heating and Power Plant.

2. An investigation should be made to determine the best location for a proposed unit as the one given in this thesis, from the viewpoint of location, maintenance, installation, and building support.

3. An investigation should be made to determine the type of high pressure boiler to set up in connection with the proposed turbo-generator. The location and installation to be given a very important part in the study.

4. An investigation should be made on the complete meter set-up in the Power Plant as to their inspection and calibration. Also the records should be logged and checked against operation periodically.

5. An investigation should be made on the heat lost due to no control on buildings. This would cover the economic standpoint as well as better studying conditions for the students.

6. An investigation should be made on other temperatures and pressures which would be suitable for the Virginia Polytechnic Institute Central Heating and Power Plant High-Pressure Boiler. Also other size turbo-generators could be considered with possibility of extraction at different pressures.

X

BIBLIOGRAPHY

1. Gebhart, G. F., "Elements of Power Plant Design," Steam Power Plant Engineering, Fifth Edition, John Wiley and Sons, New York, 1917, pp. 881-888.

2. Gorham, R. C. "Economical Size of Units," Power Economics for Engineering Students, First Edition, Pittsburgh Printing Co., Pittsburgh, Pennsylvania, 1939, pp. 44-47.

3. Gorham, R. C. "Load Forecasting," Power Economics for Engineering Students, Pittsburgh Printing Co., Pittsburgh, Pennsylvania, 1939, pp. 208-213.

4. Lovell, Alfred H., "Power Plant Load Curves," Generating Stations, Third Edition, McGraw-Hill Book Co., New York, 1941, pp. 143-165.

5. Morse, F. T., "The Variable Load Problem," Power Plant Engineering and Design, Second Edition, D. Van Nostrand Co., New York, 1942, pp. 17-43.

6. Bulletin of Virginia Polytechnic Institute, Blacksburg, (Virginia) Weather, Vol. XXXVIII, No. 5, March, 1945, compiled by R. M. Brown.

7. Seeyle, H. P., "Trend Prediction Important in Planning," Electrical World, Vol. 125, No. 25, June 22, 1946, pp. 79-81.

8. Gaffert, G. A., "Load Curves and Plant Location," Steam Power Stations, Third Edition, McGraw-Hill Book Co., 1946, pp. 474-493.

9. Residential Loads-Old and New, "Electrical World, Vol. 129, No. 21, May 22, 1948, p. 115.

10. Feaman, M. M., "Ready and Waiting . . . The Water Heating Load," Electrical World, Vol. 129, No. 13, March 27, 1948, p. 96.

11. Bary, Constine, "Load Research Findings Help to Foresee Future Conditions," Electrical World, Vol. 129, No. 21, May 22, 1948, pp. 127-132.

12. "Load Research Methods," Electrical World, Vol. 129, No. 21, May 22, 1948, pp. 123-126.

13. "Unit Sales Up . . .Unit Revenues Down," Electrical World, Vol. 129, No. 21, May 22, 1948, pp. 104-105.

14. Hansen, M. R., "Increased Facilities Geared to Analysis of Load Trends," Electrical World, Vol. 130, No. 9, August 28, 1948, pp. 84-86.

15. Carlson, G. V., Earle, C. R., "University of Illinois Growth Requires Abbott Power Station Expansion," Power Generation, Vol. 52, No. 2, February, 1948, pp. 52-57.

16. "A Look Ahead," Electrical World, Vol. 131, No. 5, January 29, 1949, pp. 99-101.

17. Robinson, P. H., McNeese, C. L., "Load Studies," Electric Light and Power, Vol. 128, No. 5, May 1950, pp. 72-76.

18. "Blue Printing The Future," Electrical World, Vol. 133, No. 21, May 22, 1950, pp. 99-130.

19. Somes, A. D., Progress in Development of Process Steam Turbines for Industry, Paper No. 51 F 34, American Society of Mechanical Engineers, printed by General Electrical Co., 1951, p. 5.

20. "General Considerations in Plant Design," District Heating Handbook, Third Edition, National District Heating Association, Pittsburgh, Pennsylvania, 1951, pp. 87-100.

21. "Modern Power Backs Modern Education at The University of Oklahoma," Power Engineering, Vol. 55, No. 10, October, 1951, pp. 70-72.

22. "More Power and Still More Power," Power Engineering, Vol. 56, No. 1, January, 1952, pp. 55-72

XI

VITA

Victor Fontaine Anderson, was born in Martinsburg, West Virginia, on May 19, 1925. His family has maintained its residence in Martinsburg for the past twenty-eight years. There Victor Anderson completed part of his secondary education. His education was interrupted by World War II. He joined the U. S. Marine Corps on September 23, 1943, and served overseas in the Pacific until March 17, 1946 when he was honorably discharged at Bainbridge, Maryland. While serving overseas Victor Anderson completed his high school education.

After his discharge he returned to Martinsburg High School and graduated in the class of 1946.

In the fall of 1946 he entered the Virginia Polytechnic Institute as a student in Mechanical Engineering. He played varsity football and track in the years 1946, 1947, and 1948. He received his Bachelor of Science Degree in Mechanical Engineering in June 1950. He then went to work for Eastern Gas and Fuel Corporation at Wharton No. 2 Mines, West Virginia. Here he worked on a training program for one year. He left Eastern Gas and Fuel Corporation in June 1951 and went to work for Hercules Powder Company, Radford, Virginia. In September 1951 he received an appointment as a graduate fellow im Power and Fuel Engineering at the Virginia Polytechnic Institute.

Victor Anderson has accepted an offer with the Shell Chemical Corporation in Houston, Texas.

Victor F. Anderson

XII

APPENDICES

TABLE NO. III

Expected Low Pressure Steam Demand, 100 #'s/hr, For Heating Season 1958-1959

	Average Outdoor Temperature								
Time of Day	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	462	512	475	487	424	418	433	421	308
8:00 A. M.	494	525	509	502	447	429	441	428	301
9:00 A. M.	578	548	530	528	467	453	447	435	310
10:00 A. M.	588	547	537	513	469	463	439	424	272
11:00 A. M.	579	540	520	504	469	442	449	420	267
12:00 A. M.	535	541	517	502	465	439	449	415	256
1:00 P. M.	571	541	511	490	454	436	447	417	253
2:00 P. M.	574	528	522	497	438	417	426	407	253
3:00 P. M.	574	531	513	488	433	428	420	405	253
4:00 P. M.	573	528	512	493	431	431	414	414	252
5:00 P. M.	576	531	512	486	447	451	409	441	251
6:00 P. M.	576	536	511	486	451	452	409	442	253
7:00 P. M.	573	524	515	482	451	451	411	443	253
8:00 P. M.	574	526	513	488	451	451	420	422	261
9:00 P. M.	574	524	511	487	451	451	421	426	261
10:00 P. M.	574	527	506	487	447	452	424	426	260
11:00 P. M.	552	495	484	481	433	451	512	416	261
12:00 P. M.	454	444	432	404	434	443	376	367	261
1:00 A. M.	425	381	375	388	384	409	336	346	261
2:00 A. M.	390	376	349	363	358	386	319	329	261
3:00 A. M.	379	364	343	349	348	363	310	346	258
4:00 A. M.	349	359	336	341	342	354	310	328	258
5:00 A. M.	390	381	342	388	337	391	333	343	291
6:00 A. M.	391	400	392	418	304	398	342	387	312

TABLE NO. II

Expected Low Pressure Steam Demand, 100 #'s/hr, For Heating Seasons 1956-1957 And 1957-1958

Time of Day	Average Outdoor Temperature								
	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	450	499	463	474	413	407	422	410	301
8:00 A. M.	481	512	496	489	436	418	430	417	294
9:00 A. M.	563	535	516	515	455	442	436	424	303
10:00 A. M.	573	533	523	500	457	431	428	419	265
11:00 A. M.	564	527	506	491	457	431	438	409	260
12:00 A. M.	570	528	502	489	453	428	438	405	250
1:00 P. M.	556	528	498	478	442	428	436	406	247
2:00 P. M.	560	514	508	485	427	406	415	397	247
3:00 P. M.	560	518	501	476	422	418	410	395	247
4:00 P. M.	558	514	499	480	420	420	404	404	246
5:00 P. M.	562	518	499	473	436	439	398	430	245
6:00 P. M.	562	522	498	473	439	440	398	431	247
7:00 P. M.	558	511	502	470	439	439	401	433	247
8:00 P. M.	560	513	501	476	439	439	410	412	255
9:00 P. M.	560	511	498	474	439	439	411	415	255
10:00 P. M.	560	514	494	474	436	400	413	415	254
11:00 P. M.	538	482	472	469	422	439	401	406	255
12:00 P. M.	443	432	422	429	423	432	366	358	255
1:00 A. M.	414	371	365	378	374	398	328	338	255
2:00 A. M.	380	366	340	354	349	377	311	321	255
3:00 A. M.	370	355	335	340	339	354	303	338	251
4:00 A. M.	340	346	328	332	334	345	303	320	251
5:00 A. M.	380	371	333	378	329	381	324	334	284
6:00 A. M.	382	390	382	407	296	388	333	378	305

TABLE NO. I

Low Pressure Steam Demand, 100 #'s/hr, For Heating Season 1951-1952

Time of Day	Average Outdoor Temperature								
	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	396	439	407	417	363	358	371	361	265
8:00 A. M.	423	450	436	430	383	368	378	367	258
9:00 A. M.	495	470	454	453	400	388	383	373	266
10:00 A. M.	504	469	460	440	402	397	376	368	233
11:00 A. M.	496	463	445	432	402	379	385	360	229
12:00 A. M.	501	464	443	430	398	376	385	356	220
1:00 P. M.	489	464	438	420	389	376	383	357	217
2:00 P. M.	492	452	447	426	375	357	365	349	217
3:00 P. M.	492	455	440	418	371	367	360	347	217
4:00 P. M.	491	452	439	422	369	369	355	355	216
5:00 P. M.	494	455	439	416	383	386	350	378	215
6:00 P. M.	494	459	438	416	386	387	350	379	217
7:00 P. M.	491	449	441	413	386	386	352	380	217
8:00 P. M.	492	451	440	418	386	386	360	362	224
9:00 P. M.	492	449	438	417	386	386	361	365	224
10:00 P. M.	492	452	434	417	383	387	363	365	223
11:00 P. M.	473	424	415	412	371	386	353	357	224
12:00 P. M.	390	380	370	377	372	380	322	315	224
1:00 A. M.	364	326	321	332	329	350	288	297	224
2:00 A. M.	334	322	299	311	307	331	273	282	224
3:00 A. M.	325	312	294	299	298	311	266	297	221
4:00 A. M.	299	308	288	292	293	303	266	281	221
5:00 A. M.	334	326	293	332	289	335	285	294	250
6:00 A. M.	335	343	336	358	260	341	293	332	268

TABLE NO. IV

Expected Kw Loading, Old Units Supplying Low Pressure Steam Demand, Heating Seasons 1956-1957 And 1957-1958

Time of Day	20 F Outdoor Temp. Day			25 F Outdoor Temp. Day			30 F Outdoor Temp. Day		
	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total
7:00 A. M.	1020	370	1390	1202	280	1300	1020	415	1435
8:00 A. M.	1020	415	1435	1020	520	1540	1020	465	1485
9:00 A. M.	1020	638	1658	1020	580	1580	1020	525	1545
10:00 A. M.	1020	638	1658	1020	575	1595	1020	550	1570
11:00 A. M.	1020	638	1658	1020	565	1585	1020	490	1510
12:00 A. M.	1020	638	1658	1020	570	1590	1020	480	1500
1:00 P. M.	1020	638	1658	1020	570	1590	1020	470	1490
2:00 P. M.	1020	638	1658	1020	525	1545	1020	500	1520
3:00 P. M.	1020	638	1658	1020	530	1550	1020	475	1495
4:00 P. M.	1020	638	1658	1020	525	1545	1020	470	1490
5:00 P. M.	1020	638	1658	1020	530	1550	1020	470	1490
6:00 P. M.	1020	638	1658	1020	535	1555	1020	470	1490
7:00 P. M.	1020	638	1658	1020	510	1530	1020	480	1500
8:00 P. M.	1020	638	1658	1020	520	1540	1020	475	1495
9:00 P. M.	1020	638	1658	1020	510	1530	1020	470	1490
10:00 P. M.	1020	638	1658	1020	525	1545	1020	455	1475
11:00 P. M.	1020	600	1620	1020	420	1440	1020	415	1435
12:00 P. M.	1020	375	1395	1020	295	1315	1020	270	1290
1:00 A. M.	1020	275	1295	1020	80	1100	1020	60	1080
2:00 A. M.	1020	125	1145	1020	65	1085	1020	40	1060
3:00 A. M.	1020	80	1100	1020	10	1030	1020	30	1050
4:00 A. M.	1020	10	1030	1020	10	1030	1020	10	1030
5:00 A. M.	1020	125	1145	1020	85	1105	1020	30	1050
6:00 A. M.	1020	130	1150	1020	170	1190	1020	135	1155

TABLE NO. IV

Expected Kw Loading, Old Units Supplying Low Pressure Steam Demand, Heating Seasons 1956-1957 And 1957-1958

Time of Day	35 F Outdoor Temp. Day			40 F Outdoor Temp. Day			45 F Outdoor Temp. Day		
	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total
7:00 A. M.	1020	415	1435	1020	270	1290	1020	240	1260
8:00 A. M.	1020	435	1455	1020	315	1335	1020	270	1290
9:00 A. M.	1020	520	1540	1020	385	1405	1020	335	1355
10:00 A. M.	1020	470	1490	1020	395	1415	1020	380	1400
11:00 A. M.	1020	440	1460	1020	395	1415	1020	295	1315
12:00 A. M.	1020	435	1455	1020	375	1395	1020	275	1295
1:00 P. M.	1020	415	1435	1020	335	1355	1020	275	1295
2:00 P. M.	1020	425	1445	1020	275	1295	1020	235	1255
3:00 P. M.	1020	415	1435	1020	270	1290	1020	270	1290
4:00 P. M.	1020	415	1435	1020	270	1290	1020	270	1290
5:00 P. M.	1020	415	1435	1020	315	1335	1020	325	1345
6:00 P. M.	1020	415	1435	1020	325	1345	1020	330	1350
7:00 P. M.	1020	415	1435	1020	325	1345	1020	325	1345
8:00 P. M.	1020	415	1435	1020	325	1345	1020	325	1345
9:00 P. M.	1020	415	1435	1020	325	1345	1020	325	1345
10:00 P. M.	1020	415	1435	1020	315	1335	1020	330	1350
11:00 P. M.	1020	415	1435	1020	270	1290	1020	325	1345
12:00 P. M.	1020	280	1300	1020	270	1290	1020	300	1320
1:00 A. M.	1020	120	1140	1020	100	1120	1020	210	1320
2:00 A. M.	1020	40	1060	1020	80	1100	1020	110	1130
3:00 A. M.	1020	35	1055	1020	50	1070	1020	50	1070
4:00 A. M.	1020	20	1040	1020	10	1030	1020	20	1040
5:00 A. M.	1020	120	1140	1020	0	1020	1020	125	1145
6:00 A. M.	1020	240	1240	965	0	965	1020	165	1185

TABLE NO. IV

Expected Kw Loading, Old Units Supplying Low Pressure Steam Demand, Heating Seasons 1956-1957 And 1957-1958

Time of Day	50 F Outdoor Temp. Day			55 F Outdoor Temp. Day			60 F Outdoor Temp. Day		
	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total
7:00 A. M.	1020	270	1290	1020	260	1280	985		985
8:00 A. M.	1020	280	1300	1020	270	1290	950		950
9:00 A. M.	1020	320	1340	1020	270	1290	990		990
10:00 A. M.	1020	275	1295	1020	270	1290	840		840
11:00 A. M.	1020	325	1345	1020	250	1270	820		820
12:00 A. M.	1020	325	1345	1020	230	1250	780		780
1:00 P. M.	1020	320	1340	1020	235	1255	770		770
2:00 P. M.	1020	270	1290	1020	200	1220	770		770
3:00 P. M.	1020	260	1280	1020	190	1210	770		770
4:00 P. M.	1020	235	1255	1020	230	1250	765		765
5:00 P. M.	1020	210	1230	1020	285	1305	760		760
6:00 P. M.	1020	210	1230	1020	290	1310	770		770
7:00 P. M.	1020	225	1245	1020	300	1320	770		770
8:00 P. M.	1020	260	1280	1020	265	1285	800		800
9:00 P. M.	1020	265	1285	1020	270	1290	880		800
10:00 P. M.	1020	270	1290	1020	270	1290	795		795
11:00 P. M.	1020	220	1240	1020	235	1255	800		800
12:00 P. M.	1020	60	1080	1020	40	1060	800		800
1:00 A. M.	1020	20	1040	1020	20	1040	800		800
2:00 A. M.	1020	0	1020	1020	10	1030	800		800
3:00 A. M.	1020	0	1020	1020	20	1040	780		780
4:00 A. M.	1020	0	1020	1020	10	1030	780		780
5:00 A. M.	1020	10	1030	1020	15	1035	920		920
6:00 A. M.	1020	20	1040	1020	120	1140	990		990

TABLE NO. V

Expected Kw Loading, Old Units Supplying Low Pressure Steam Demand, Heating Season 1958-1959

Time of Day	20 F Outdoor Temp. Day			25 F Outdoor Temp. Day			30 F Outdoor Temp. Day		
	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total
7:00 A. M.	1020	420	1440	1020	520	1540	1020	425	1445
8:00 A. M.	1020	485	1505	1020	550	1570	1020	505	1525
9:00 A. M.	1020	638	1658	1020	625	1645	1020	570	1590
10:00 A. M.	1020	638	1658	1020	620	1640	1020	585	1605
11:00 A. M.	1020	638	1658	1020	605	1625	1020	535	1555
12:00 A. M.	1020	550	1570	1020	610	1630	1020	525	1545
1:00 P. M.	1020	638	1658	1020	610	1630	1020	515	1535
2:00 P. M.	1020	638	1658	1020	565	1585	1020	514	1534
3:00 P. M.	1020	638	1658	1020	575	1595	1020	525	1545
4:00 P. M.	1020	638	1658	1020	565	1585	1020	520	1540
5:00 P. M.	1020	638	1658	1020	575	1595	1020	520	1540
6:00 P. M.	1020	638	1658	1020	580	1600	1020	515	1535
7:00 P. M.	1020	638	1658	1020	545	1565	1020	540	1560
8:00 P. M.	1020	638	1658	1020	555	1575	1020	525	1545
9:00 P. M.	1020	638	1658	1020	545	1565	1020	515	1535
10:00 P. M.	1020	638	1658	1020	560	1585	1020	490	1510
11:00 P. M.	1020	638	1658	1020	465	1485	1020	420	1440
12:00 P. M.	1020	420	1440	1020	340	1360	1020	290	1310
1:00 A. M.	1020	270	1290	1020	130	1150	1020	100	1120
2:00 A. M.	1020	165	1185	1020	110	1130	1020	30	1050
3:00 A. M.	1020	120	1140	1020	50	1070	1020	30	1050
4:00 A. M.	1020	40	1060	1020	40	1060	1020	20	1040
5:00 A. M.	1020	165	1185	1020	130	1150	1020	30	1050
6:00 A. M.	1020	170	1190	1020	215	1235	1020	170	1190

TABLE NO. V

Expected Kw Loading, Old Units Supplying Low Pressure Steam Demand, Heating Season 1958-1959

Time of Day	35 F Outdoor Temp. Day			40 F Outdoor Temp. Day			45 F Outdoor Temp. Day		
	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total
7:00 A. M.	1020	430	1450	1020	270	1290	1020	270	1290
8:00 A. M.	1020	475	1495	1020	350	1370	1020	285	1305
9:00 A. M.	1020	565	1585	1020	415	1435	1020	375	1395
10:00 A. M.	1020	520	1540	1020	415	1435	1020	415	1435
11:00 A. M.	1020	485	1505	1020	415	1435	1020	335	1355
12:00 A. M.	1020	475	1495	1020	415	1435	1020	325	1345
1:00 P. M.	1020	435	1455	1020	380	1400	1020	315	1335
2:00 P. M.	1020	470	1490	1020	320	1340	1020	370	1290
3:00 P. M.	1020	435	1455	1020	300	1320	1020	280	1300
4:00 P. M.	1020	450	1470	1020	290	1310	1020	285	1305
5:00 P. M.	1020	430	1450	1020	350	1370	1020	370	1390
6:00 P. M.	1020	430	1450	1020	375	1395	1020	375	1395
7:00 P. M.	1020	415	1435	1020	375	1395	1020	370	1390
8:00 P. M.	1020	435	1455	1020	375	1395	1020	370	1390
9:00 P. M.	1020	435	1455	1020	375	1395	1020	370	1390
10:00 P. M.	1020	435	1455	1020	350	1370	1020	375	1395
11:00 P. M.	1020	415	1435	1020	300	1320	1020	370	1390
12:00 P. M.	1020	330	1350	1020	305	1325	1020	340	1360
1:00 A. M.	1020	165	1185	1020	140	1160	1020	250	1270
2:00 A. M.	1020	50	1070	1020	40	1060	1020	150	1170
3:00 A. M.	1020	30	1050	1020	30	1050	1020	50	1070
4:00 A. M.	1020	20	1040	1020	20	1040	1020	40	1060
5:00 A. M.	1020	165	1185	1020	30	1050	1020	175	1195
6:00 A. M.	1020	270	1290	990	0	990	1020	200	1220

TABLE NO. V

Expected Kw Loading, Old Units Supplying Low Pressure Steam Demand, Heating Season 1958-1959

Time of Day	50 F Outdoor Temp. Day			55 F Outdoor Temp. Day			60 F Outdoor Temp. Day		
	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total	A. C. Unit	West. Unit	Total
7:00 A. M.	1020	300	1320	1020	270	1290	1010		1010
8:00 A. M.	1020	340	1360	1020	280	1300	980		980
9:00 A. M.	1020	350	1370	1020	315	1335	1020		1020
10:00 A. M.	1020	325	1345	1020	270	1290	870		870
11:00 A. M.	1020	365	1385	1020	270	1290	845		845
12:00 A. M.	1020	365	1385	1020	270	1290	800		800
1:00 P. M.	1020	350	1370	1020	270	1290	785		785
2:00 P. M.	1020	270	1290	1020	240	1260	785		785
3:00 P. M.	1020	270	1290	1020	235	1255	785		785
4:00 P. M.	1020	270	1290	1020	270	1290	780		780
5:00 P. M.	1020	250	1270	1020	335	1355	775		775
6:00 P. M.	1020	250	1270	1020	340	1360	785		785
7:00 P. M.	1020	260	1280	1020	345	1365	785		785
8:00 P. M.	1020	270	1290	1020	270	1290	825		825
9:00 P. M.	1020	270	1290	1020	270	1290	825		825
10:00 P. M.	1020	270	1290	1020	270	1290	820		820
11:00 P. M.	1020	265	1285	1020	270	1290	828		828
12:00 P. M.	1020	120	1140	1020	75	1095	825		825
1:00 A. M.	1020	15	1035	1020	30	1050	825		825
2:00 A. M.	1020	10	1030	1020	10	1030	855		855
3:00 A. M.	1020	0	1020	1020	30	1050	810		810
4:00 A. M.	1020	0	1020	1020	10	1030	810		810
5:00 A. M.	1020	20	1040	1020	15	1035	940		940
6:00 A. M.	1020	20	1040	1020	150	1170	1020		1020

TABLE NO. VI

Expected Kw Loading, Proposed Unit Supplying Low Pressure Steam Demand,
For Heating Seasons 1956-1957 And 1957-1958 From Steam Conditions at 600 Psig And 750°F

	Average Outdoor Temperature								
Time of Day	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	3100	3430	3180	3260	2840	2800	2900	2820	2070
8:00 A. M.	3310	3520	3410	3360	3000	2860	2960	2865	2020
9:00 A. M.	3870	3680	4550	3540	3130	3040	3000	2915	2080
10:00 A. M.	3940	3660	3600	3440	3140	2960	2950	2880	1820
11:00 A. M.	3880	3620	3480	3375	3140	2960	3010	2810	1790
12:00 A. M.	3920	3630	3450	3360	3110	2950	3010	2785	1720
1:00 P. M.	3820	3630	3420	3290	3040	2950	3000	2790	1700
2:00 P. M.	3850	3530	3490	3335	2940	2990	2850	2730	1700
3:00 P. M.	3850	3560	3440	3270	2900	2860	2820	2710	1700
4:00 P. M.	3840	3530	3430	3300	2890	2890	2780	2780	1690
5:00 P. M.	3860	3560	3430	3250	3000	3020	2730	2955	1685
6:00 P. M.	3860	3590	3420	3250	3020	3025	2730	2960	1700
7:00 P. M.	3840	3510	3450	3230	3020	3020	2755	2975	1700
8:00 P. M.	3850	3520	3440	3270	3020	3020	2820	2830	1750
9:00 P. M.	3850	3510	3420	3260	3020	3020	2825	2850	1750
10:00 P. M.	3850	3530	3395	3260	3000	2950	2840	2850	1745
11:00 P. M.	3700	3310	3240	3220	2900	3020	2755	2790	1750
12:00 P. M.	3040	2970	2900	2950	2910	2970	2515	2460	1750
1:00 A. M.	2845	2550	2510	2600	2570	2740	2250	2320	1750
2:00 A. M.	2610	2520	2340	2435	2400	2690	2140	2210	1750
3:00 A. M.	2540	2440	2300	2340	2330	2430	2080	2320	1725
4:00 A. M.	2340	2380	2255	2280	2300	2310	2080	2200	1725
5:00 A. M.	2610	2550	2290	2600	2260	2620	2230	2295	1950
6:00 A. M.	2620	2680	2620	2800	2035	2670	2290	2600	2100

TABLE NO. VII

Expected Kw Loading, Proposed Unit Supplying Low Pressure Steam Demand,
For Heating Season, 1958-1959 From Steam Conditions at 600 Psig And 750°F

Time of Day	Average Outdoor Temperature								
	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	3175	3520	3260	3340	2910	2880	2980	2880	2120
8:00 A. M.	3400	3600	3500	3450	3080	2950	3030	2840	2070
9:00 A. M.	3970	3765	3640	3625	3210	3110	3070	2990	2130
10:00 A. M.	4040	3760	3690	3520	3220	3180	3010	2910	1870
11:00 A. M.	3980	3710	3575	3460	3220	3040	3090	2890	1835
12:00 A. M.	3680	3720	3550	3450	3200	3020	3090	2850	1760
1:00 P. M.	3930	3720	3510	3360	3120	3000	3070	2860	1740
2:00 P. M.	3940	3630	3590	3410	3020	2860	2930	2790	1740
3:00 P. M.	3940	3650	3530	3360	2980	2940	2890	2780	1740
4:00 P. M.	3935	3630	3520	3380	2960	2960	2840	2840	1730
5:00 P. M.	3960	3650	3520	3340	3070	3100	2810	3030	1725
6:00 P. M.	3960	3680	3510	3340	3100	3110	2810	3035	1740
7:00 P. M.	3935	3600	3540	3310	3100	3100	2830	3040	1740
8:00 P. M.	3940	3615	3530	3360	3100	3100	2890	2900	1795
9:00 P. M.	3940	3600	3510	3350	3100	3100	2895	2915	1795
10:00 P. M.	3940	3630	3480	3350	3070	3110	2915	2915	1790
11:00 P. M.	3800	3400	3430	3310	2980	3100	2830	2860	1795
12:00 P. M.	3120	3050	2970	2780	2990	3040	2580	2510	1795
1:00 A. M.	2920	2620	2580	2670	2640	2710	2410	2380	1795
2:00 A. M.	2680	2580	2400	2500	2460	2650	2190	2260	1795
3:00 A. M.	2600	2500	2360	2400	2390	2500	2130	2380	1770
4:00 A. M.	2400	2410	2310	2240	2350	2430	2130	2270	1770
5:00 A. M.	2680	2620	2350	2670	2310	2630	2390	2360	2000
6:00 A. M.	2690	2750	2700	2880	2690	2740	2350	2660	2140

TABLE NO. VIII

Expected Kw Loading, Proposed Unit Supplying Low Pressure Steam Demand,
For Heating Seasons 1956-1957 And 1957-1958 From Steam Conditions at 850 Psig And 825°F

	Average Outdoor Temperature								
Time of Day	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	3350	3640	3440	3520	3060	3020	3140	3050	2280
8:00 A. M.	3580	3810	3690	3640	3240	3110	3250	3100	2185
9:00 A. M.	4190	3980	3840	3830	3380	3290	3240	3150	2250
10:00 A. M.	4250	3960	3890	3720	3400	3210	3180	3115	1970
11:00 A. M.	4190	3920	3760	3650	3400	3210	3260	3040	1930
12:00 A. M.	4240	3930	3730	3637	3370	3180	3260	3010	1860
1:00 P. M.	4210	3930	3700	3500	3280	3180	3240	3020	1835
2:00 P. M.	4160	3820	3780	3600	3180	3007	3090	2950	1835
3:00 P. M.	4160	3850	3720	3540	3140	3110	3050	2940	1835
4:00 P. M.	4150	3920	3710	3570	3120	3120	3005	3000	1830
5:00 P. M.	4175	3850	3710	3517	3280	3265	2960	3200	1820
6:00 P. M.	4175	3880	3100	3517	3265	3220	2960	3200	1835
7:00 P. M.	4150	3800	3730	3495	3265	3265	2980	3220	1835
8:00 P. M.	4160	3820	3720	3540	3265	3265	3050	3060	1900
9:00 P. M.	4160	3800	3700	3520	3265	3265	3055	3085	1900
10:00 P. M.	4160	3820	3670	3520	3240	2975	3070	3085	1890
11:00 P. M.	4000	3580	3510	3485	3140	3265	2980	3020	1900
12:00 P. M.	3290	3210	3140	3185	3145	3215	2720	2660	1900
1:00 A. M.	3080	2760	2720	2810	2780	2960	2440	2515	1900
2:00 A. M.	2820	2720	2530	2630	2595	2800	2310	2390	1900
3:00 A. M.	2750	2640	2490	2530	2520	2630	2250	2510	1870
4:00 A. M.	2525	2570	2340	2470	2480	2570	2750	2480	1870
5:00 A. M.	2820	2760	2480	2810	2340	2830	2410	2480	2110
6:00 A. M.	2840	2900	2840	3022	2200	2880	2475	2710	2270

TABLE NO. IX

Expected Kw Loading, Proposed Unit Supplying Low Pressure Steam Demand,
For Heating Season 1958-1959 From Steam Conditions at 850 Psig And 825° F

	Average Outdoor Temperature								
Time of Day	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	3440	3810	3530	3620	3150	3110	3220	3130	2290
8:00 A. M.	3670	3900	3780	3715	3330	3190	3280	3185	2240
9:00 A. M.	4300	4075	3940	3920	3475	3370	3320	3235	2305
10:00 A. M.	4370	4070	3990	3810	3480	3440	3260	3150	2020
11:00 A. M.	4302	4015	3865	3740	3480	3280	3340	3120	1985
12:00 A. M.	3980	4020	3845	3715	3460	3260	3340	3085	1905
1:00 A. M.	4250	4020	3800	3640	3300	3240	3320	3100	1880
2:00 A. M.	4265	3930	3880	3700	3260	3100	3165	3020	1880
3:00 A. M.	4265	3950	3810	3620	3220	3180	3120	3010	1880
4:00 A. M.	4250	3930	3805	3660	3210	3200	3080	3080	1875
5:00 A. M.	4280	3950	3805	3615	3320	3350	3040	3280	1855
6:00 A. M.	4280	3990	3800	3615	3355	3360	3040	3285	1880
7:00 P. M.	4250	3900	3815	3580	3355	3350	3055	3290	1880
8:00 P. M.	4265	3910	3810	3625	3355	3350	3120	3140	1940
9:00 P. M.	4265	3900	3800	3620	3355	3350	3130	3165	1940
10:00 P. M.	4265	3920	3760	3620	3320	3360	3150	3165	1930
11:00 P. M.	4100	3680	3600	3580	3220	3350	3060	3090	1940
12:00 P. M.	3380	3300	3210	3000	3230	3290	2795	2730	1940
1:00 A. M.	3160	2830	2790	2880	2860	3040	2500	2570	1940
2:00 A. M.	2900	2795	2690	2700	2660	2870	2370	2445	1940
3:00 A. M.	2820	2710	2550	2690	2590	2700	2300	2560	1920
4:00 A. M.	2595	2670	2500	2535	2540	2630	2300	2440	1920
5:00 A. M.	2900	2830	2540	2880	2430	2910	2480	2550	2165
6:00 A. M.	2910	2975	2915	3110	2260	2960	2540	2880	2320

TABLE NO. X

Electrical Load, Kws, For Heating Season 1951-1952

Time of Day	Average Outdoor Temperature								
	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	1410	1560	1600	1500	1420	1490	1430	1490	1490
8:00 A. M.	2010	2090	2190	1980	1810	1940	1880	1940	1910
9:00 A. M.	2150	2200	2150	2060	1980	2100	1990	2050	1990
10:00 A. M.	2130	2220	2160	2120	1940	2140	2050	2130	1980
11:00 A. M.	2110	2240	2160	2080	2020	2250	2320	2200	2110
12:00 A. M.	2250	2320	2290	2210	2120	2250	2320	2250	2110
1:00 P. M.	1990	1980	2020	1920	1840	1860	1870	1880	1770
2:00 P. M.	1950	1990	2020	1940	1790	2020	1920	1990	1800
3:00 P. M.	1870	1940	1920	1860	1700	2010	1890	1890	1730
4:00 P. M.	1900	1960	1980	1960	1740	2010	1920	1960	1680
5:00 P. M.	2130	2240	2250	2290	1980	2260	2100	2220	2020
6:00 P. M.	2640	2720	2670	2530	2380	2560	2600	2650	2440
7:00 P. M.	2210	2200	2210	2140	2050	2260	2270	2030	2090
8:00 P. M.	2030	2040	2000	1950	1850	2090	1970	1970	1960
9:00 P. M.	1970	1960	1870	1890	1750	1950	1900	1820	1780
10:00 P. M.	1770	1750	1700	1630	1580	1740	1680	1680	1610
11:00 P. M.	1560	1500	1480	1440	1380	1540	1440	1400	1490
12:00 P. M.	1210	1210	1210	1210	1200	1200	1130	1110	1100
1:00 A. M.	1080	990	970	980	980	1020	960	930	920
2:00 A. M.	1000	930	920	900	950	910	890	860	820
3:00 A. M.	970	860	900	870	860	890	820	800	800
4:00 A. M.	940	850	870	860	860	860	800	800	690
5:00 A. M.	1040	970	1030	930	900	1010	890	860	840
6:00 A. M.	1130	1150	1400	1160	1030	1160	1090	1110	1170

TABLE NO. XI

Expected Electrical Load, Kws, For Heating Season 1956-1957

Time of Day	Average Outdoor Temperature								
	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	2060	2300	2360	2190	2080	2180	2100	2180	2180
8:00 A. M.	2960	3060	3210	2910	2650	2850	2760	3850	2810
9:00 A. M.	3160	3240	3180	3030	2910	3080	2920	3000	2930
10:00 A. M.	3130	3250	3170	3110	2860	3140	3010	3130	2900
11:00 A. M.	3110	3300	3180	3050	2960	3120	3010	3110	2950
12:00 A. M.	3300	3400	3260	3250	3100	3300	3400	3300	3100
1:00 P. M.	2910	2900	2960	2820	2700	2730	2740	2760	2600
2:00 P. M.	2860	2920	2960	2840	2620	2970	2810	2860	2650
3:00 P. M.	2740	2850	2810	2740	2490	2950	2770	2770	2540
4:00 P. M.	2790	2880	2900	2870	2560	2940	2810	2870	2470
5:00 P. M.	3130	3280	3300	3360	2900	3310	3070	3250	2960
6:00 P. M.	3870	3990	3910	3710	3500	3750	3820	3880	3560
7:00 P. M.	3240	3230	3240	3140	3010	3320	3340	3120	3210
8:00 P. M.	2970	2990	2990	2860	2720	3060	2890	2900	2880
9:00 P. M.	2880	2870	2740	2770	2580	2860	2710	2670	2610
10:00 P. M.	2590	2560	2490	2390	2320	2550	2460	2460	2360
11:00 P. M.	2280	2190	2160	2110	2010	2250	2110	2050	2040
12:00 P. M.	1770	1770	1770	1790	1690	1760	1650	1620	1610
1:00 A. M.	1580	1460	1430	1440	1450	1490	1410	1370	1350
2:00 A. M.	1470	1360	1350	1330	1390	1340	1310	1260	1210
3:00 A. M.	1420	1270	1310	1270	1270	1300	1200	1180	1160
4:00 A. M.	1370	1250	1270	1260	1260	1250	1170	1170	1010
5:00 A. M.	1530	1430	1520	1360	1320	1480	1300	1260	1230
6:00 A. M.	1660	1690	2050	1700	1510	1700	1600	1630	1710

TABLE NO. XII

Expected Electrical Load, Kws, For Heating Season 1957-1958

Time of Day	Average Outdoor Temperature								
	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	2220	2480	2530	2370	2240	2380	2260	2350	2360
8:00 A. M.	3200	3300	3460	3140	2860	3080	2980	3070	3030
9:00 A. M.	3410	3500	3420	3270	3140	3320	3150	3240	3160
10:00 A. M.	3390	3520	3420	3360	3080	3390	3250	3380	3130
11:00 A. M.	3360	3560	3430	3290	3190	3370	3250	3370	3190
12:00 A. M.	3550	3670	3650	3510	3350	3560	3670	3560	3350
1:00 P. M.	3150	3130	3190	3040	2910	2940	2960	2980	2810
2:00 P. M.	3090	3160	3190	3070	2830	3200	3030	3090	2860
3:00 P. M.	2960	3080	3040	2940	2690	3190	2990	2990	2740
4:00 P. M.	3020	3010	3130	3100	2760	3180	3040	3090	2660
5:00 P. M.	3380	3550	3560	3610	3130	3580	3320	3510	3200
6:00 P. M.	4180	4310	4230	4000	3780	4050	4120	4190	3860
7:00 P. M.	3500	3480	3500	3390	3250	3590	3600	3370	3470
8:00 P. M.	3210	3230	3160	3090	2940	3310	3120	3130	3110
9:00 P. M.	3120	3100	2960	2990	2770	3090	3000	2880	2810
10:00 P. M.	2800	2770	2690	2580	2500	2750	2660	2660	2550
11:00 P. M.	2470	2370	2330	2270	2180	2430	2280	2210	2190
12:00 P. M.	1920	1910	1910	1920	1820	1900	1780	1750	1740
1:00 A. M.	1710	1570	1540	1550	1550	1610	1520	1470	1460
2:00 A. M.	1590	1470	1460	1430	1500	1450	1410	1360	1300
3:00 A. M.	1540	1370	1420	1370	1370	1400	1300	1270	1260
4:00 A. M.	1480	1350	1380	1360	1360	1350	1270	1270	1100
5:00 A. M.	1660	1540	1640	1470	1420	1590	1400	1360	1330
6:00 A. M.	1790	1820	2210	1830	1630	1830	1720	1750	1850

TABLE NO. XIII

Expected Electrical Load, Kws, For Heating Season 1958-1959

Time of Day	Average Outdoor Temperature								
	20 F	25 F	30 F	35 F	40 F	45 F	50 F	55 F	60 F
7:00 A. M.	2400	2680	2740	2560	2430	2550	2450	2540	2550
8:00 A. M.	3450	3570	3750	3400	3100	3320	3220	3320	3280
9:00 A. M.	3690	3780	3690	3540	3400	3590	3410	3510	3420
10:00 A. M.	3660	3800	3700	3640	3330	3660	3510	3660	3390
11:00 A. M.	3630	3850	3710	3560	3450	3650	3510	3650	3450
12:00 A. M.	3860	3970	3930	3790	3630	3860	3920	3840	3620
1:00 P. M.	3400	3380	3450	3290	3150	3180	3190	3220	3040
2:00 P. M.	3330	3420	3450	3320	3060	3470	3280	3340	3090
3:00 P. M.	3200	3330	3280	3190	2910	3450	3240	3230	2960
4:00 P. M.	3260	3360	3390	3350	2990	3440	3280	3350	2880
5:00 P. M.	3660	3840	3850	3920	3380	3870	3580	3790	3460
6:00 P. M.	4520	4650	4570	4330	4080	4380	4450	4530	4170
7:00 P. M.	3780	3770	3788	3670	3510	3880	3890	3640	3580
8:00 P. M.	3470	3500	3420	3340	3170	3570	3380	3380	3360
9:00 P. M.	3350	3350	3200	3240	2990	3340	3240	3110	3040
10:00 P. M.	3030	2990	2910	2780	2700	2980	2870	2870	2750
11:00 P. M.	2670	2570	2520	2460	2360	2630	2460	2390	2370
12:00 P. M.	2070	2070	2070	2080	1970	2050	1930	1890	1880
1:00 A. M.	1850	1700	1670	1680	1690	1740	1650	1590	1570
2:00 A. M.	1720	1590	1570	1550	1620	1570	1520	1470	1410
3:00 A. M.	1660	1480	1540	1480	1480	1510	1410	1370	1360
4:00 A. M.	1600	1460	1490	1480	1470	1460	1370	1370	1180
5:00 A. M.	1790	1670	1770	1590	1540	1720	1520	1480	1440
6:00 A. M.	1930	1970	2390	1980	1760	1980	1860	1900	2000

TABLE NO. XIV

Average Winter Steam Load (75# H. P.)

7:00 A. M.	8:00 A. M.	9:00 A. M.	10:00 A. M.	11:00 A. M.	12:00 A. M.	1:00 P. M.	2:00 P. M.	3:00 P. M.	4:00 P. M.	5:00 P. M.	6:00 P. M.
8504	8887	8890	8945	8456	8451	8176	8223	8312	8323	8731	8346
7:00 P. M.	8:00 P. M.	9:00 P. M.	10:00 P. M.	11:00 P. M.	12:00 P. M.	1:00 A. M.	2:00 A. M.	3:00 A. M.	4:00 A. M.	5:00 A. M.	6:00 A. M.
8284	8280	8173	8060	8029	8021	8651	8095	8109	8096	8176	8248

TABLE NO. XV

Expected Additional Kw Loading, Due To Extracting Steam at 100 Psig, From 600 Psig And 750°F Unit For the Heating Seasons of 1956-1957, 1957-1958, And 1958-1959

7:00 A. M.	8:00 A. M.	9:00 A. M.	10:00 A. M.	11:00 A. M.	12:00 A. M.	1:00 P. M.	2:00 P. M.	3:00 P. M.	4:00 P. M.	5:00 P. M.	6:00 P. M.
273	234	285	286	270	270	262	263	266	266	267	270
7:00 P. M.	8:00 P. M.	9:00 P. M.	10:00 P. M.	11:00 P. M.	12:00 P. M.	1:00 A. M.	2:00 A. M.	3:00 A. M.	4:00 A. M.	5:00 A. M.	6:00 A. M.
265	265	261	258	256	254	276	259	260	259	261	264

TABLE NO. XVI

Expected Additional Kw Loading, Due To Extracting Steam at 100 Psig, From 850 Psig and 825°F Unit For the Heating Seasons of 1956-1957, 1957-1958, And 1958-1959

7:00 A. M.	8:00 A. M.	9:00 A. M.	10:00 A. M.	11:00 A. M.	12:00 A. M.	1:00 P. M.	2:00 P. M.	3:00 P. M.	4:00 P. M.	5:00 P. M.	6:00 P. M.
334	348	349	350	331	331	320	322	326	326	326	327
7:00 P. M.	8:00 P. M.	9:00 P. M.	10:00 P. M.	11:00 P. M.	12:00 P. M.	1:00 A. M.	2:00 A. M.	3:00 A. M.	4:00 A. M.	5:00 A. M.	6:00 A. M.
325	326	320	316	315	315	339	317	318	317	321	324

TABLE NO. XVII

Savings Per Day For Each Outdoor Temperature
For The Three Heating Seasons
With Steam Condition 600 Psig - 750°F

Heating Season	Outdoor Temperature In Degrees F	Saving Per Day In Dollars Without Extraction	Saving Per Day In Dollars Due To Extraction	Total Savings Per Day In Dollars With Extraction
1956-1957	20	173.50	.0	173.00
1956-1957	25	184.50	4.67	189.17
1956-1957	30	196.20	1.7	197.90
1956-1957	35	188.00	2.45	190.45
1956-1957	40	214.00	3.50	217.50
1956-1957	45	178.00	12.80	190.80
1956-1957	50	191.50	9.35	200.85
1956-1957	55	187.00	14.00	201.00
1956-1957	60	134.50	32.10	166.50
1957-1958	20	204.00	1.168	205.16
1957-1958	25	222.00	3.50	225.50
1957-1958	30	229.00	10.50	239.50
1957-1958	35	201.00	5.25	206.25
1957-1958	40	231.00	8.17	239.17
1957-1958	45	187.00	23.30	210.30
1957-1958	50	198.50	19.85	218.35
1957-1958	55	202.00	24.50	226.50
1957-1958	60	143.50	33.90	177.40
1958-1959	20	239.00	2.34	241.34
1958-1959	25	259.00	8.17	267.17
1958-1959	30	259.00	10.50	269.50
1958-1959	35	249.00	9.35	258.35
1958-1959	40	179.00	25.70	204.70
1958-1959	45	263.00	16.35	279.35
1958-1959	50	249.00	26.8	275.80
1958-1959	55	208.00	23.4	231.40
1958-1959	60	153.00	33.9	236.90

TABLE NO. XVIII

Savings Per Day For Each Outdoor Temperature
For The Three Heating Seasons
With Steam Condition 850 Psig - 825°F

Heating Season	Outdoor Temperature In Degrees F	Saving Per Day In Dollars Without Extraction	Saving Per Day In Dollars Due To Extraction	Total Savings Per Day In Dollars With Extraction
1956-1957	20	173.00	.0	173.00
1956-1957	25	192.00	.70	192.70
1956-1957	30	217.00	.93	217.93
1956-1957	35	204.00	1.1648	205.16
1956-1957	40	185.00	1.28	186.28
1956-1957	45	189.00	4.20	193.20
1956-1957	50	197.00	4.77	201.77
1956-1957	55	203.00	6.45	209.45
1956-1957	60	163.00	33.89	196.89
1957-1958	20	178.50	.0	178.50
1957-1958	25	201.00	1.164	202.16
1957-1958	30	243.00	2.91	245.91
1957-1958	35	225.00	4.07	229.07
1957-1958	40	233.00	3.03	336.03
1957-1958	45	230.00	21.00	251.00
1957-1958	50	218.00	10.50	228.50
1957-1958	55	218.00	14.55	232.55
1957-1958	60	143.50	35.50	179.00
1958-1959	20	238.00	1.75	239.75
1958-1959	25	263.00	4.65	267.65
1958-1959	30	256.00	9.9	265.90
1958-1959	35	237.00	5.25	242.25
1958-1959	40	280.00	6.4	286.40
1958-1959	45	238.00	25.00	263.00
1958-1959	50	285.00	25.60	310.60
1958-1959	55	276.00	30.30	306.30
1958-1959	60	192.00	46.00	238.00

B. Sample Calculations

1. Future Expected Electric Energy Load:

$$Ef = \left(1 + \frac{X}{100}\right)^n \times Ep$$

Where: Ef is the future electric energy load, kw (Table No. XI)

X is the present increase expected per year

Ep is the per cent electric energy load, kw (Table No. IV)

n is the number of years

For heating season 1956-1957, 7:00 A. M. with an average outdoor temperature of 20°F.

$$Ef = \left(1 + \frac{8.0}{100}\right)^5 \times 1400 \text{ kw}$$

$$Ef = \underline{2060 \text{ kw}}$$

2. Per Cent Increase In Low Pressure Steam Demand For The Heating Season 1951-1952:

It was assumed that the increase in low pressure steam demand would be proportional to the increase in connected building radiation.

$$\% \text{ increase} = 100 \times \frac{(\text{Radiation 1956-1957} - \text{Radiation 1951-1952})}{\text{Radiation 1951-1952}}$$

$$\% \text{ increase} = 100 \left(\frac{276{,}665 \text{ sq. ft.} - 243{,}316 \text{ sq. ft.}}{243{,}316 \text{ sq. ft.}}\right)$$

$$\% \text{ increase} = 13.72\%$$

3. It is expected that the connected radiation for the heating season 1957-1958 will be the same as for 1956-1957.

4. The per cent increase in low pressure steam demand for the heating season of 1958-1959 above the heating season of 1951-1952 was calculated as in calculation No. 2, above.

5. Future Low Pressure Steam Demands:

$$Sf = \left(1 + \frac{X}{100}\right) \times Sp$$

Where: Sf is the future steam demand, #'s/hr (Table No. II)

Sp is the present steam demand, #'s/hr (Table No. I)

X is the per cent increase in low pressure steam demand for 1951-1952

For heating season 1956-1957, 7:00 A. M. with an average outdoor temperature of 20°F.

$$Sf = \left(1 + \frac{13.72}{100}\right) \times 39{,}600 \text{ \#'s/hr}$$

$$Sf = \underline{45{,}050 \text{ \#'s/hr}}$$

6. Electric energy that could be generated by the present turbo-generator units was determined by use of Willans Line curves for these units. See Fig. 55, page 77.

7. Electric Energy That Could Be Generated By The Proposed Unit With The Expected Future Low Pressure Steam Demands With Steam Condition At 600 psig - 750°F.:

$$EE = \frac{W}{w}$$

Where: EE is the Electric Energy expected from the proposed unit, kw (Table No. VI)

W is the expected low pressure steam demand, #'s/hr (Table No. II)

w is the turbine's steam rate at steam conditions 600 psig 750°F, #'s/hr.

For heating season 1956-1957, 7:00 A. M. with an average outdoor temperature pf 20°F.

$$EE = \frac{45,050}{14.55}$$

$$EE = \underline{3100 \text{ kw}}$$

8. Electric Energy That Could Be Generated By The Proposed Unit With The Expected Future Low Pressure Steam Demands With Steam Condition At 850 psig - 825°F:

$$EE = \frac{W}{w}$$

Where: EE is the Electric Energy expected from the proposed unit, kw (Table No. VIII)

W is the expected low pressure steam demand, #'s/hr (Table No. II)

w is the turbine steam rate at steam conditions 850 psig and 825°F, #'s/hr.

For heating season 1956-1957, 7:00 A. M. with an average outdoor temperature of 20°F.

$$EE = \frac{45,050}{13.45}$$

$$EE = \underline{3,350 \text{ kw}}$$

9. Electric Energy That Could Be Generated By The Proposed Unit With Extraction For The Expected High Pressure Steam Demands With Steam Conditions At 600 psig - 750°F:

$$EE = \frac{W}{w}$$

Where: EE is the Electric Energy expected from the proposed unit, kw (Table No. XV)

W is the expected high pressure steam demand for winter season, #'s/hr (Table No. XIV)

w is the turbine steam rate for steam conditions at 600 psig and 750°F, with the present required quantity of steam required from the turbine being extracted at 100 psig.

For heating seasons 1956-1957, 1957-1958, and 1958-1959, 7:00 A. M. with an average outdoor temperature of 20°F.

$$EE = \frac{8504}{31.3}$$

$$EE = \underline{273kw}$$

10. Electric Energy That Could Be Generated By The Proposed Unit With Extraction For The Expected High Pressure Steam Demands With Steam Condition At 850 psig-825°F.:

$$EE = \frac{W}{w}$$

Where: EE is the Electric Energy expected from the proposed unit, kw (Table No. XVI)

W is the expected high pressure steam demand, #'s/hr

w is the turbine steam rate for steam conditions at

850 psig and 825°F. with extraction at 100 psig, #'s/hr

For heating seasons, 1956-1957, 1957-1958, and 1958-1959, 7:00 A. M. with an average outdoor temperature of 20°F.

$$EE = \frac{8504}{2515}$$

$$EE = \underline{3.34 \text{ kw}}$$

11. Cost Of Steam In Cents Per 1000 Pounds From A New Boiler To The Proposed Turbines:

Where: C is the cost of steam at the throttle of proposed unit, cents /#

For a new unit just being put in operation the cost per 1000 lbs burning coal, such as that being used in Boiler No. 6, and operating under conditions similar to that of No. 6, should be at a maximum of 20 cents per 1000 lbs.

C = $0.20/1000 #'s

12. Fuel Cost Per kw-hr Generated In Plant On Steam From Boiler:

$$Ce = Cs \times \frac{1}{ha} \times hex$$

Where: Ce is the fuel cost per kw-hr generated in the plant, ¢/1000 lbs

ha is the heat added in the boiler at steam condition 600 psig-750°F, per pound of steam, BTU/lbs

hex is the heat extracted from the steam in BTU/kw-hr generated[19]

$$Ce = \frac{20¢}{1000\#} \times \frac{\#}{1181\ BTU} \times \frac{4250\ BTU}{kw\text{-}hr}$$

$$Ce = .0718¢/kw\text{-}hr$$

$$Ce = \$0.00072 \text{ per kw-hr}$$

13. Fuel Cost Per kw-hr Generated In Plant On Steam From Boiler:

$$Ce = Cs \times \frac{1}{ha} \times hex$$

Where: Ce is the fuel cost per kw-hr generated in the plant, ¢/kw-hr

Cs is the cost of steam from boiler, ¢/1000 lbs

ha is the heat added in the boiler at steam condition 850 psig and 825°F, per pound of steam, BTU/lbs

hex is the heat extracted from the steam in BTU/kw-hr generated[19]

$$Ce = \frac{20¢}{1000\#} \times \frac{\#}{1214\ BTU} \times \frac{4250\ BTU}{kw\text{-}hr}$$

$$Ce = .070¢/kw\text{-}hr$$

$$Ce = \$0.00070 \text{ per kw-hr}$$

14. Saving Per kw-hr Generated In Plant At Steam Condition 600 psig and 750°F.:

$$S = Cu - Ce$$

Where: S is savings

Cu is the loss of kw-hr from utility, ¢/kw-hr

Ce is the cost of a kw-hr generated in plant, ¢/kw-hr

S = $0.0008- $0.00072

S = $0.00728 per kw-hr

15. Saving Per kw-hr Generated In Plant At Steam Condition 850 psig and 825°F:

S = Cu - Ce

Where: S is savings

Cu is the cost of kw-hr from utility, ¢/kw-hr

Ce is the cost of a kw-hr generated in plant, ¢/kw-hr

S = $0.008 - $0.00070

S = $0.0073 per kw-hr

16. Saving For A Given Average Outdoor Temperature Day For A Future Heating Season:

S' = A x C x S

Where: S' is the saving in dollars per day

A is the area representing additional kw-hrs that could be generated with the proposed unit operating under conditions at 600 psig and 750°F, sq. in., From Figures

C is the scale constant for the curves, kw-hrs/sq. in.

S is the savings for kw-hrs generated in plant, dollars

For heating season 1956-1957, with an average outdoor temperature of 20°F, at steam condition 600 psig and 750°F.,

Fig. (28) for both non-extraction and extraction savings

non-extraction

$$S' = 14.85 \text{ sq in} \times \frac{1600 \text{ kw-hrs}}{\text{sq in}} \times \frac{\$0.00728}{\text{kw-hr}}$$

$S' = \$173.00$ per day

due to extraction

$$S'' = 0 \text{ sq in} \times \frac{1600 \text{ kw-hr}}{\text{sq in}} \times \frac{\$0.00728}{\text{kw-hr}}$$

$S'' = \$0.00$ per day

17. Saving For A Given Average Outdoor Temperature Day For A Future Heating Season:

$S' = A \times C \times S$

Where: S' is the saving in dollars per day

A is the area representing additional kw-hrs that could be generated with the proposed unit operating under condition at 850 psig and 825°F, sq in, From Figures

C is the scale constant for the curves, kw-hrs/sq in

S is the savings for kw-hrs generated in plant, dollars

For heating season 1956-1957, with an average outdoor temperature of 20°F at steam conditions 850 psig and 825°F, Fig. (1) for both non-extraction and extraction savings:

non-extraction

$$S' = 14.85 \text{ sq in} \times \frac{1600 \text{ kw-hrs}}{\text{sq in}} \times \frac{\$0.0073}{\text{kw-hr}}$$

$S' = \$173.00$ per day non-extraction

due to extraction

$$S'' = 0 \text{ sq in} \times \frac{1600 \text{ kw-hrs}}{\text{sq in}} \times \frac{\$0.0073}{\text{kw-hr}}$$

$S'' = \$0.00$ per day extraction

18. Saving For A Given Outdoor Temperature Day, For A Future Heating Season For An Extraction Unit Will Be The Saving Of Non-Extraction Plus That Of Extraction:

$S''' = S' + S''$

Where: S''' is total savings of extraction in dollars

S' is saving at non-extraction in dollars

S'' is saving due to extraction in dollars

$S''' = \$173.00 - \$0.00$

$S''' = \$173.00$ per day