AN ECONOMIC STUDY OF A PROPOSED 5000 KW THREE STAGE EXTRACTION CONDENSING TURBO-GENERATOR UNIT IN THE VIRGINIA POLYTECHNIC INSTITUTE HEATING AND POWER PLANT

by

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IV

INTRODUCTION

The present Heating and Power Plant of Virginia Polytechnic Institute produces the steam required to heat the college buildings and also the process steam used in the dairy, laundry, dining hall, and hospital. The space heating steam is supplied at about five psig, while the process steam is supplied at 75 psig and 165 psig. Approximately one-half of the electric power supplied to the college and to the community is generated as a by-product in the plant. This by-product power is generated by passing the space heating steam through turbo-generator units before sending it from the plant. The rest of the electric power is purchased from the Appalachian Electric Power Company.

The space heating load has increased in recent years because of the physical growth of the college. The building program is expected to continue to parallel the anticipated increase in enrollment. The electric power load has increased considerably in recent years, and this increase is expected to continue because of the growth of the community and the growing popularity of electrical appliances.

At the present time there are six steam generating units in the Heating and Power Plant. Boilers No. 1 and No. 2, Casey Hedges Co., age, 27 years, are capable of producing 15,000 pounds per hour each of saturated steam at 165 psig; Boilers No. 3 and No. 4, Hedges-Walsh Weidner Co., age, 25 years, are capable of producing 20,000 pounds per hour each of steam at 165 psig and 75°F of superheat; Boiler No. 5, E. Keeler Co., age, 15 years, is capable of producing 35,000 pounds per hour of steam at 250 psig

and 100 °F of superheat; Boiler No. 6, Edge Moor Co., age, 4 years, is capable of producing 60,000 pounds per hour of steam at 250 psig and 100°F superheat.

The turbo-generator units in operating condition in the plant are: Allis-Chalmers Co., Turbo-Generator, 1000 Kw at 80 per cent power factor, steam conditions 225 psig and 100°F superheat, at a back pressure of 20 to 35 psia, age 24 years; 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 psia, age, 25 years.

Some of the present equipment is antiquated and its future life is definitely limited. Therefore, the college is faced with the problem of how to replace some of the present equipment in the Heating and Power Plant. This investigation compares certain aspects of three of the possible solutions to the replacement problem.

The plans considered in this investigation are:

Plan No. 1: The Heating and Power Plant will furnish all the heating and process steam, while all the electric power will be purchased from the Appalachian Electric Power Co.

Plan No. 2: A 5000 Kw two stage extraction back pressure turbo-generator will be installed to generate electric power as a by-product of the heating and process steam. Some electric power will still have to be purchased from the Appalachian Electric Power Co.

Plan No. 3: A 5000 Kw three stage extraction condensing turbo-generator will be installed. This unit will supply all the necessary electric power.

Since the investment required for these plans cannot be determined at the present time because of the fluctuations of the business cycle,

this investigation will only compare the annual savings in the cost to the college of steam and electric power.

V

REVIEW OF LITERATURE

"New uses of electricity such as house heating, the heat pump, television, the clothes dryer, and high-frequency heating, will require significant increase in generating capacity and in general, system facilities in the next 15 years." [1]

"Each new use of electricity points the way to still others. This is why the electrical load curve rises at a much higher rate than the population curve. Indeed, the expansion of the electric power industry is unparalleled. From 1922 to 1951 the consumption of electric power has increased by 7 per cent annually, compared to a 3 per cent annual rise in over-all national production. At the present time this rate of increase in use of electrical energy is close to 8 per cent." [2]

"In residential energy sales there are no signs of slowing up. The year to year increase keeps on getting larger. In 1947, the increase was 5.6 billion Kw-hrs over 1946; in 1948, it was 6.4 billion over 1947." [3]

At the end of 1947, there were between 6 and 7 residential customers to everyone in all other classes together. Customers in this group bought only 23 per cent of the electricity sold in the year, but from them came 39 per cent of the revenue. Their preponderant majority in the total number makes residential customers and their load characteristics a matter of vital concern to utility management and whether a utility does or does not promote residential uses of electricity makes no difference; the load and energy sales in that customer class will increase." [4]

"Kilowatt-hour sales to residential customers vary directly with

the population of Public Service territory."

"The extent to which each customer uses his electric facilities is another factor to be considered in estimating residential sales. In 1930, the average residential customer used 44 Kw-hrs in December; by 1940, he was consuming 72 Kw-hrs, and in December, 1946, his use was 100 Kw-hrs. It is estimated that the average residential use per customer will increase to 140 Kw-hrs in December, 1956." [5]

"Long term forecasting has to do with prediction of load changes within individual areas and for the system as a whole for periods ranging from 3 to 15 years. Even under normal conditions it takes around three years from the inception of plans for a new power plant to the placing of new generating units on the line for regular operation."

"Since it will not normally be possible to determine individual customer's power requirements for longer than two, or at the most three years in advance, making a long-range forecast will require a greater degree of reliance on past trends in system load growth, as projected over the period covered by the study." [6]

"Load and kilowatt-hour forecasts are approached from two points of view - the long-range and the near-term. Ten year estimates of loads and kilowatt-hour sales and outputs, assuming normal business conditions, are made by projecting into the future the upward-sweeping curves of normal growth - the secular trends which persist despite recurrent business booms and depressions." [7]

"The most common method of estimating the future trend of any variable quantity is to plot its past history on a curve and by laying a

straight edge between some two selected points, attempt to extrepolate it into the years to come." [8]

"During preliminary design of this plant extensive studies were made of the past and present requirements for electrical energy, process and heating steam required by all the buildings on the campus. From these results, combined with the University's near future building program, the installed capacity of the power plant was established." [9]

"One large company estimates that three to four degrees of temperature change will cause one percent change in load. As the temperature lowers in winter, the load increases, and as it rises in summer, to a reasonably warm day, the load decreases. When and if air conditioning comes more and more into use, the load will tend to increase more for temperatures above 70°F." [10]

"Obsolescence is the loss in value or in economic usefulness brought about by engineering developments, by an increase of scientific knowledge or by perfection of methods." [11]

"Whether the present equipment should be replaced before it is worn out depends upon the amount of saving in operating expenses which the modern equipment could effect as against increased fixed charges due to its purchase and the retirement of the old units." [12]

"Present equipment should be replaced or superseded before it is worn out by modern equipment, if the annual saving which can be affected due to lowering operating costs are satisfactory." [13]

"In many industries there is a need for heat, both for process and space heating. The power supply problem and the heat supply problem then become one, and in the consideration of an industrial plant must be linked together".

"In order to supply the process and space heating need, a boiler plant is required. If, before the steam is used, it is allowed to expand in an engine or turbine, power will be generated."

"These so-called "back pressure" steam plants are much more efficient in producing power than the typical condensing plant, in the latter type of plant, from two-thirds to three-quarters of the initial total heat of the steam remains in the steam exhausted to the condenser and is absorbed by the circulating water. On the other hand, in the back pressure plant, the heat of the exhaust steam is not chargeable to the production of power, but is charged to the processes that use it."

"There is always a diversity of opinion as to what part of the total cost of producing steam and power is chargeable to power generation or to steam generation. To separate the costs in this way is erroneous. Overall total cost for both products is the prime consideration, and in economic studies involving the supply of either steam or power from some competitive source, the cost of one should not be separated from the other." [14]

"Where there is a combined demand for electric power and process heat, the steam system offers the potentiality of the dual purpose, or a "by-product" power plant. The boiler pressure can often be selected so as to produce much, if not all, of the electric power as a by-product of the process or building heating requirements." [15]

"It is usually cheaper to make than to buy power when the steam heating, or the process load which could be supplied by exhaust steam, is relatively large in comparison with the power load. Thus, if one-half of

the engine or turbine exhaust be utilized to replace direct steam from the boilers, the fuel cost of power is almost halved. This applies to plants of all sizes. Where the heating load is fluctuating or seasonal, but of sufficient amount, high efficiency can be maintained by combining condensing and noncondensing power units to balance the requirements at all times. Or such a steam balance may be very simply secured by use of the bleeder type of turbine generator." [16]

"The bleeder or extraction condensing machine would often be used where neither the back pressure turbine nor the straight condensing turbine would give a good heat balance. Thus, if the demand for medium or low pressure process or heating steam changes radically, seasonally, or periodically, this type of unit automatically adjusts itself to maintain an economical heat balance at all times." [17]

"Automatic extraction steam turbines are the multi-purpose tools of the power plant designer. They meet exacting needs for both power and steam without special attention from their operators; they maintain steam pressure constant in one or more process lines; they can hold electrical frequency close enough for operation of electric clocks. And they do these many purpose tasks with efficiencies approaching those of single-purpose turbines." [18]

"Automatic extraction steam turbines are often provided with one or more uncontrolled extraction openings from which steam is extracted in small quantities for process or feed-water heating. These applications cover the range in which the use of multiple automatic extraction is not economical." [19]

"Comparing fuel consumption of automatic extraction steam

turbines at different initial steam conditions can be misleading if you use only a steamflow basis."[20]

VI

INTRODUCTORY SUMMARY

This investigation was conducted to determine the indicated annual savings which could be expected from the proposed installation of a 5000 Kw turbo-generator unit in the Virginia Polytechnic Institute Heating and Power Plant. These savings were determined by comparing three proposed plans of generating or purchasing electric power while supplying the college with steam.

The daily log sheets and flow meter charts of the plant were used to determine the electric load curves and the steam demand curves for the year 1952. These curves were projected into the future to include the years, 1956, 1957, 1958, and 1959. These curves, together with performance curves for a 5000 Kw two stage extraction back-pressure turbo-generator and a 5000 Kw three stage extraction condensing turbo-generator were used in the investigation. The average outdoor temperature days were grouped in 5°F increments from 20°F through 70°F. A set of four daily load curves was plotted for each 5°F increment. Curve No. 1 shows the total electric load on the system. Curve No. 2 shows the steam demand on the plant when the proposed 5000 Kw three stage extraction condensing turbo-generator is carrying the total electric load while extracting the heating and process steam. Curve No. 3 shows the electric power that the proposed 5000 Kw two stage extraction back pressure turbo-generator would generate while meeting the heating and process steam demand. Curve No. 4 shows the total heating and process steam demand.

The area under curve No. 1 represents the total electric load in

kilowatt-hours on the system for a day. The area under curve No. 4 represents the total heating and process steam demand in pounds for a day. The daily cost of plan No. 1 was obtained by multiplying these areas by their respective scale constants and then adding these products. The area under curve No. 3 and under curve No. 1 where curve No. 1 is below curve No. 3 represents the electric power in kilowatt-hours that could be generated by the proposed back-pressure unit. The daily saving of plan No. 2 was determined by multiplying this area by its scale constant. The daily cost of plan No. 2 was obtained by subtracting this saving from the daily cost of plan No. 1. The area under curve No. 2 and curve No. 4 where curve No. 4 is above curve No. 2 represents the steam demand in pounds for a day of the condensing unit carrying the total electric load while extracting the heating and process steam. The daily cost of plan No. 3 was obtained by multiplying this area by its scale constant. The daily saving obtained by using the extraction condensing turbine over the plan of purchasing all the electric power was determined by subtracting the daily cost of plan No. 3 from that of plan No. 1. The daily saving obtained by using the extraction condensing turbine over the back-pressure turbine was determined by subtracting the daily cost of plan No. 3 from that of plan No. 2.

The yearly costs and savings were determined by multiplying the daily costs and savings by the number of days in each group of average outdoor temperature days and adding these products. The expected yearly saving of plan No. 3 over plan No. 1 for 1956 would be $137,400.00, for 1957, $147,600.00; for 1958, $158,000.00 and for 1959, $171,300.00. The

expected yearly saving of plan No. 3 over plan No. 2 for 1956 would be $64,300.00; for 1957, $73,200.00; for 1958, $79,900.00 and for 1959, $93,300.00.

VII

THE INVESTIGATION

A. Object

The object of this investigation is to determine the indicated yearly savings, from the first few years of operation, resulting from the installation of a proposed 5000 Kw three stage extraction condensing turbo-generator unit in the Virginia Polytechnic Institute Heating and Power Plant.

B. Procedure

This investigation consisted of the collection, analysis, and projection of data concerning the various steam and electric loads on the Virginia Polytechnic Institute Heating and Power Plant to determine the annual saving that might be obtained by the installation of a new 5000 Kw three stage extraction condensing turbo-generator operating under the following conditions: throttle pressure and temperature, 600 psig and 750°F; exhaust, 2 in. Hg. abs.; automatic extraction at 5 psig; non-automatic extraction at 75 psig and 165 psig.

As it was known that the outdoor temperature greatly affected both the steam demand and the electric load, it was decided to base the investigation on average outdoor temperatures.

The year 1952 was chosen to be used as the base year because the plant records were current, also the monthly and yearly average outdoor temperatures compared very favorably with the 51-year average outdoor temperatures. The average outdoor temperature for 1952 was 51.8° while the 51-year average outdoor temperature was 52.4°F. [21]

The daily 5 psig steam demand was plotted against the average outdoor temperature for the year 1952. A straight regression line was then drawn through these points so that days near this line could be considered typical days. However, following the advice of the Virginia Polytechnic Institute Statistics Department, this method of sampling was abandoned. The reason for this was that the peak loads occurred at different times of the day throughout the various seasons of the year and this variation of the peak loads was not being taken into consideration by the selection of a day based on its total steam demand.

The following system of sampling was then suggested and followed throughout the investigation. The days were collected into eleven groups having average outdoor temperatures of 20°F - 25°F, 25°F - 30°F, 30°F - 35°F, 35°F - 40°F, 40°F - 45°F, 45°F - 50°F, 50°F - 55°F, 55°F - 60°F, 60°F - 65°F, 65°F - 70°F, and days above 70°F. The off heating season days were placed in the group of days above 70°F; this was because of the great similarity of the loads of the off heating season days. The seasonal variation of the peaks loads was accounted for by selecting sample days for each group based on a ratio of days in each month. For example: in the 50°F - 55°F group, January had 4 days; March, 2 days; April, 5 days; May, 1 day; October, 8 days, and November 5 days. From this group a sample was taken from each month in the ratio of days in each month, from January, 2 days; March, 1 day; April, 2 days; May, 1 day; October, 3 days, and November, 2 days. In selecting the days from each month, median days were chosen. The loads for the days in each group were then tabulated on a three-hour basis and averaged, thus, giving

an average daily load curve. The same days were used when obtaining the 75 psig steam and electric loads so that conditions creating the demand would be the same for both the steam and electric loads.

The electric load was taken from the daily log sheet as a sum of the electric power purchased from the Appalachian Electric Power Co. and the electric power generated in the Heating Power Plant. The 5 psig steam load was determined by the flow meter charts from the flow meters on the low pressure header No. 1, low pressure header No. 2, domestic hot water heaters, and feedwater heaters. The 75 psig steam load was determined by the flow meter on the 75 psig header. As the 165 psig steam would be used primarily in the plant auxiliaries and as the auxiliaries for the proposed high pressure addition to the plant have not yet been determined, the 165 psig steam load was assumed to be 4000 pounds per hour.

The average electric loads were projected into the future at a yearly eight per cent increase. This yearly increase of eight per cent was decided upon after discussions with the college utility engineer and a study of local, national, and expected national load increases as discussed in current engineering magazines. The 5 psig steam load was projected into the future in proportion to the increase in building radiation. This information was furnished by the college planning engineer. This projection assumes that the steam demand is proportional to the amount of connected building radiation.

Turbine performance curves for a 5000 Kw back-pressure turbo-generator and a 5000 Kw automatic extraction condensing turbo-generator were supplied by the Westinghouse Co.[22] The 75 psig and 165 psig nonautomatic extraction performance curves were added to the original performance

curves by a method suggested by Mr. E. V. Polland, Section Engineer, Turbine Engineering Division, General Electric Co.[19] The performance curves for the back-pressure unit were used to determine the electric power that would be generated when the heating and process steam was passing through the unit. The performance curves for the extraction condensing unit were used to determine the steam demand of the unit when the unit was carrying the total electric load and extracting the heating and process steam.

From the steam demand, electric load, and turbo-generator performance curves, a set of four curves was plotted for each average outdoor temperature day group for each year considered in this study. Curve No. 1 shows the total electric load on the Plant. Curve No. 2 shows the steam demand on the plant when the proposed 5000 Kw three stage extraction condensing turbo-generator is carrying the total electric load while extracting the heating and process steam. Curve No. 3 shows the electric power that the proposed 5000 Kw two stage extraction back-pressure turbo-generator would generate while meeting the heating and process steam demand. Curve No. 4 shows the total heating and process steam demand.

The next step in the investigation was to measure the area under the various curves and then to evaluate these areas. The area under curve No. 1 represents the total electric load in kilowatt-hours on the system for a day. The area under curve No. 4 represents the total heating and process steam demand in pounds for a day. The area under curve No. 3 and curve No. 1 where curve No. 1 is below curve No. 3 represents the electric power in kilowatt-hours that could be generated by the proposed back-pressure unit. The area under curve No. 2 and curve No. 4 where

curve No. 4 is above No. 2 represants the steam demand in pounds for a day of the extraction condensing unit carrying the total electric load while extracting the heating and process steam.

The daily cost of plan No. 1 was determined by multiplying the area in square inches under curve No. 1 by its scale constant of $12.80 per square inch and multiplying the area in square inches under curve No. 4 by its scale constant of $8.00 per square inch. These values were added thereby giving the daily cost of purchasing all electric power from the Appalachian Electric Power Co. while meeting the steam demand of the college. The daily saving of plan No. 2 was determined by multiplying the area in square inches under curve No. 3 and curve No. 1 where No. 1 is below curve No. 3 by its scale constant of $12.80 per square inch. The daily cost of using the back-pressure unit was obtained by subtracting the saving of plan No. 2 from the cost of plan No. 1. The daily cost of plan No. 3 was determined by multiplying the area in square inches under curve No. 2 and curve No. 4 by its scale constant to $8.00 per square inch. The daily saving of using the condensing unit over plan No. 1 was obtained by subtracting the daily cost of plan No. 3 from the daily cost of plan No. 1. The daily saving of using the condensing unit over the back-pressure unit was obtained by subtracting the daily cost of plan No. 3 from the daily cost of plan No. 1.

The yearly costs and savings were determined by multiplying the daily costs and savings by the number of days in each group of average outdoor temperature days and adding these products.

In calculating the costs of the electric power, the lowest curve was always used, while in calculating the costs of the steam, the highest curve was always used.

C. Results

Annual Indicated Savings For 1956 Based
On Cost Of Purchased Power

Average Outdoor Temperature Day Groups	Number Of Days In Groups	Saving Of Back-Pressure Unit Over Purchased Power	Saving Of Condensing Unit Over Purchased Power	Saving Of Condensing Unit Over Back-Pressure Unit
20°F - 25°F	11	4,610.00	5,080.00	462.00
25°F - 30°F	20	8,720.00	9,350.00	620.00
30°F - 35°F	34	13,500.00	15,600.00	2,110.00
35°F - 40°F	38	14,500.00	17,200.00	2,580.00
40°F - 45°F	30	10,300.00	12,600.00	2,310.00
45°F - 50°F	32	10,300.00	13,100.00	2,850.00
50°F - 55°F	25	7,000.00	9,610.00	2,620.00
55°F - 60°F	16	4,080.00	5,960.00	1,890.00
60°F - 65°F	19	0.00	6,600.00	6,600.00
65°F - 70°F	18	0.00	6,150.00	6,150.00
Days Above 70°F	122	0.00	36,100.00	36,100.00
Total Annual Savings		$73,010.00	$137,400.00	$64,290.00

Annual Indicated Savings For 1957 Based
On Cost Of Purchased Power

Average Outdoor Temperature Day Groups	Number Of Days In Groups	Saving Of Back-Pressure Unit Over Purchased Power	Saving Of Condensing Unit Over Purchased Power	Saving Of Condensing Unit Over Back-Pressure Unit
20°F - 25°F	11	4,690.00	5,460.00	770.00
25°F - 30°F	20	8,900.00	9,860.00	980.00
30°F - 35°F	34	13,800.00	16,700.00	2,920.00
35°F - 40°F	38	14,900.00	18,400.00	3,460.00
40°F - 45°F	30	10,500.00	13,700.00	3,240.00
45°F - 50°F	32	10,400.00	14,200.00	3,740.00
50°F - 55°F	25	7,070.00	10,200.00	3,120.00
55°F - 60°F	16	4,150.00	6,450.00	2,300.00
60°F - 65°F	19	0.00	7,050.00	7,050.00
65°F - 70°F	18	0.00	6,600.00	6,600.00
Days Above 70°F	122	0.00	39,000.00	39,000.00
Total Annual Savings		$74,410.00	$147,600.00	$73,180.00

Annual Indicated Savings For 1958 Based
On Cost Of Purchased Power

Average Outdoor Temperature Day Groups	Number Of Days In Groups	Saving Of Back-Pressure Unit Over Purchased Power	Saving Of Condensing Unit Over Purchased Power	Saving Of Condensing Unit Over Back-Pressure Unit
20°F - 25°F	11	4,830.00	5,810.00	990.00
25°F - 30°F	20	9,240.00	10,700.00	1,460.00
30°F - 35°F	34	14,300.00	17,900.00	3,600.00
35°F - 40°F	38	16,000.00	19,600.00	3,610.00
40°F - 45°F	30	11,200.00	14,700.00	3,950.00
45°F - 50°F	32	10,800.00	15,000.00	4,220.00
50°F - 55°F	25	7,420.00	11,100.00	3,620.00
55°F - 60°F	16	4,270.00	6,880.00	2,610.00
60°F - 65°F	19	0.00	7,620.00	7,620.00
65°F - 70°F	18	0.00	7,110.00	7,110.00
Days Above 70°F	122	0.00	41,600.00	41,600.00
Total Annual Savings		$78,060.00	$158,000.00	$79,890.00

Annual Indicated Savings For 1959 Based
On Cost Of Purchased Power

Average Outdoor Temperature Day Groups	Number Of Days In Groups	Saving Of Back-Pressure Unit Over Purchased Power	Saving Of Condensing Unit Over Purchased Power	Saving Of Condensing Unit Over Back-Pressure Unit
20°F - 25°F	11	4,910.00	6,240.00	1,320.00
25°F - 30°F	20	9,400.00	11,400.00	2,040.00
30°F - 35°F	34	14,500.00	19,200.00	4,720.00
35°F - 40°F	38	15,600.00	21,100.00	5,470.00
40°F - 45°F	30	10,900.00	16,200.00	5,210.00
45°F - 50°F	32	10,900.00	16,300.00	5,370.00
50°F - 55°F	25	7,420.00	11,800.00	4,420.00
55°F - 60°F	16	4,290.00	7,340.00	3,040.00
60°F - 65°F	19	0.00	8,200.00	8,200.00
65°F - 70°F	18	0.00	7,690.00	7,690.00
Days Above 70°F	122	0.00	45,800.00	45,800.00
Total Annual Savings		$77,290.00	$171,300.00	$93,280.00

CURVE CHART

Curve No. 1 = The expected total electric load on the Heating and Power Plant.

Curve No. 2 = The expected steam demand on the Heating and Power Plant when the proposed 5000 Kw three stage extraction condensing turbo-generator is carrying the total electric load while extracting the heating and process steam.

Curve No. 3 = The expected electric power generated by the proposed 5000 Kw two stage extracting back-pressure turbo-generator would generate while meeting the heating and process steam demand on the Heating and Power Plant.

Curve No. 4 = The expected total heating and process steam demand on the Heating and Power Plant.

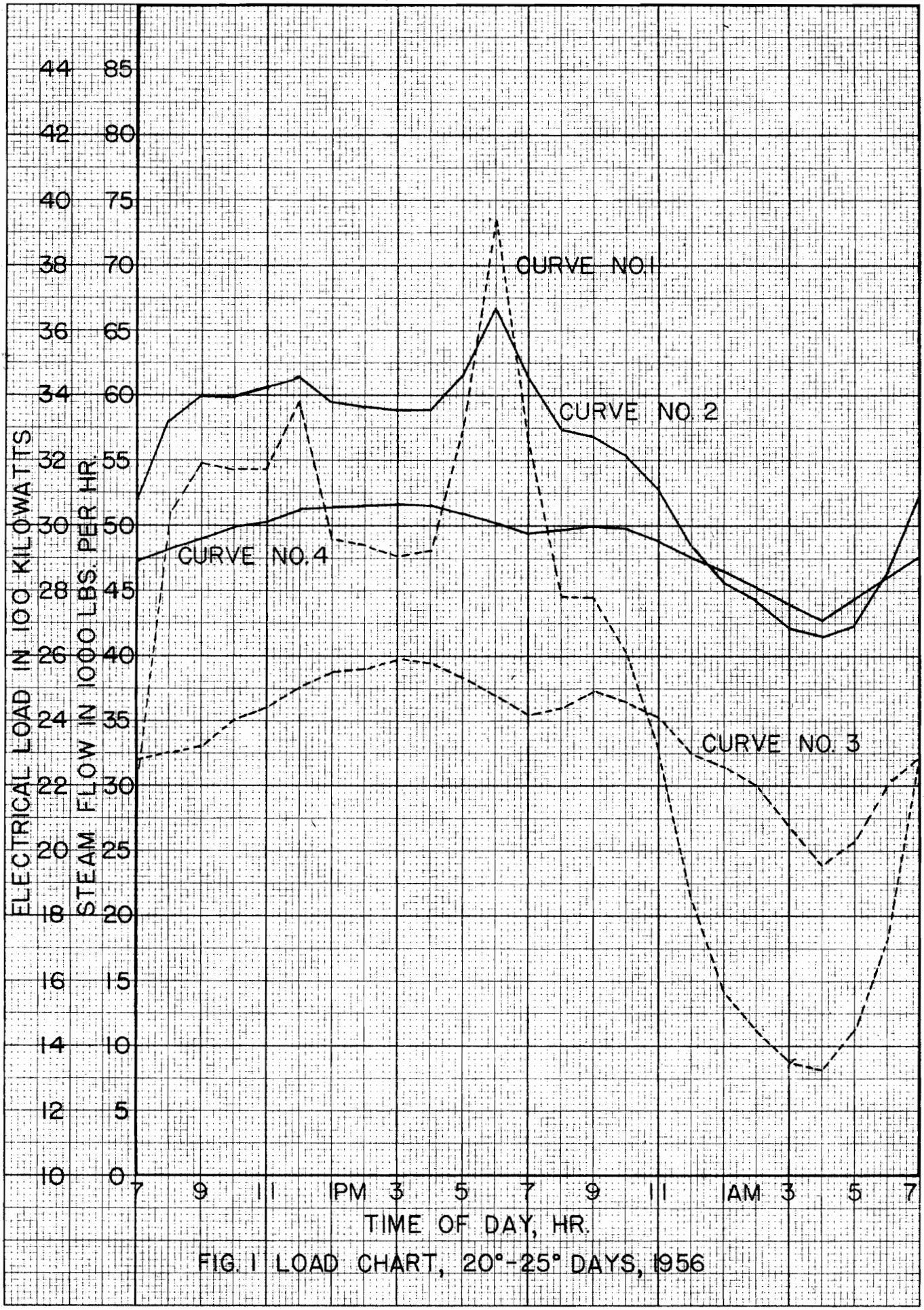


FIG. 1 LOAD CHART, 20°-25° DAYS, 1956

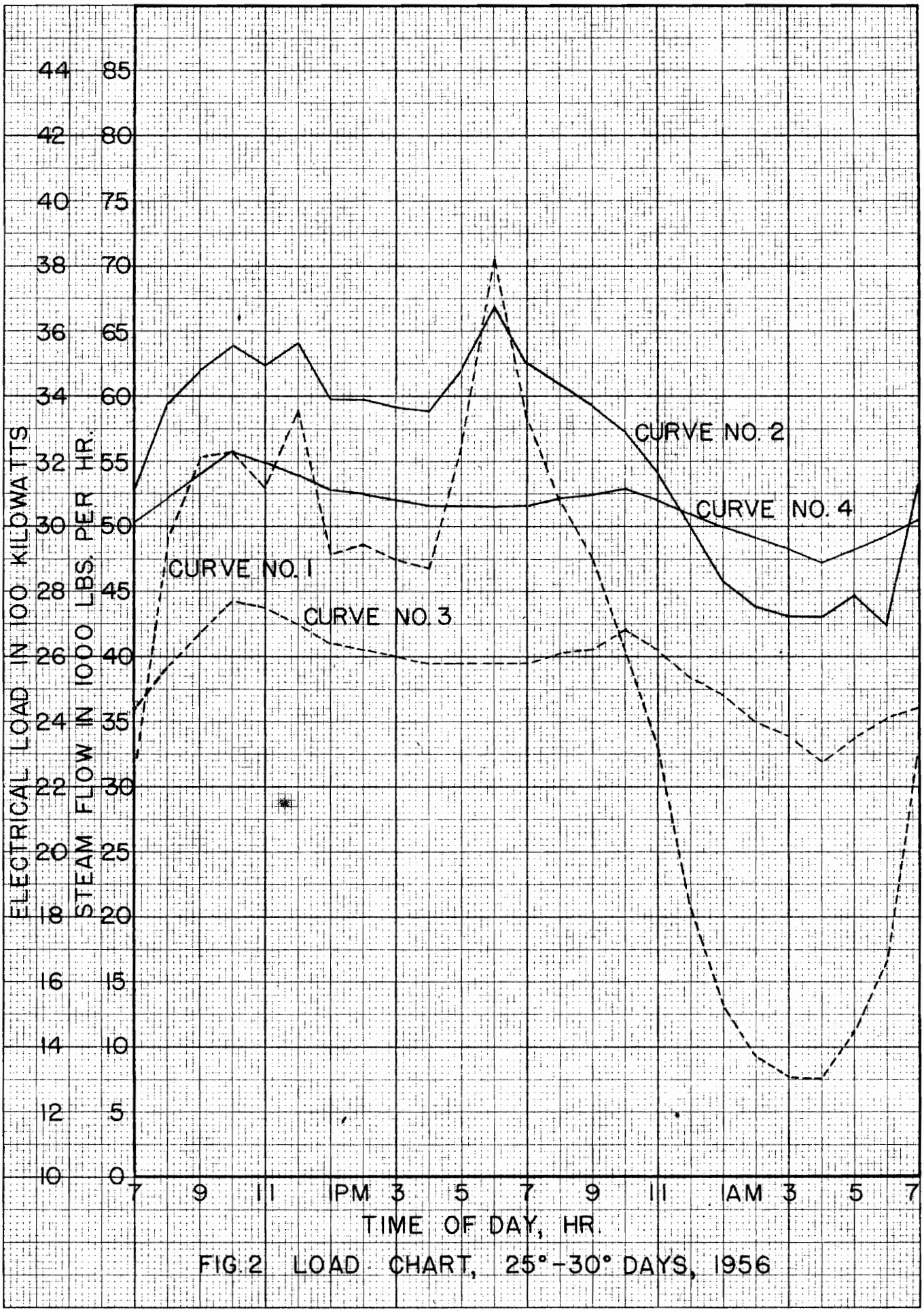


FIG. 2 LOAD CHART, 25°-30° DAYS, 1956

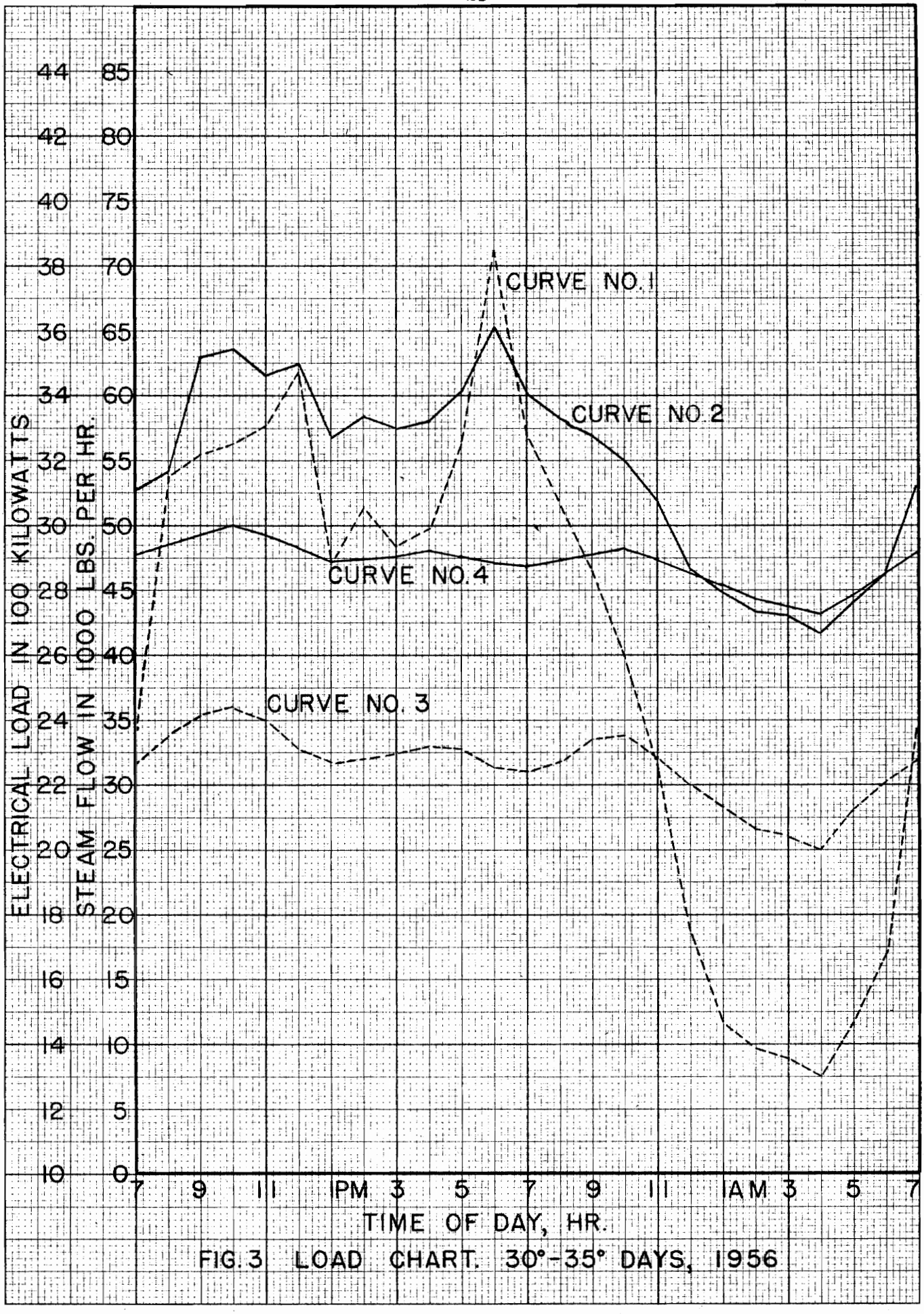


FIG. 3 LOAD CHART. 30°-35° DAYS, 1956

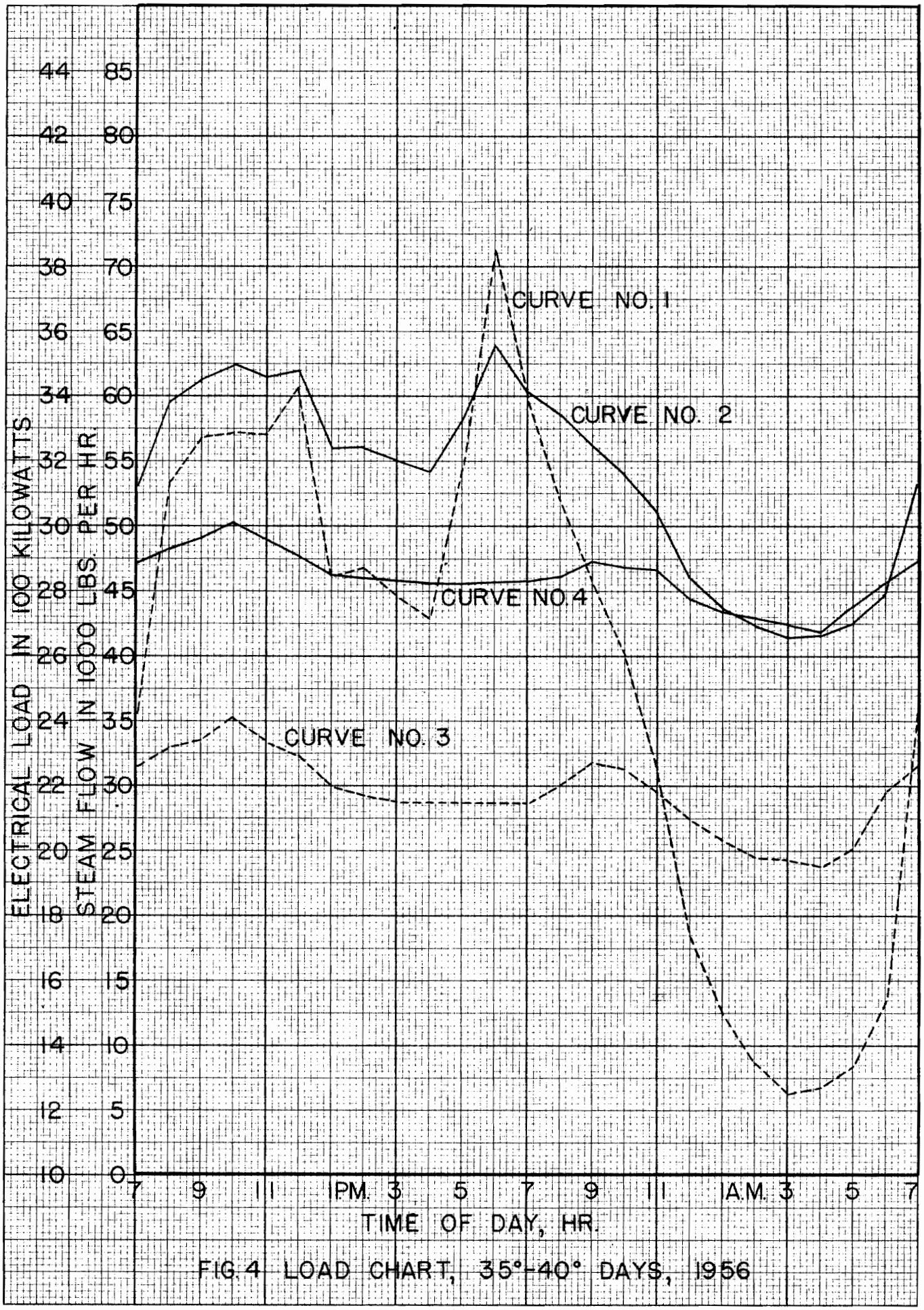


FIG. 4 LOAD CHART, 35°-40° DAYS, 1956

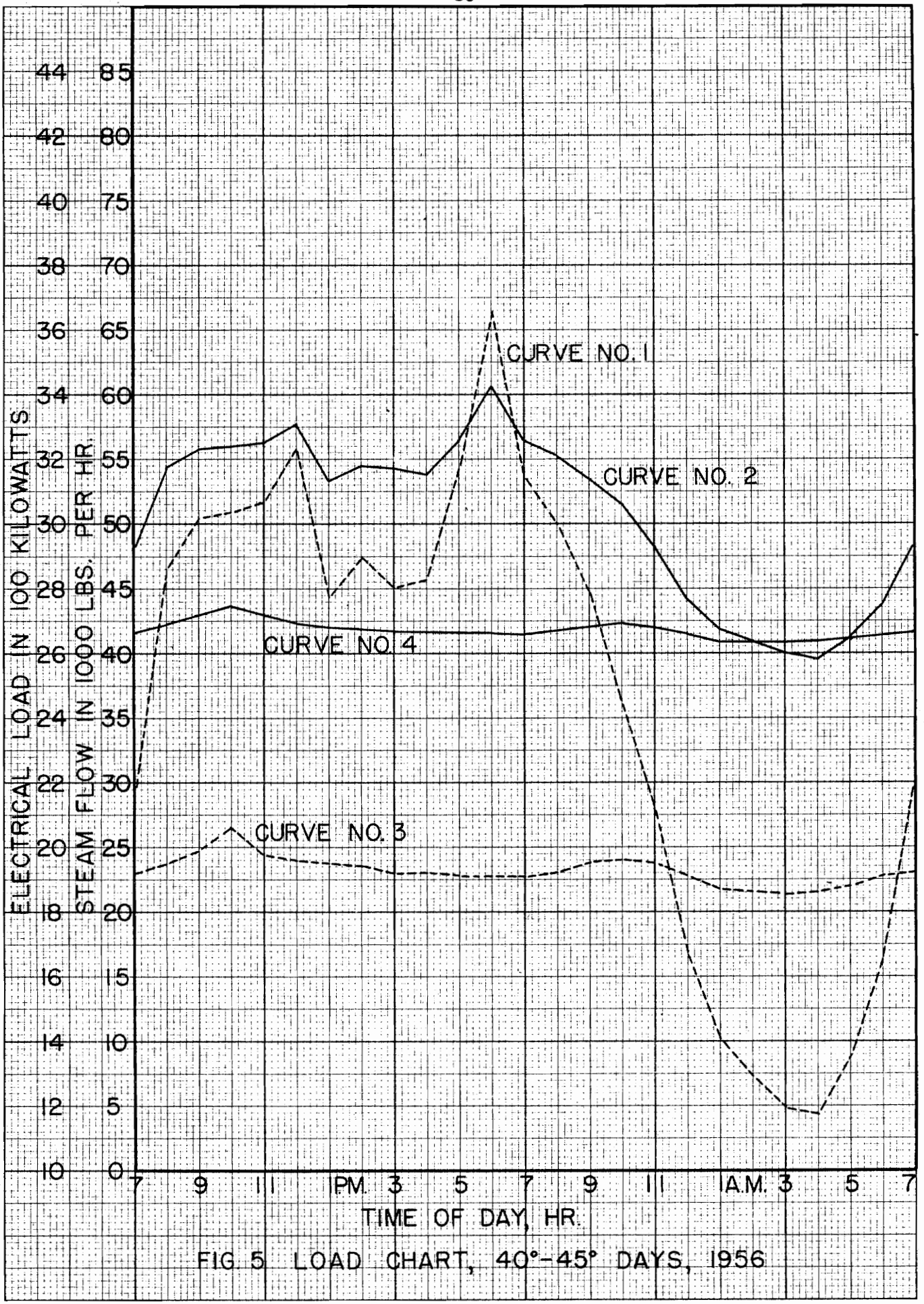


FIG. 5 LOAD CHART, 40°-45° DAYS, 1956

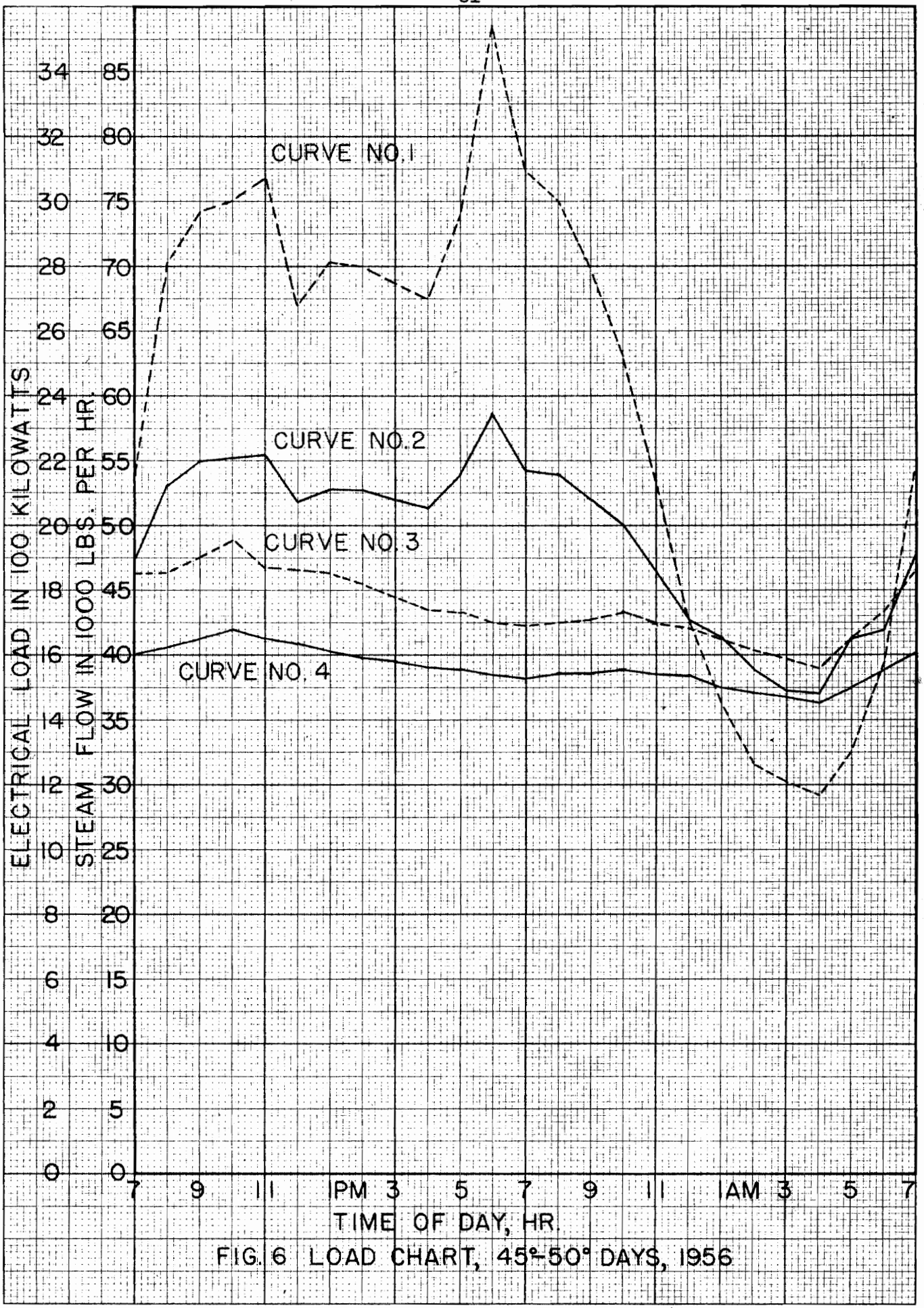


FIG. 6 LOAD CHART, 45°-50° DAYS, 1956

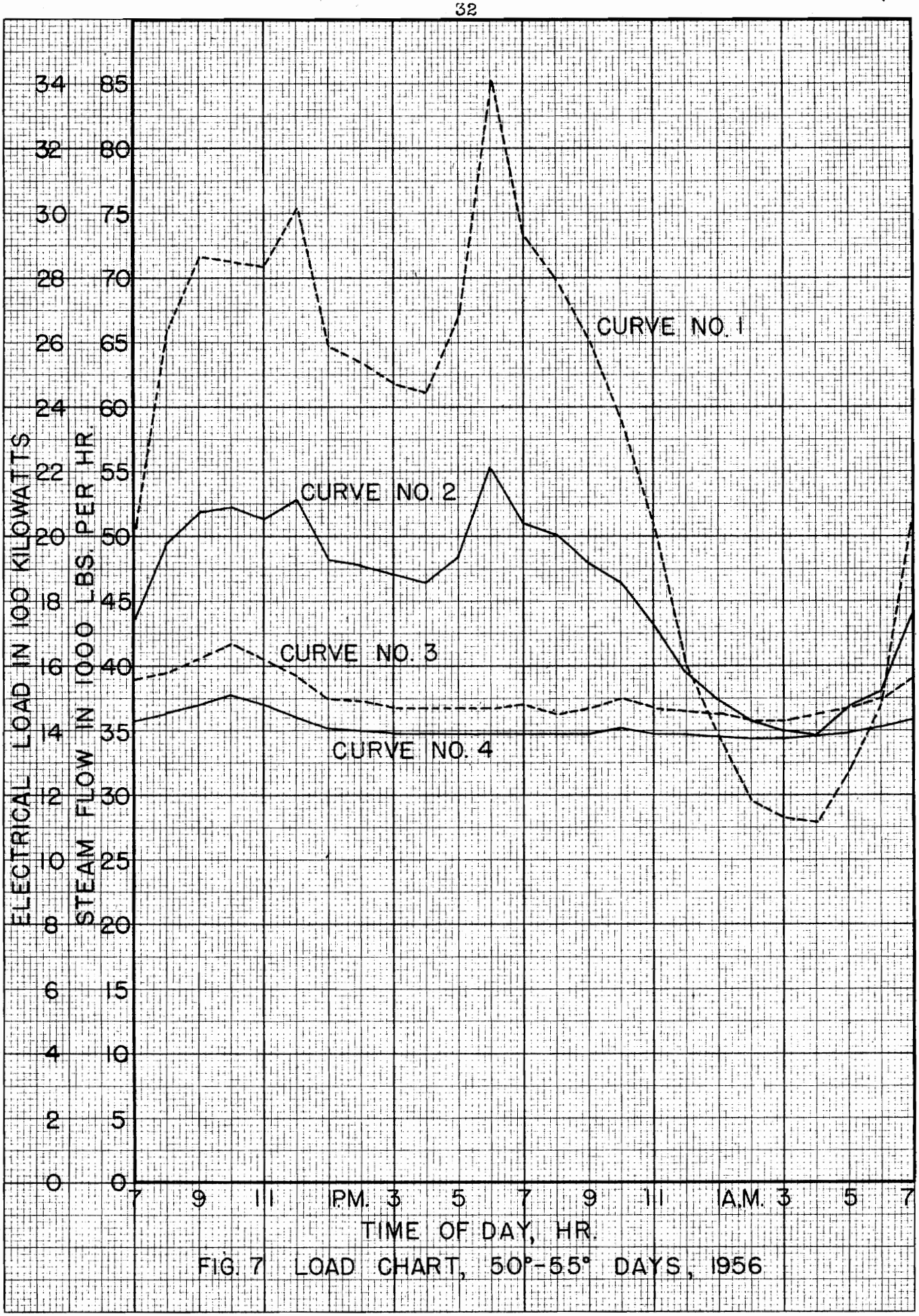


FIG. 7 LOAD CHART, 50°-55° DAYS, 1956

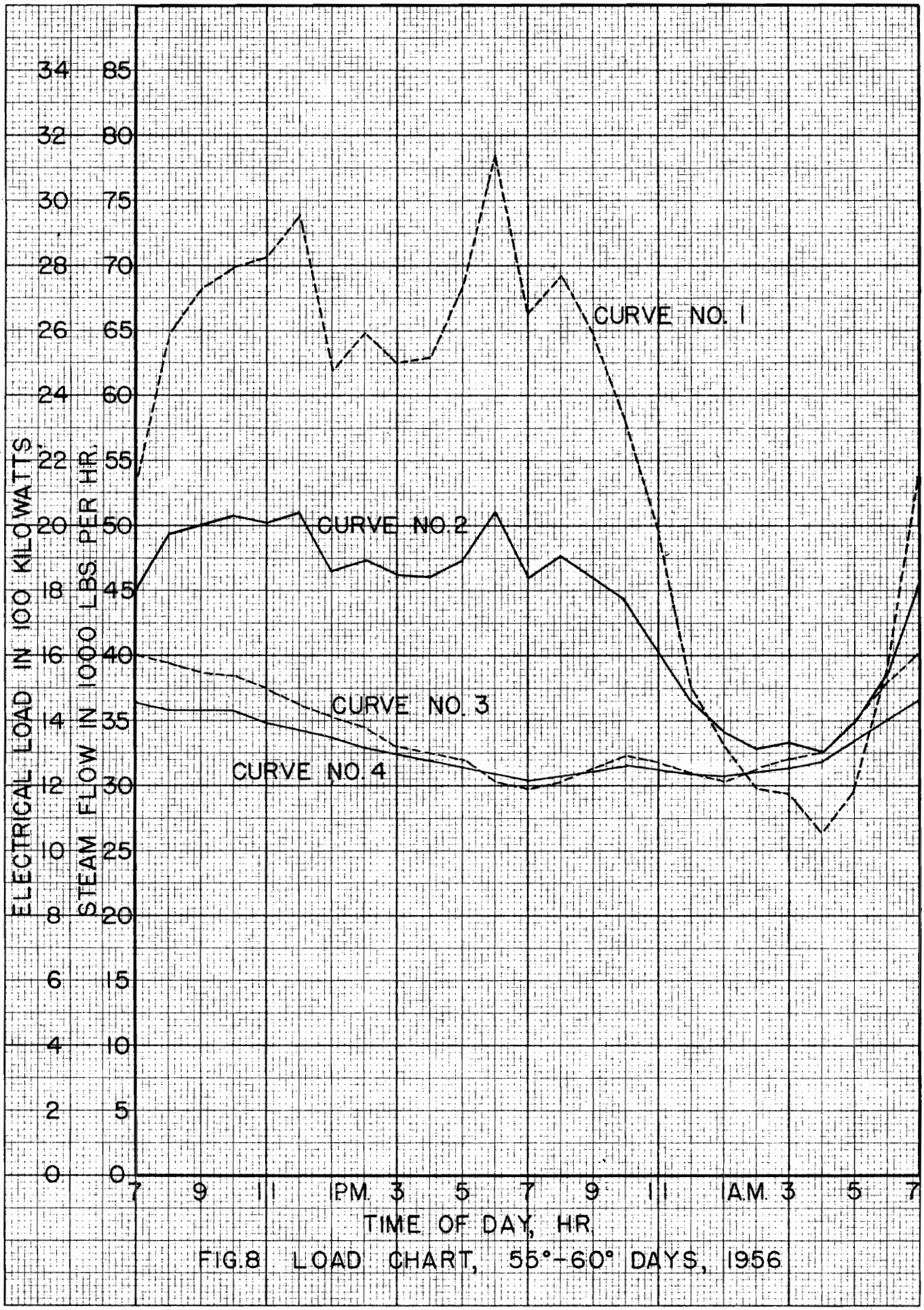


FIG.8 LOAD CHART, 55°-60° DAYS, 1956

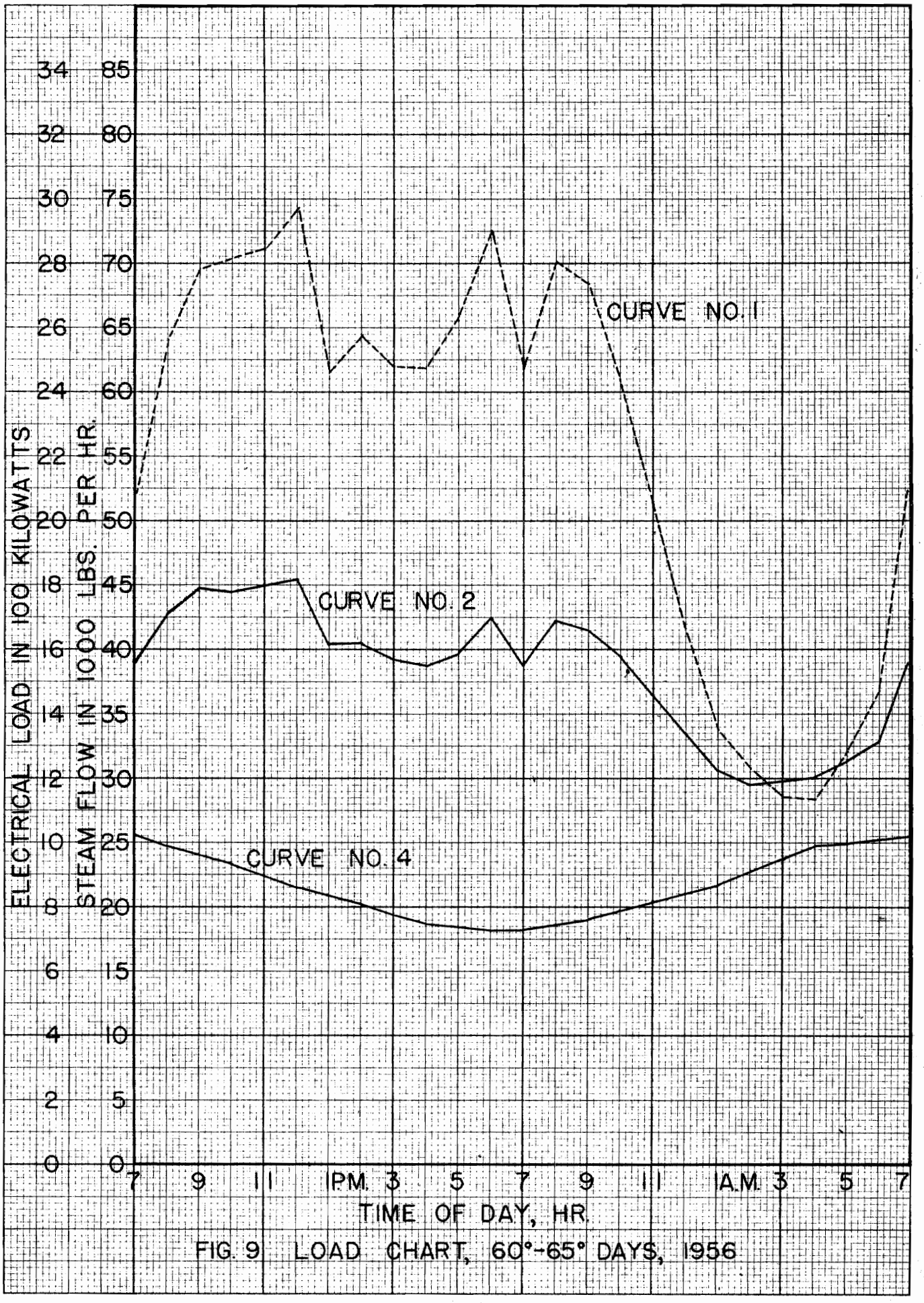


FIG. 9 LOAD CHART, 60°-65° DAYS, 1956

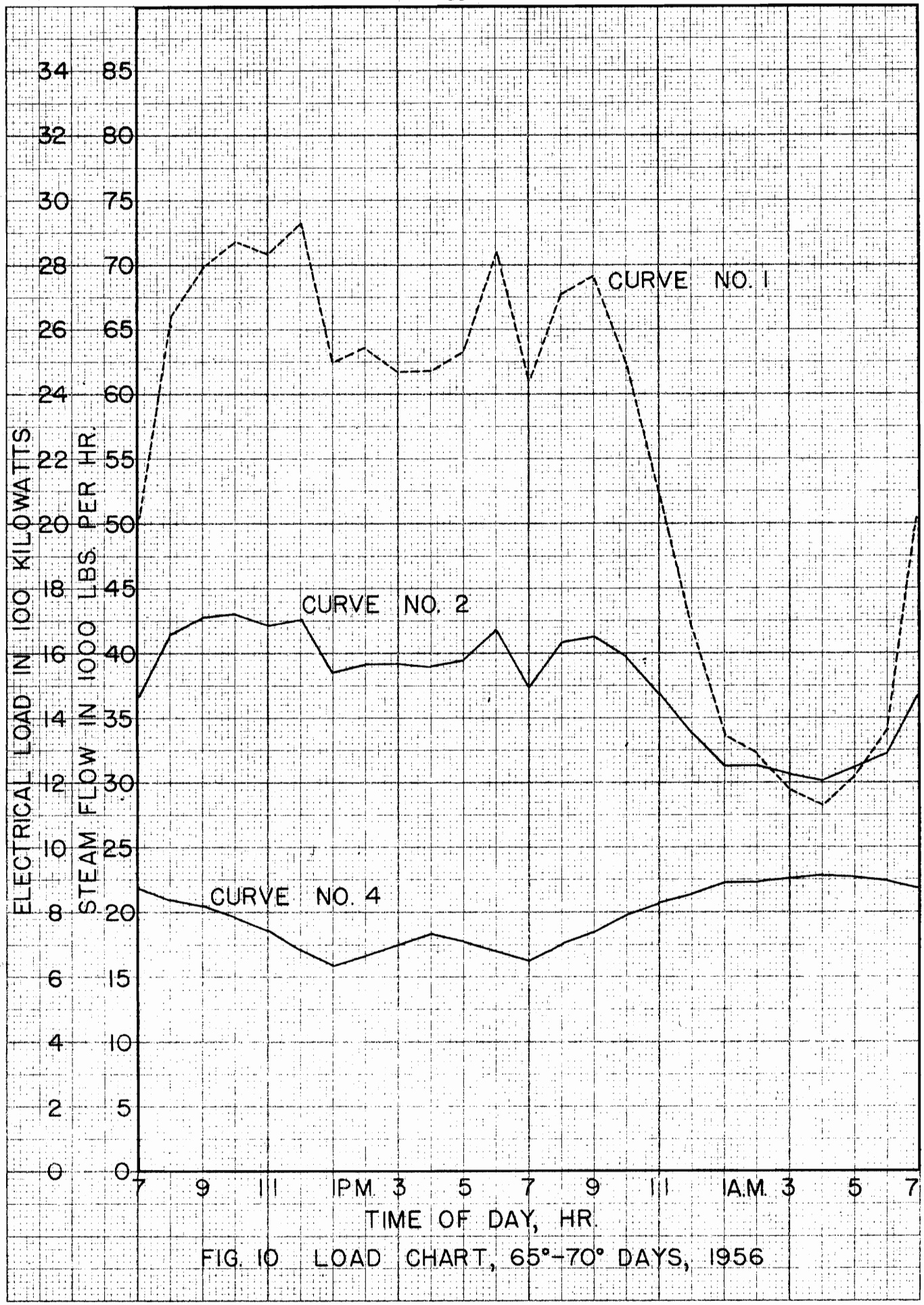


FIG. 10 LOAD CHART, 65°-70° DAYS, 1956

FIG. 11 LOAD CHART, DAYS ABOVE 70°, 1956

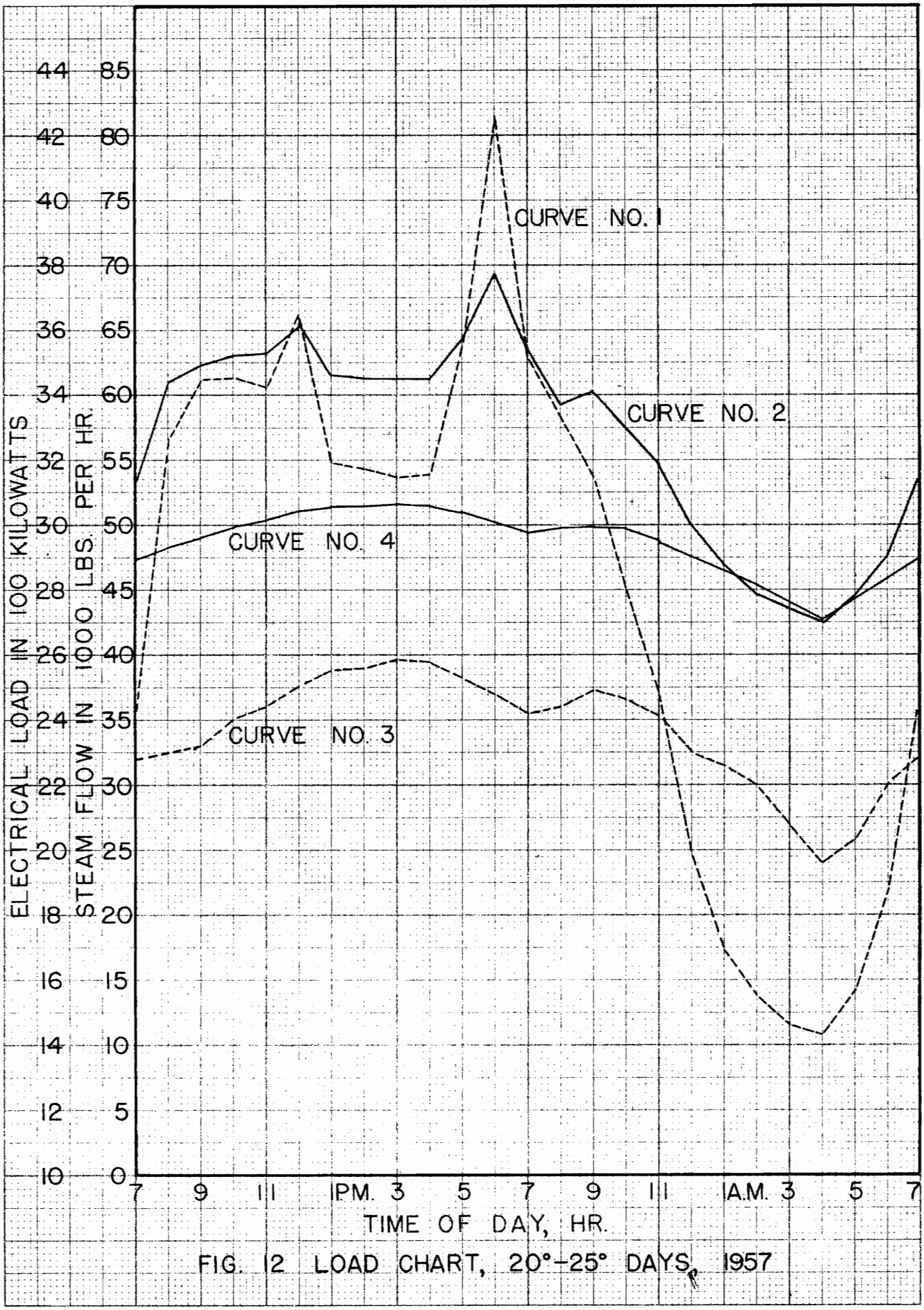


FIG. 12 LOAD CHART, 20°-25° DAYS, 1957

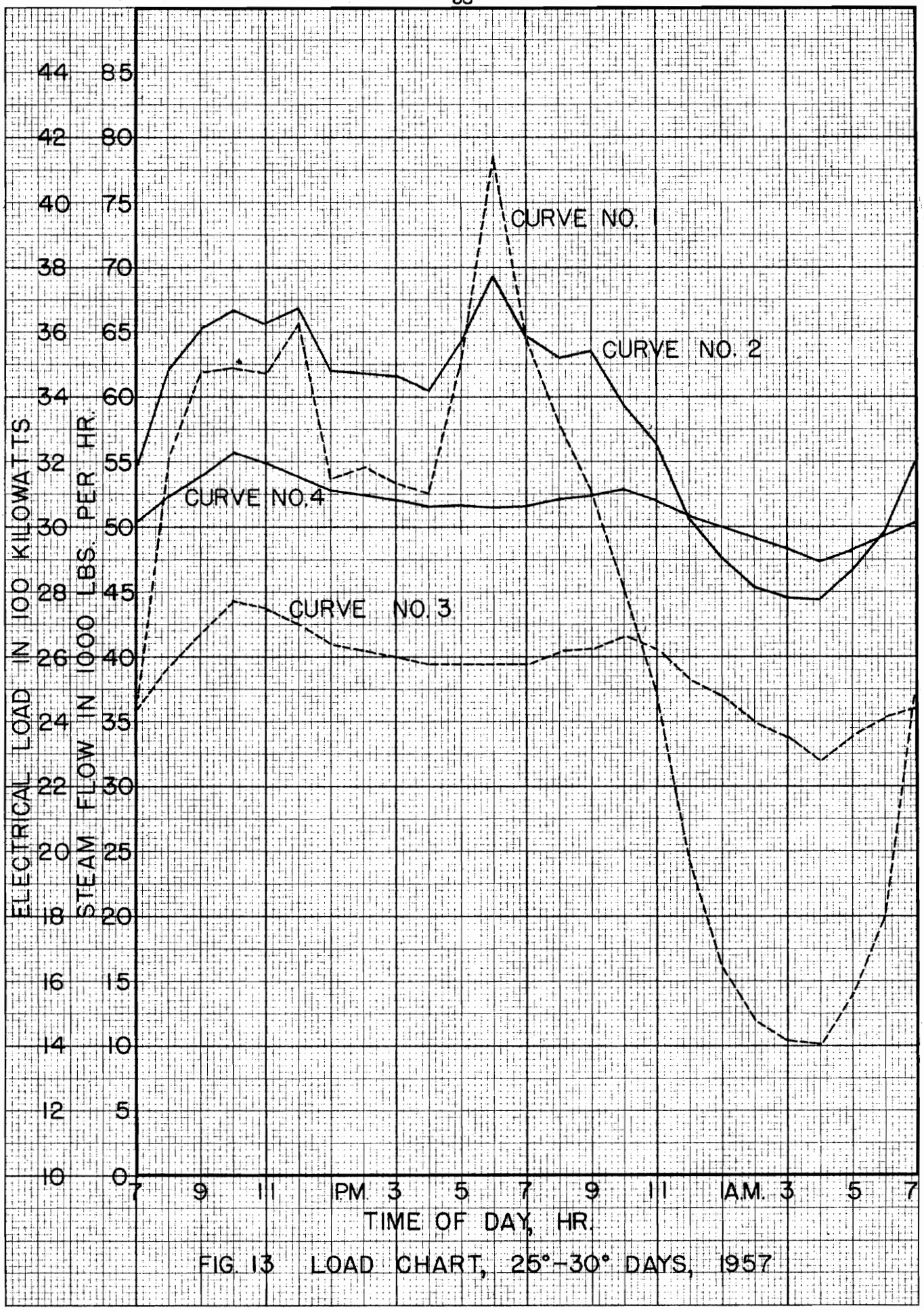


FIG. 13 LOAD CHART, 25°-30° DAYS, 1957

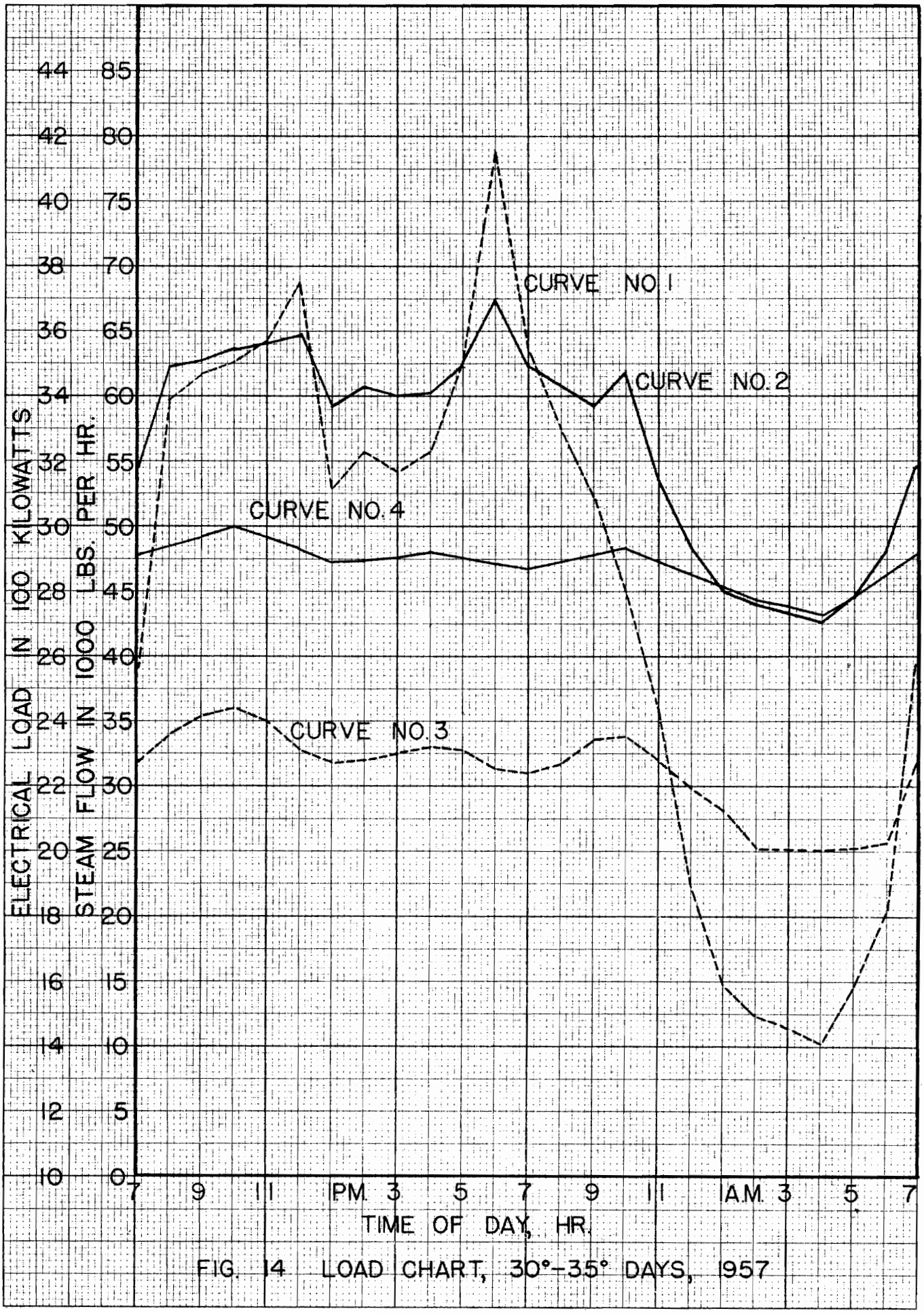


FIG. 14 LOAD CHART, 30°-35° DAYS, 1957

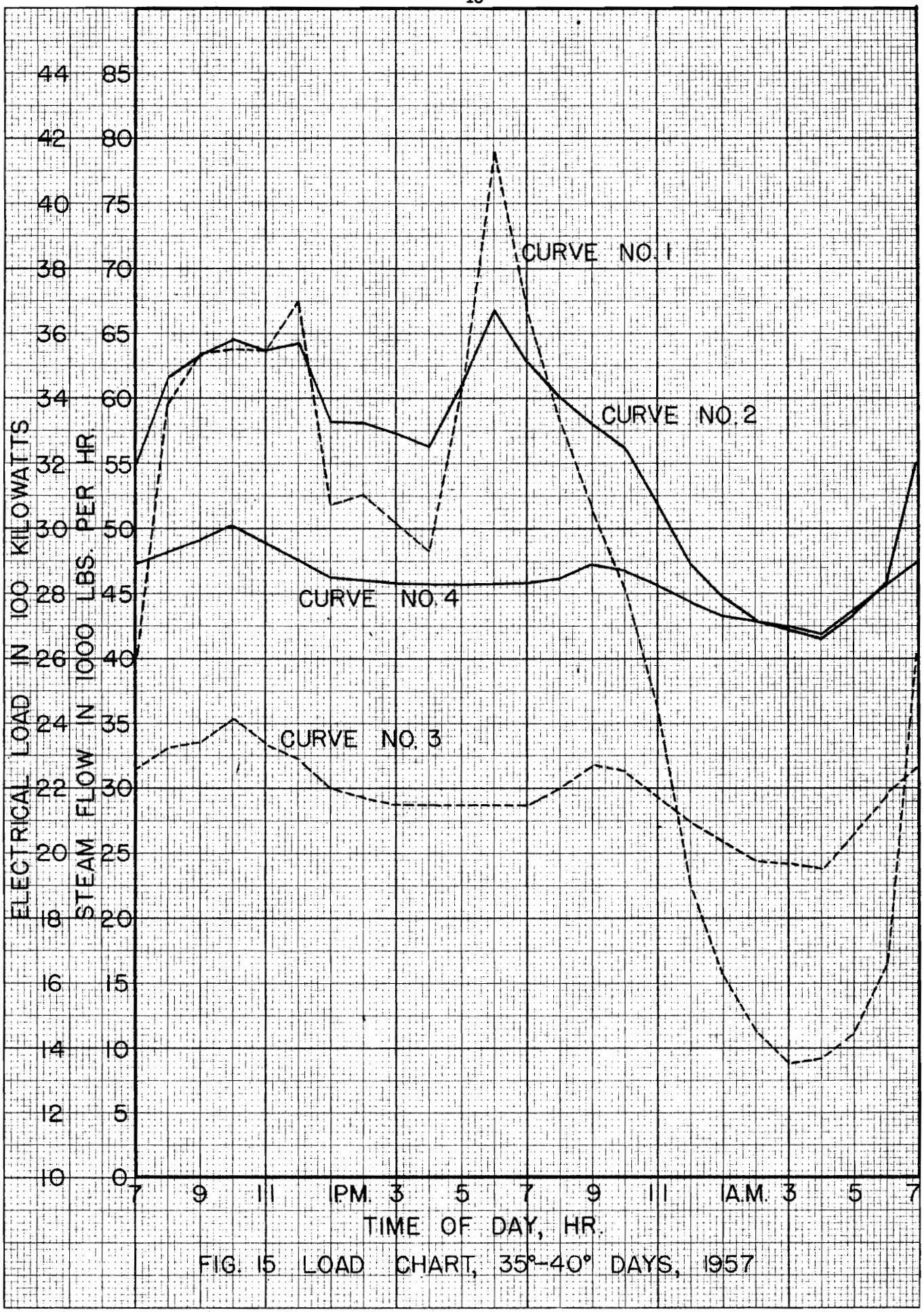


FIG. 15 LOAD CHART, 35°-40° DAYS, 1957

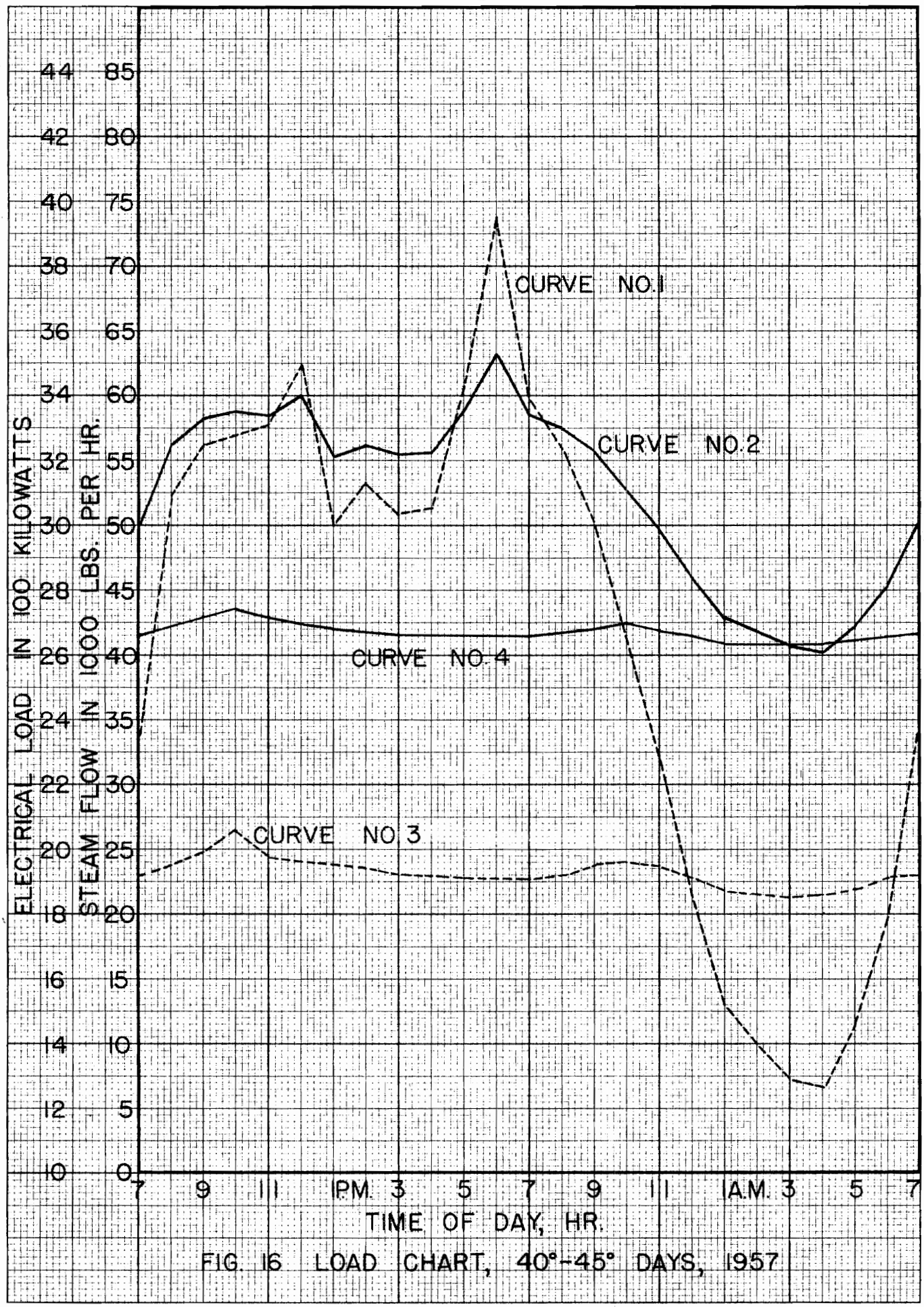


FIG. 16 LOAD CHART, 40°-45° DAYS, 1957

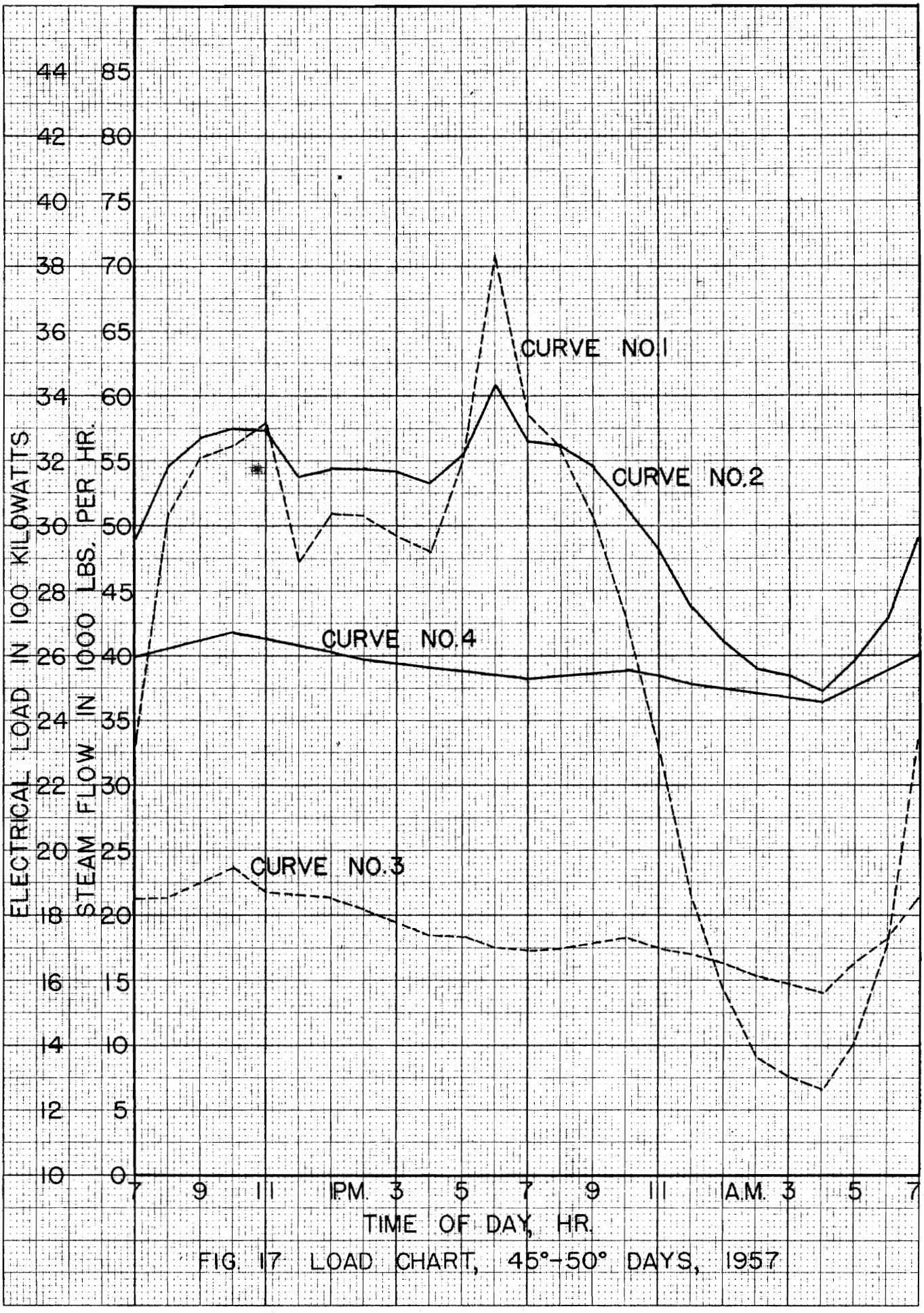


FIG 17 LOAD CHART, 45°-50° DAYS, 1957

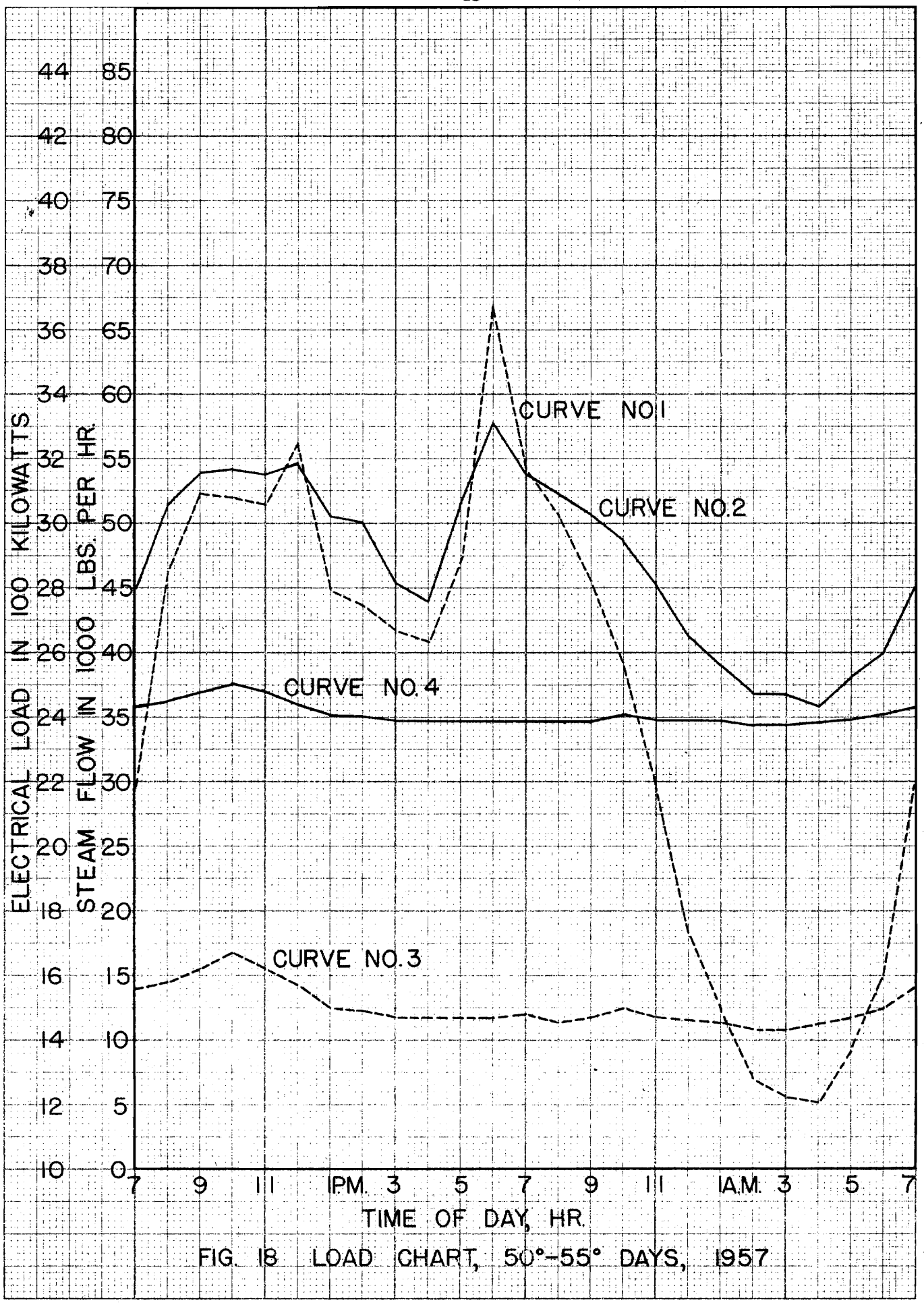


FIG. 18 LOAD CHART, 50°-55° DAYS, 1957

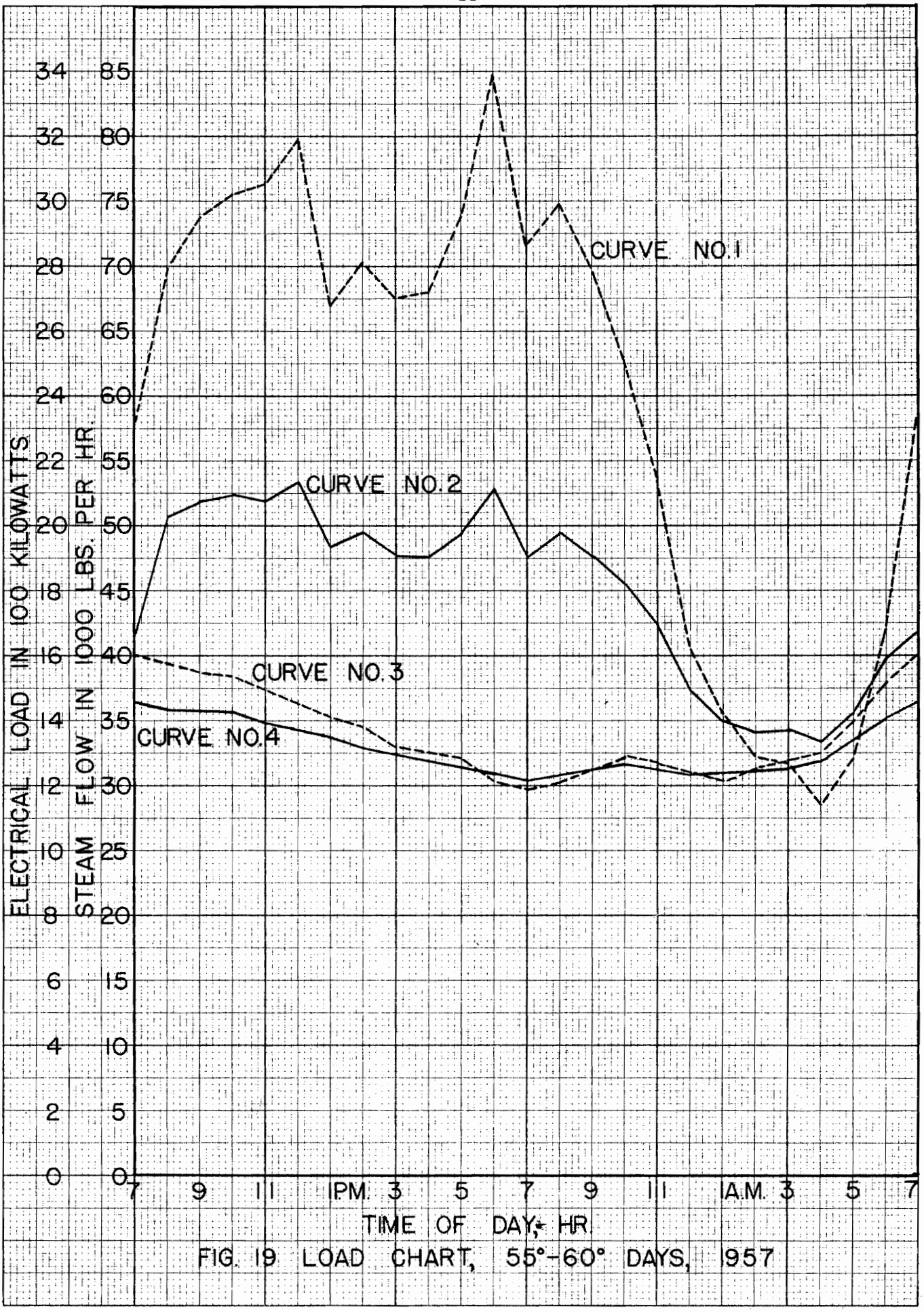


FIG. 19 LOAD CHART, 55°-60° DAYS, 1957

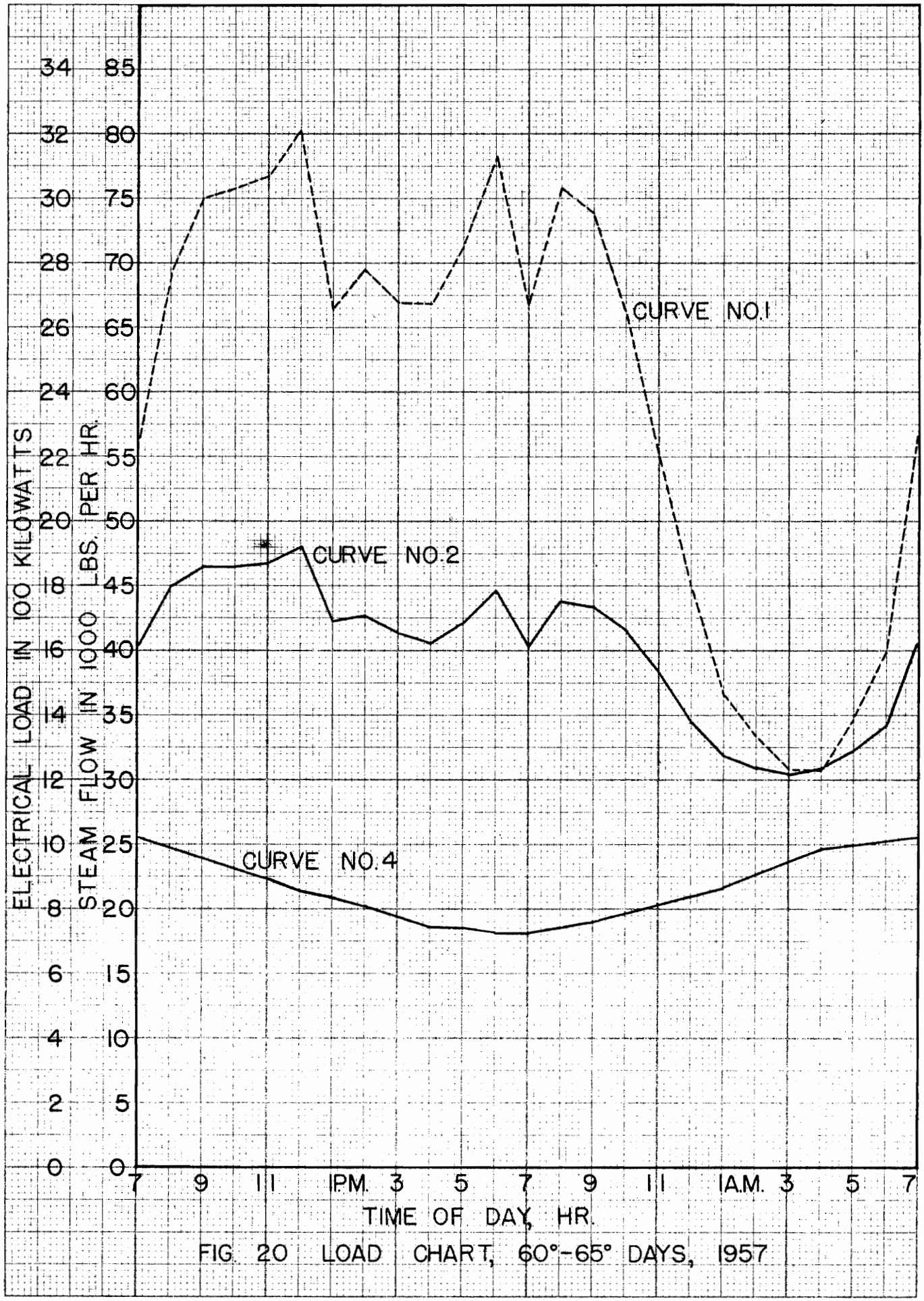


FIG. 20 LOAD CHART, 60°-65° DAYS, 1957

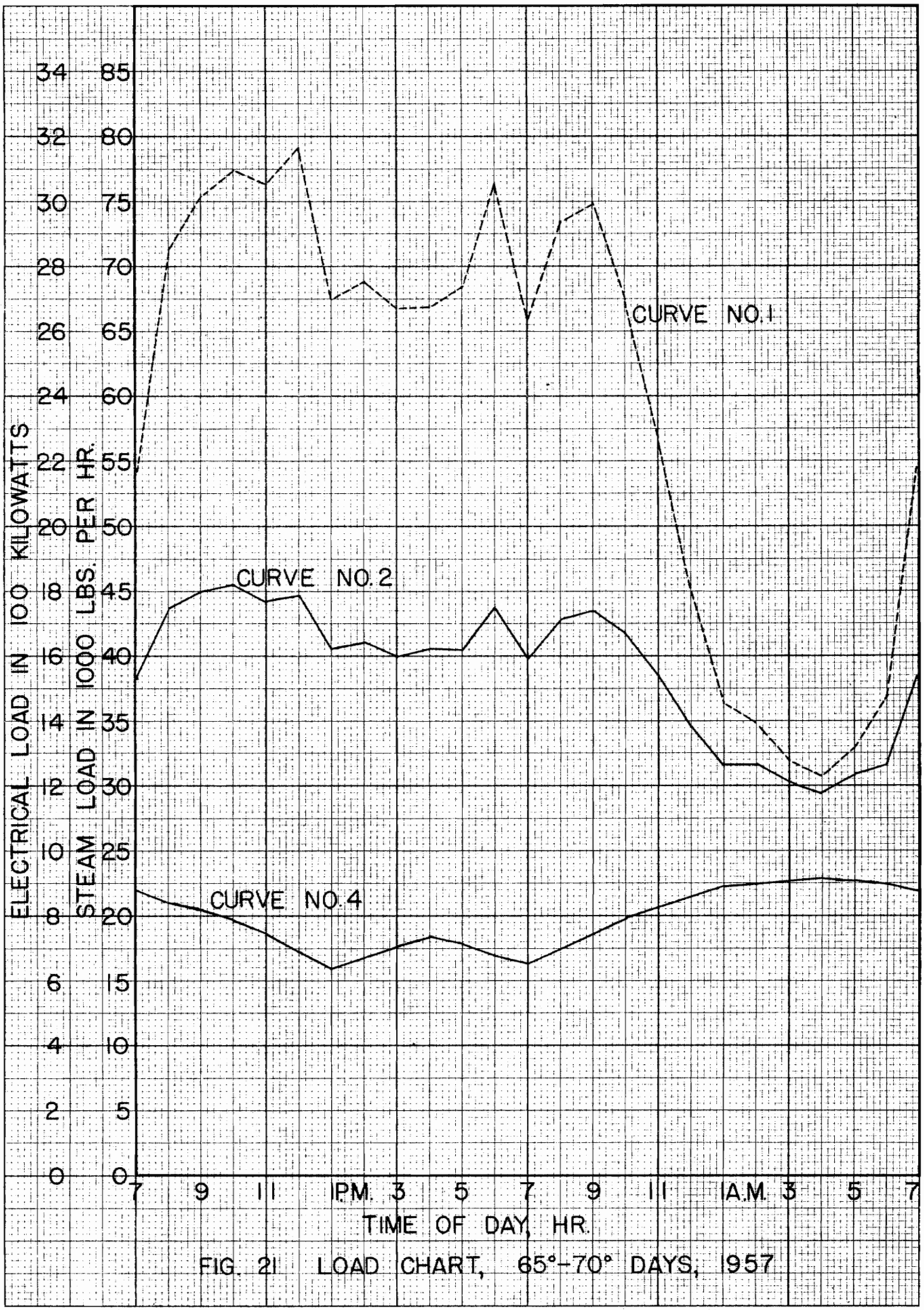


FIG. 21 LOAD CHART, 65°-70° DAYS, 1957

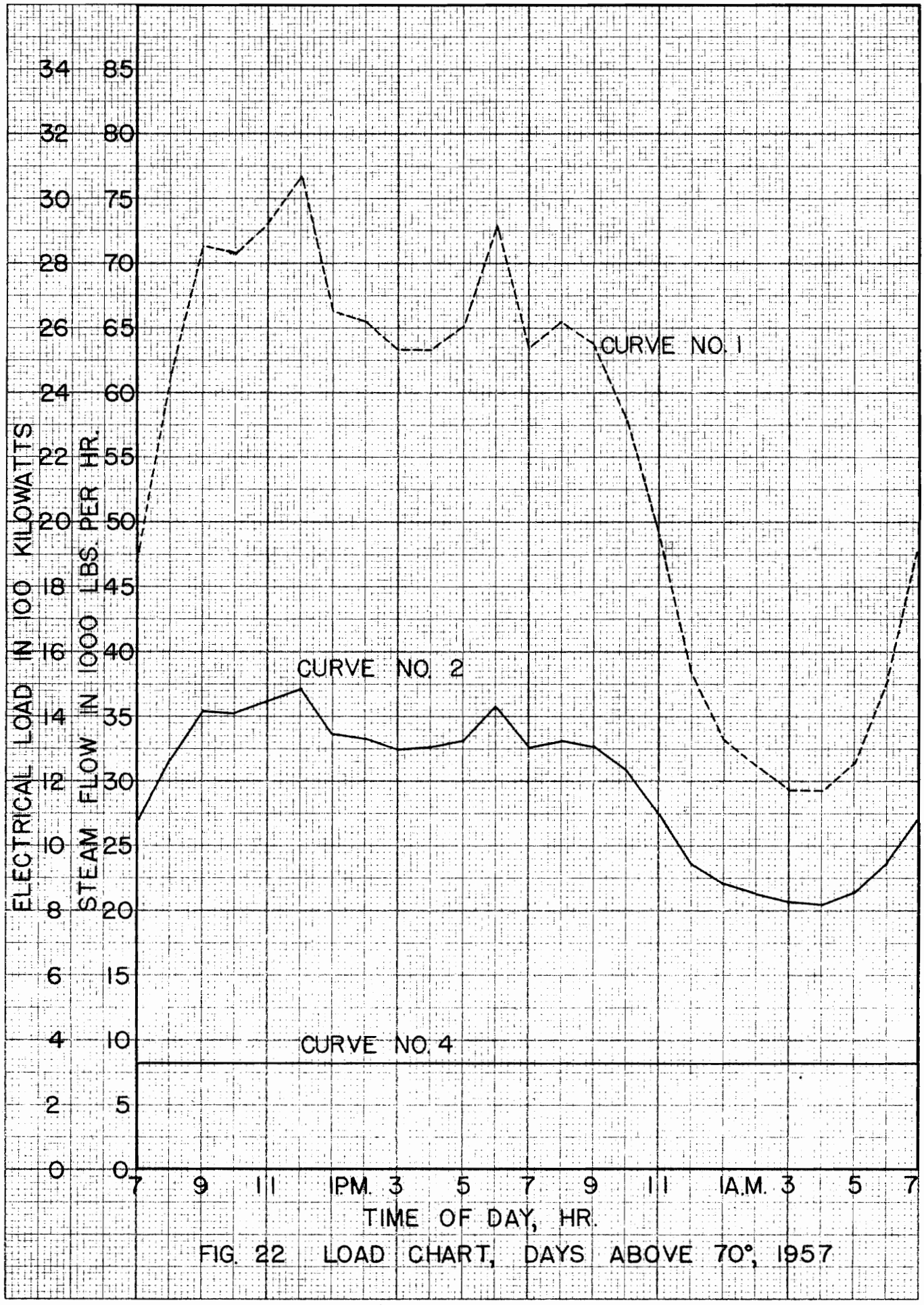


FIG. 22 LOAD CHART, DAYS ABOVE 70°, 1957

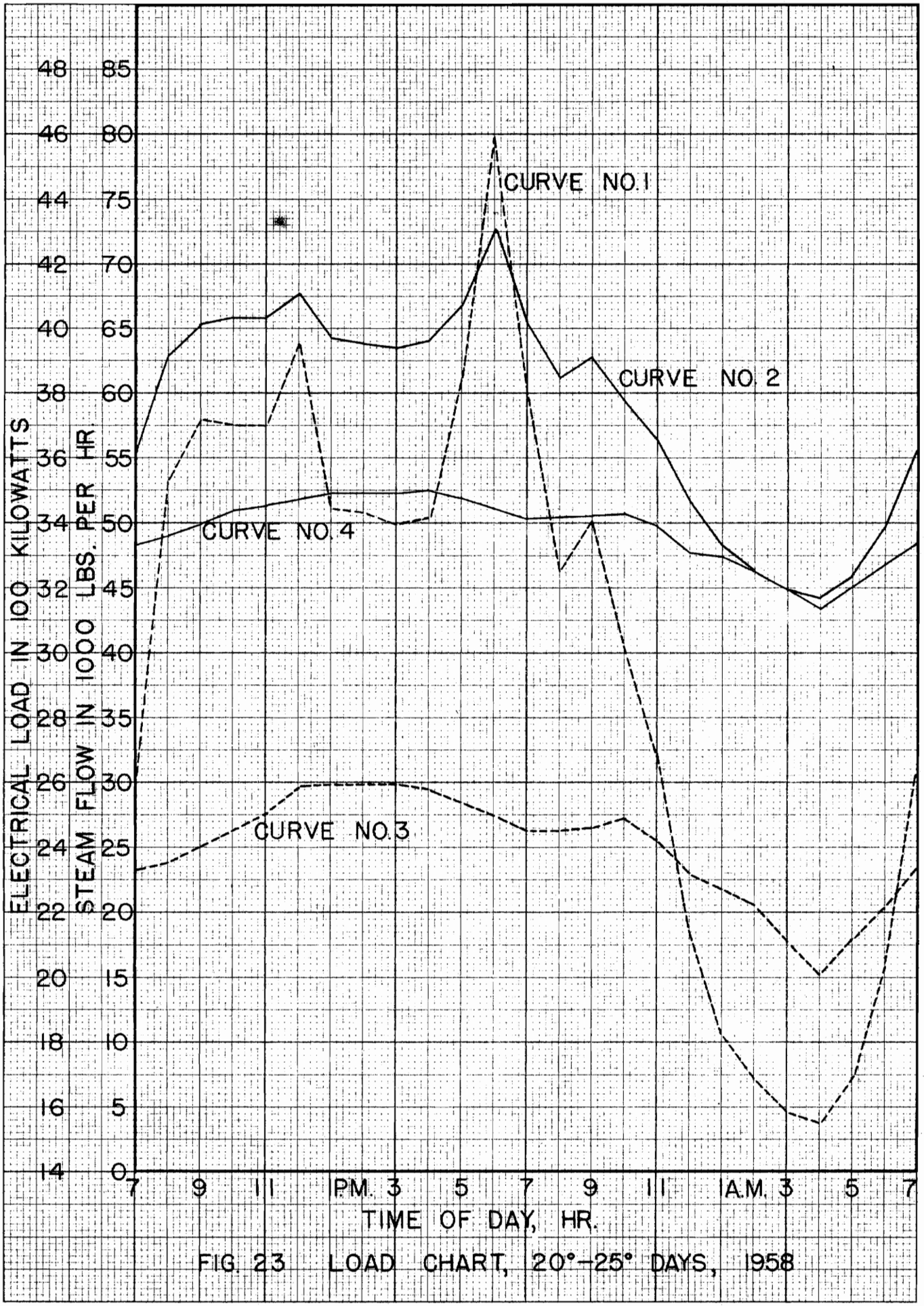


FIG. 23 LOAD CHART, 20°–25° DAYS, 1958

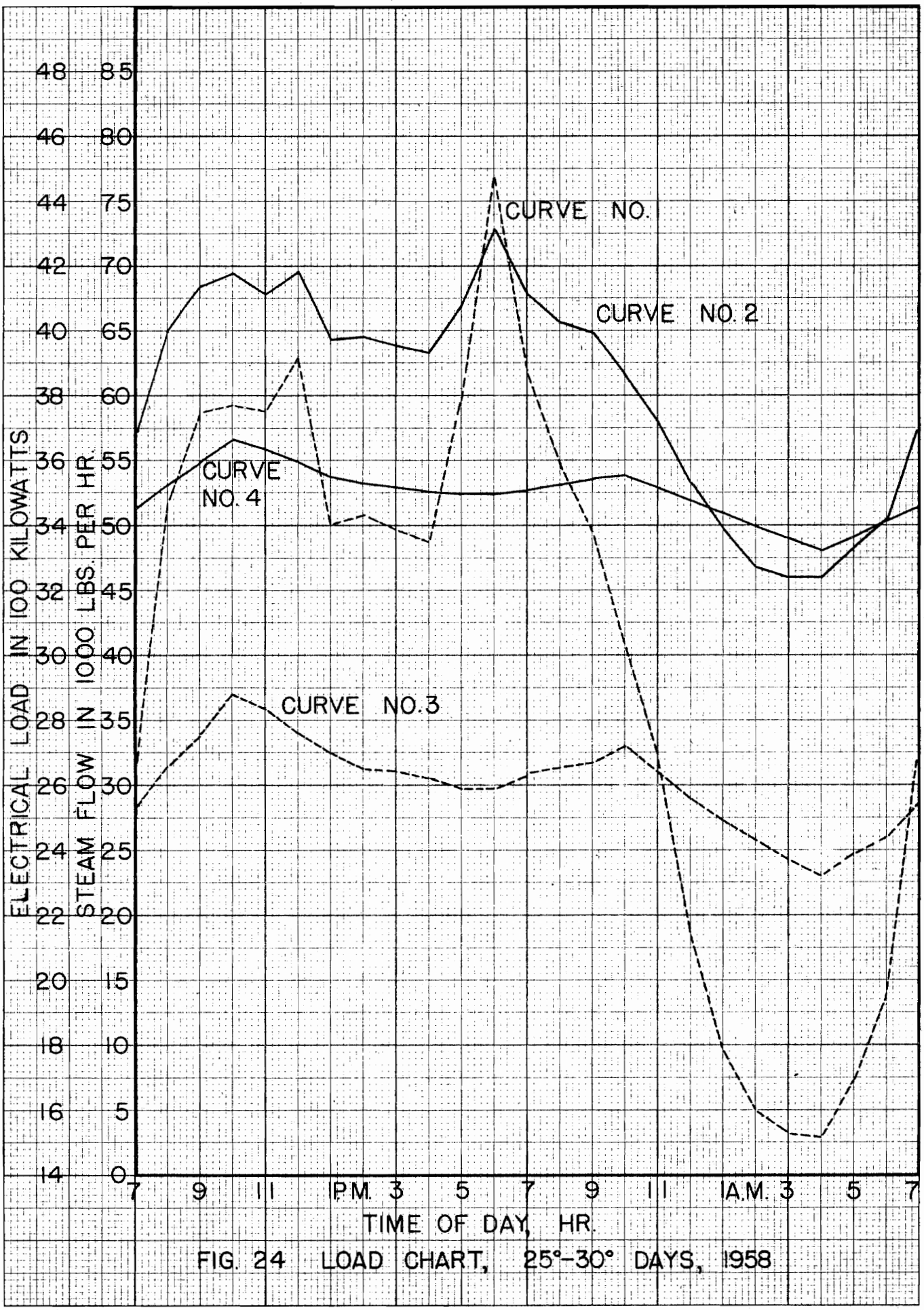


FIG. 24 LOAD CHART, 25°-30° DAYS, 1958

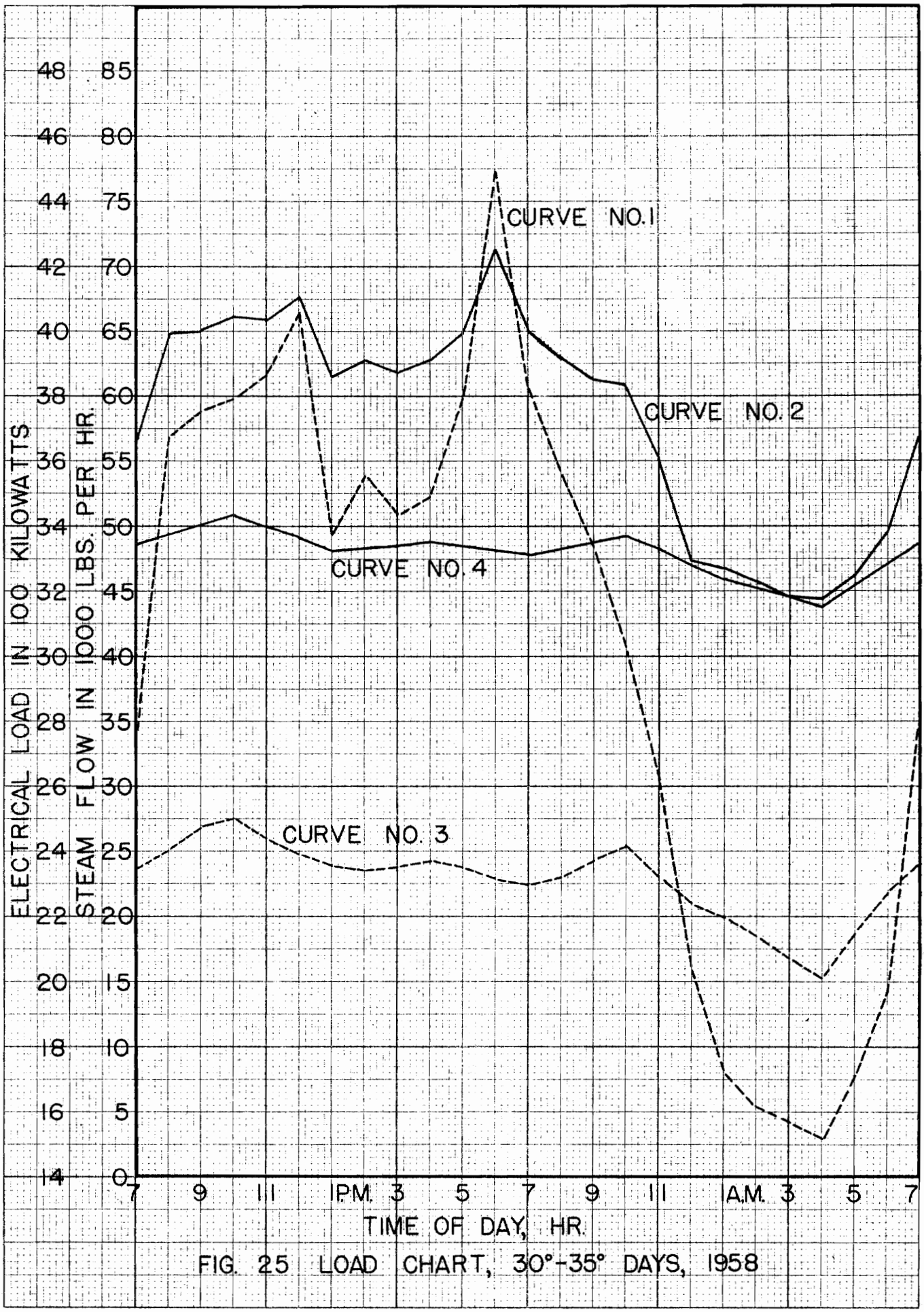


FIG. 25 LOAD CHART, 30°-35° DAYS, 1958

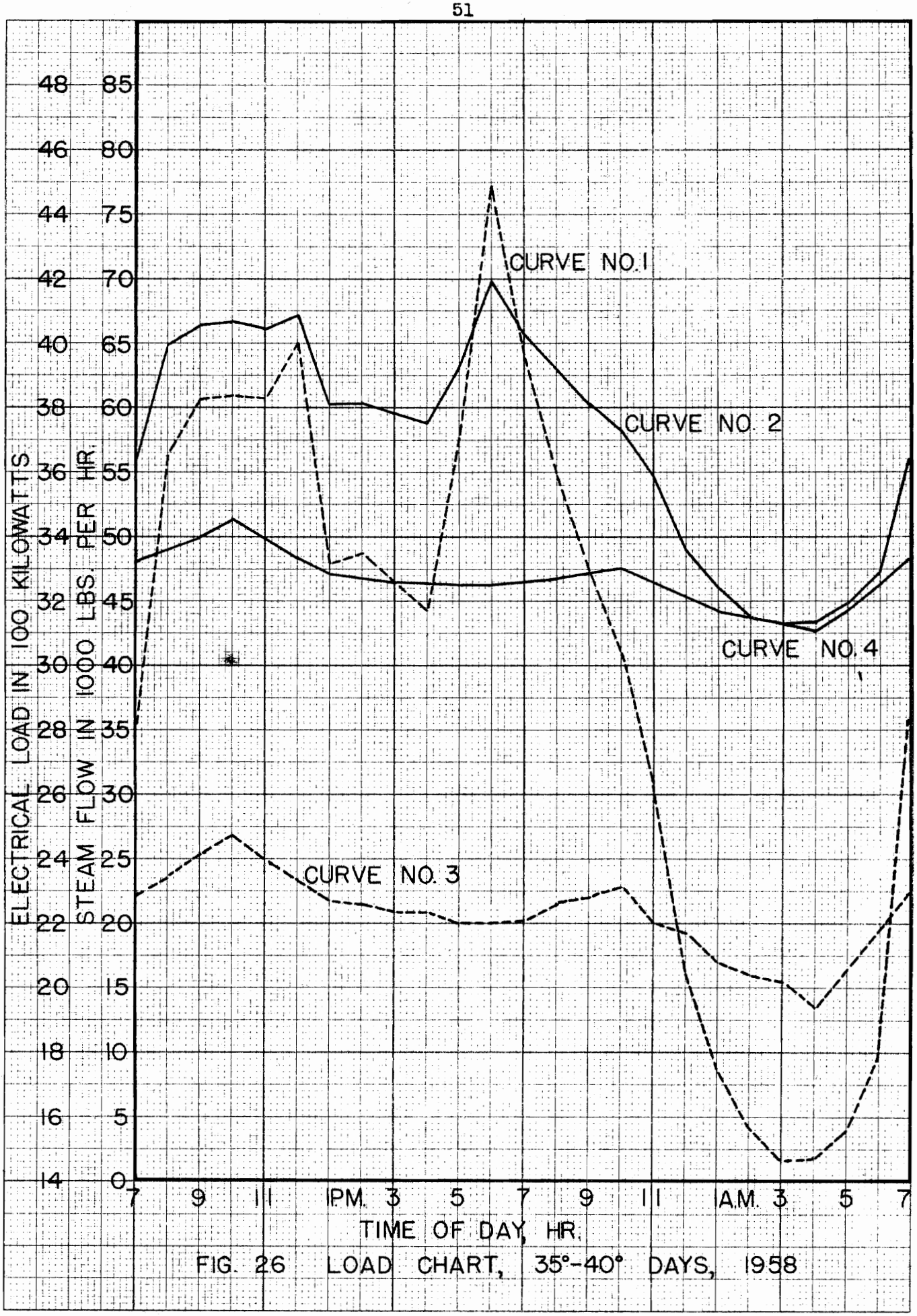


FIG. 26 LOAD CHART, 35°-40° DAYS, 1958

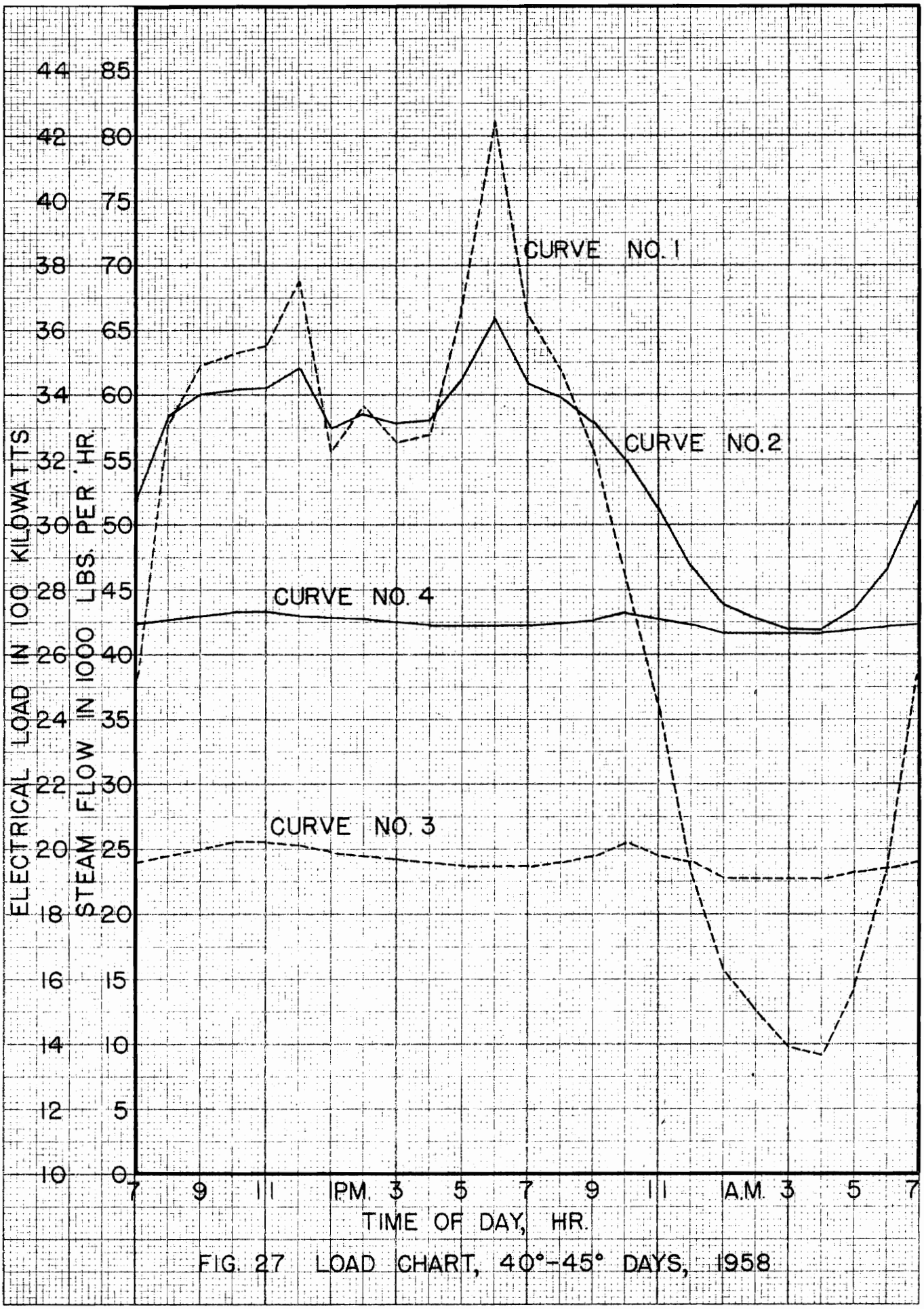


FIG. 27 LOAD CHART, 40°-45° DAYS, 1958

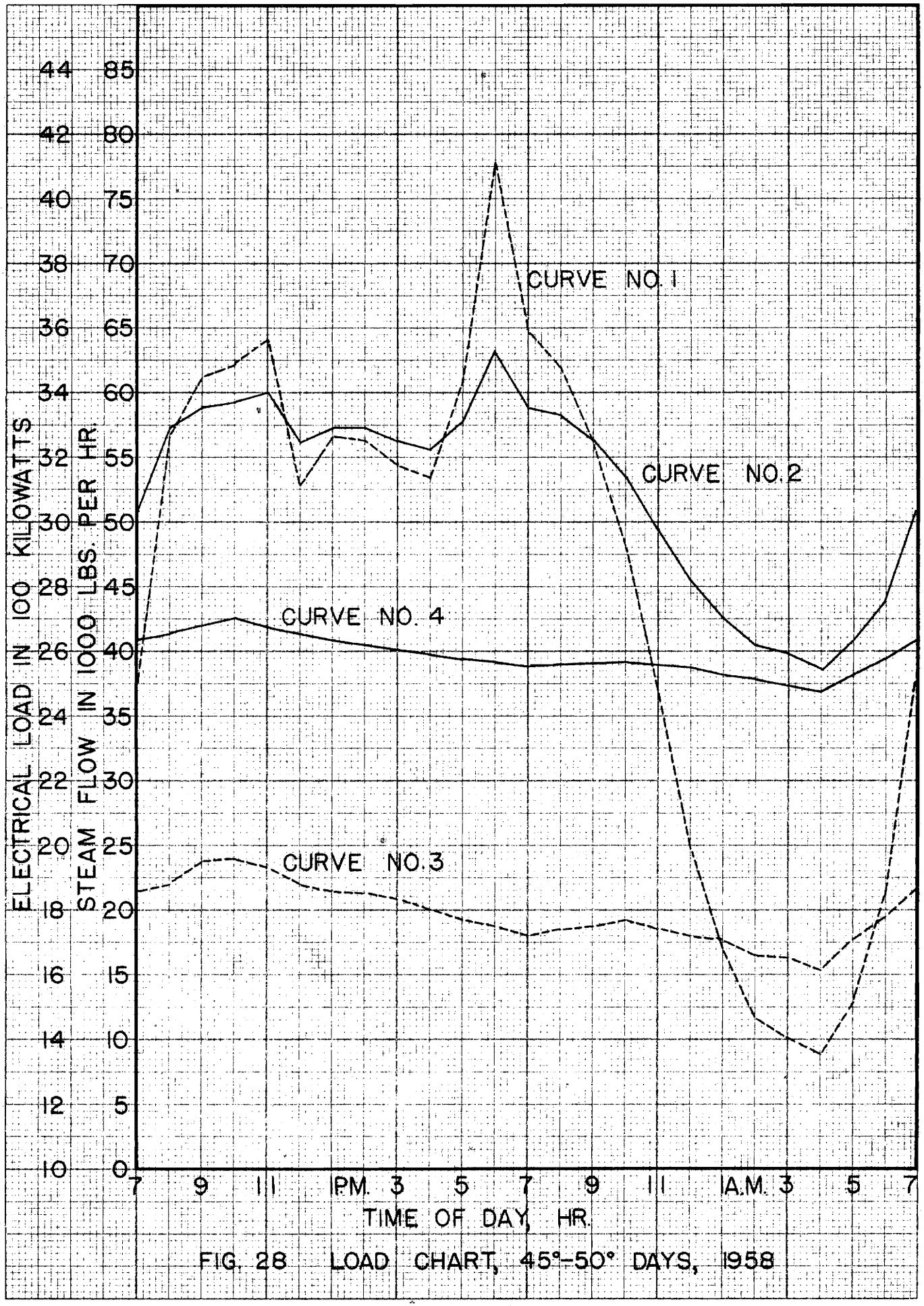


FIG. 28 LOAD CHART, 45°-50° DAYS, 1958

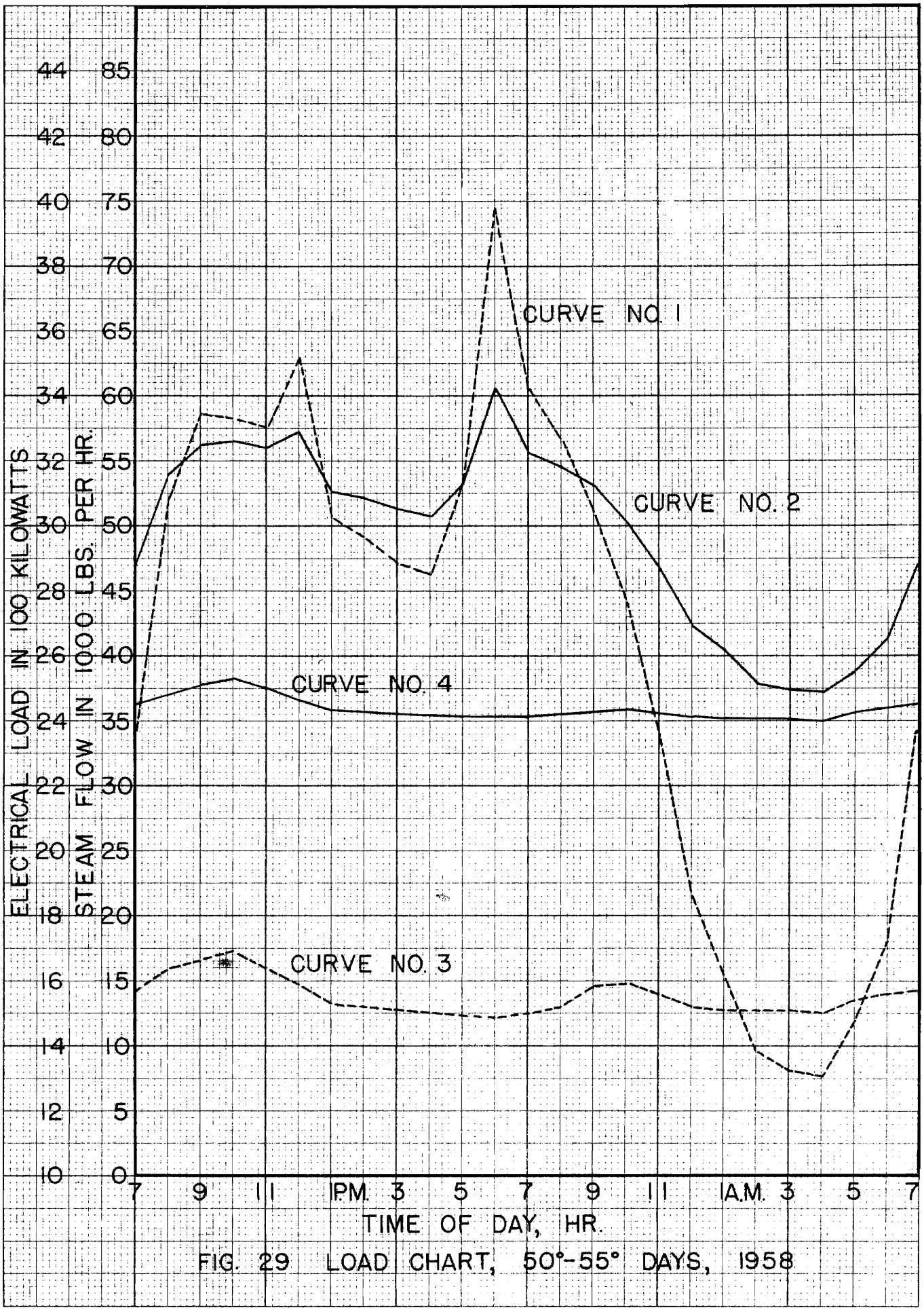


FIG. 29 LOAD CHART, 50°-55° DAYS, 1958

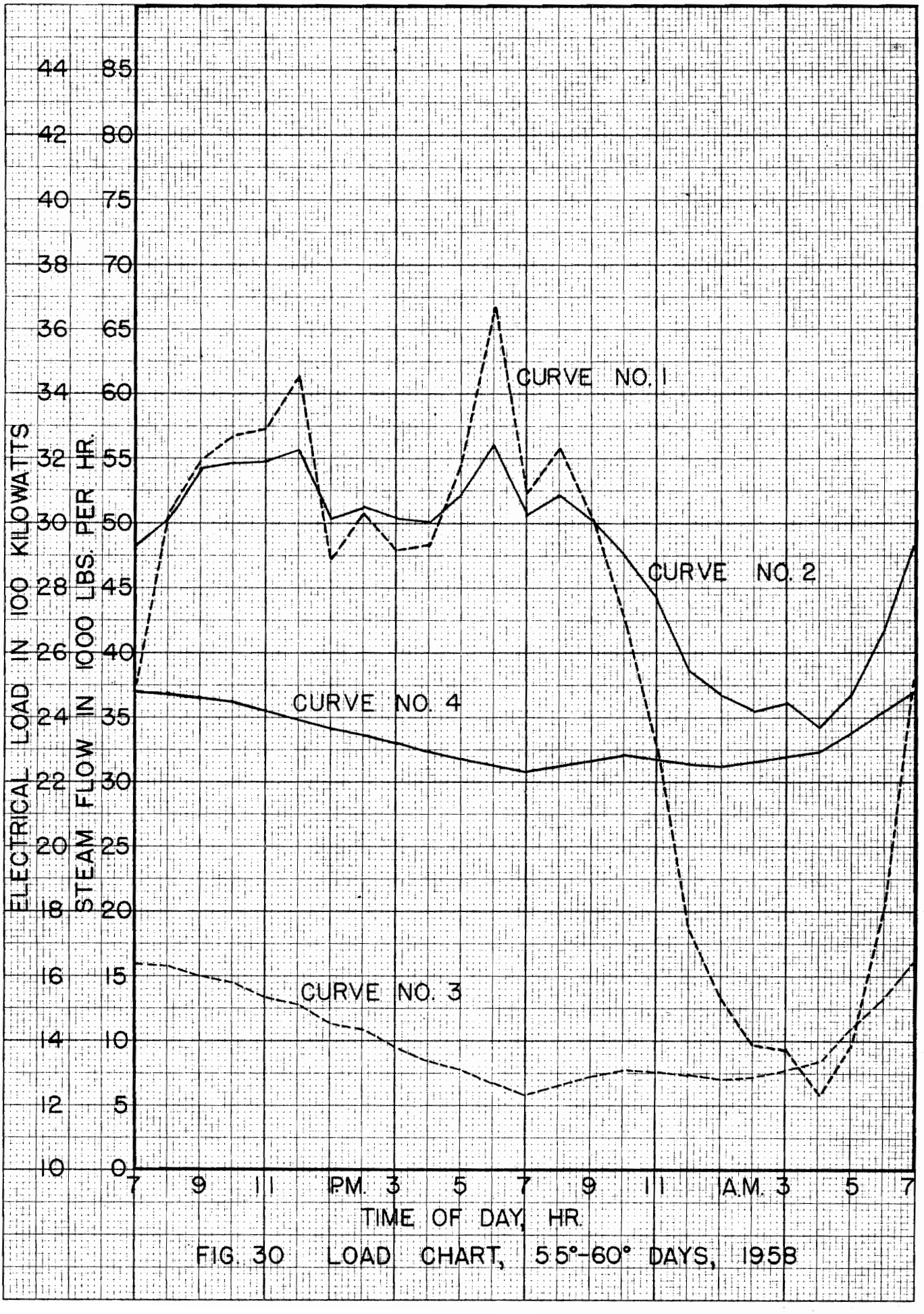


FIG. 30 LOAD CHART, 55°-60° DAYS, 1958

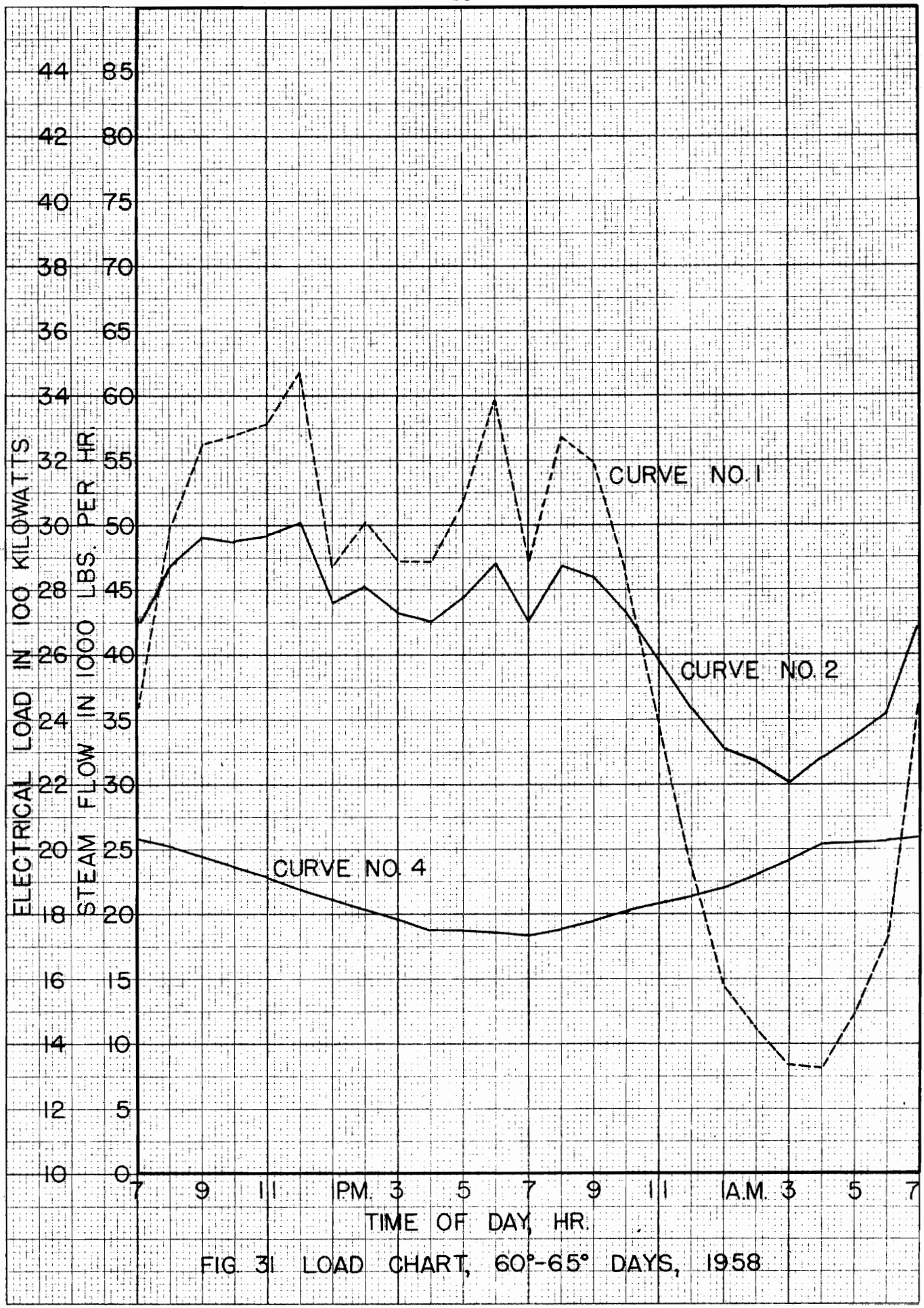


FIG. 31 LOAD CHART, 60°-65° DAYS, 1958

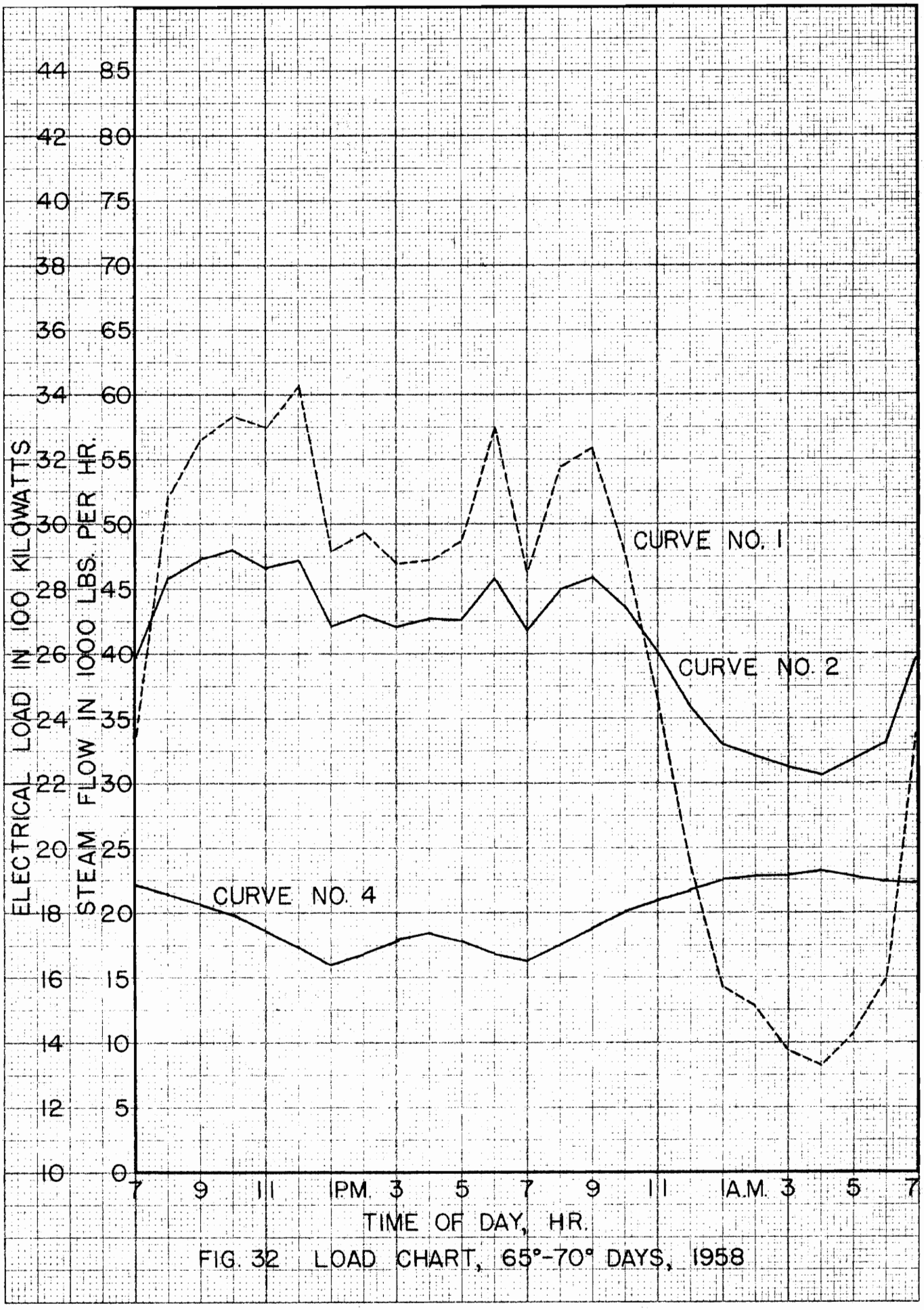


FIG. 32 LOAD CHART, 65°-70° DAYS, 1958

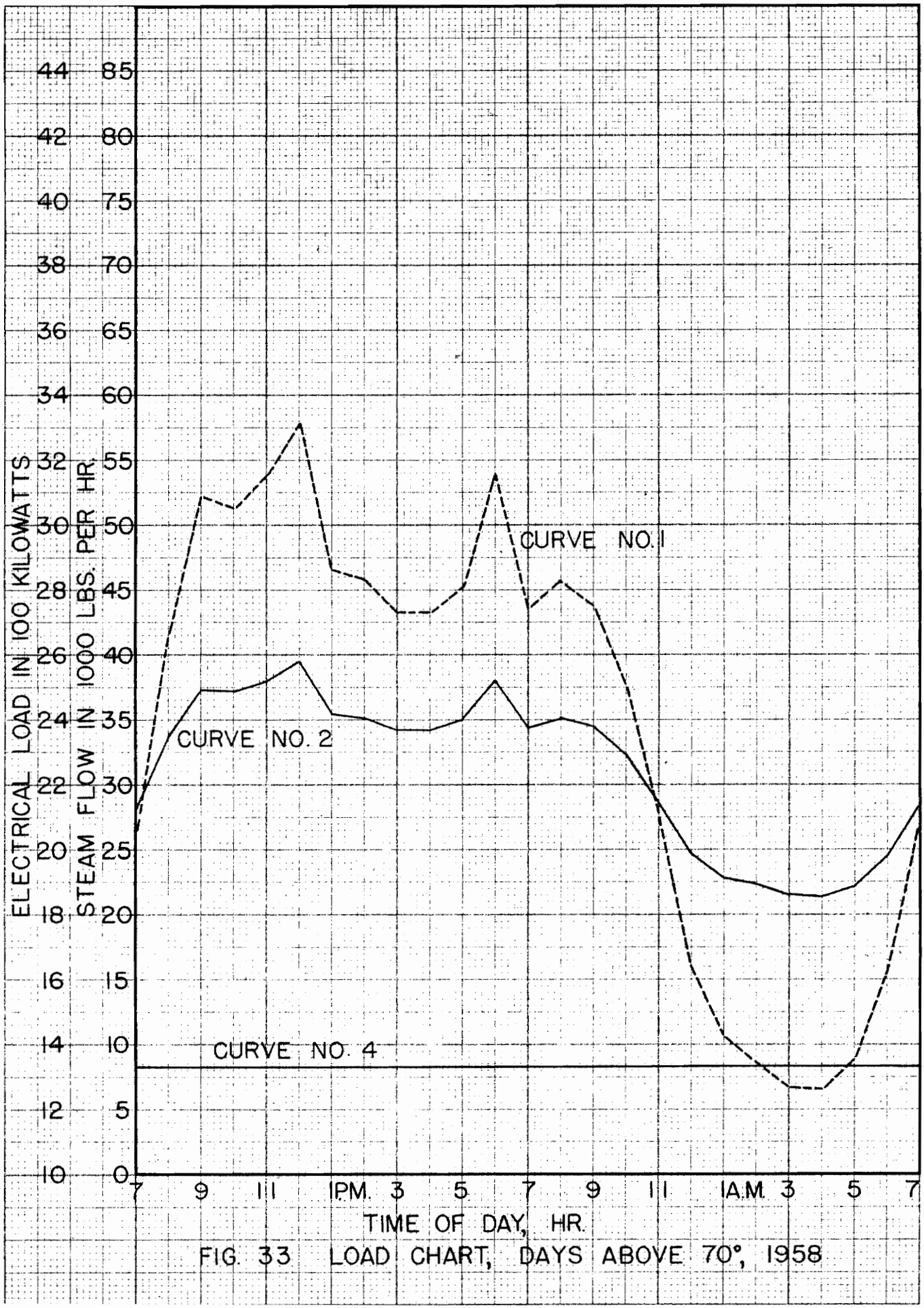


FIG. 33 LOAD CHART, DAYS ABOVE 70°, 1958

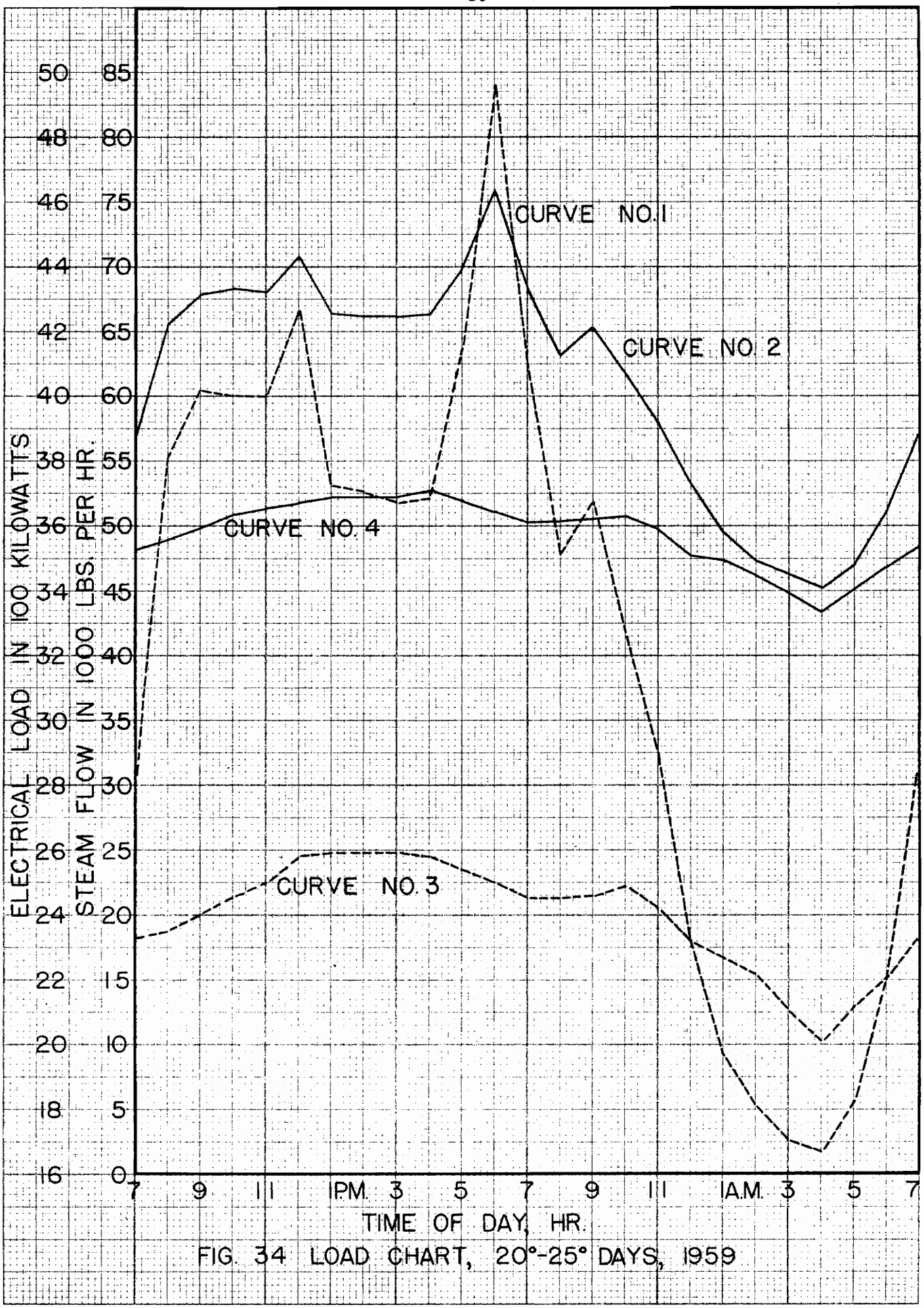


FIG. 34 LOAD CHART, 20°-25° DAYS, 1959

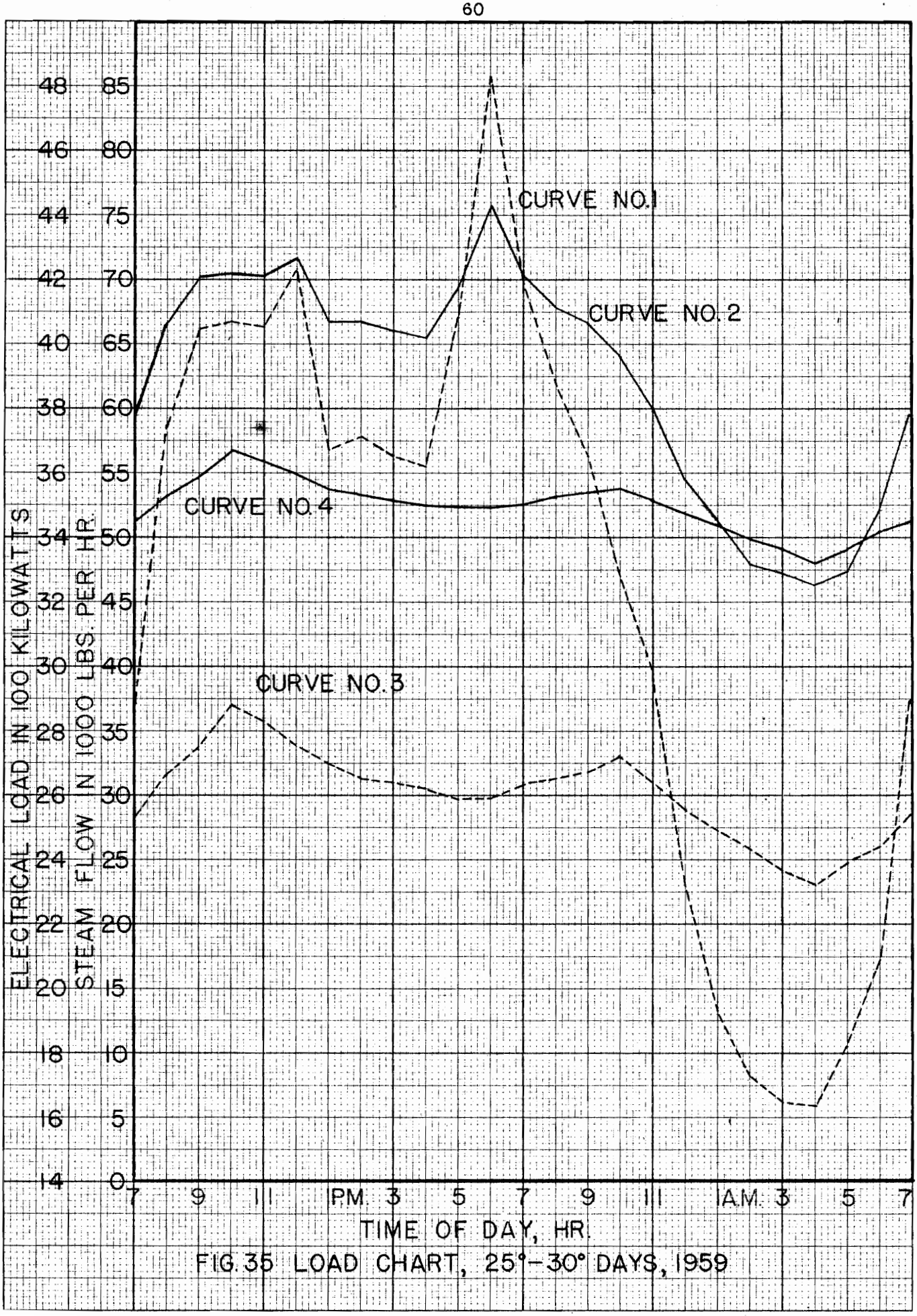


FIG. 35 LOAD CHART, 25°–30° DAYS, 1959

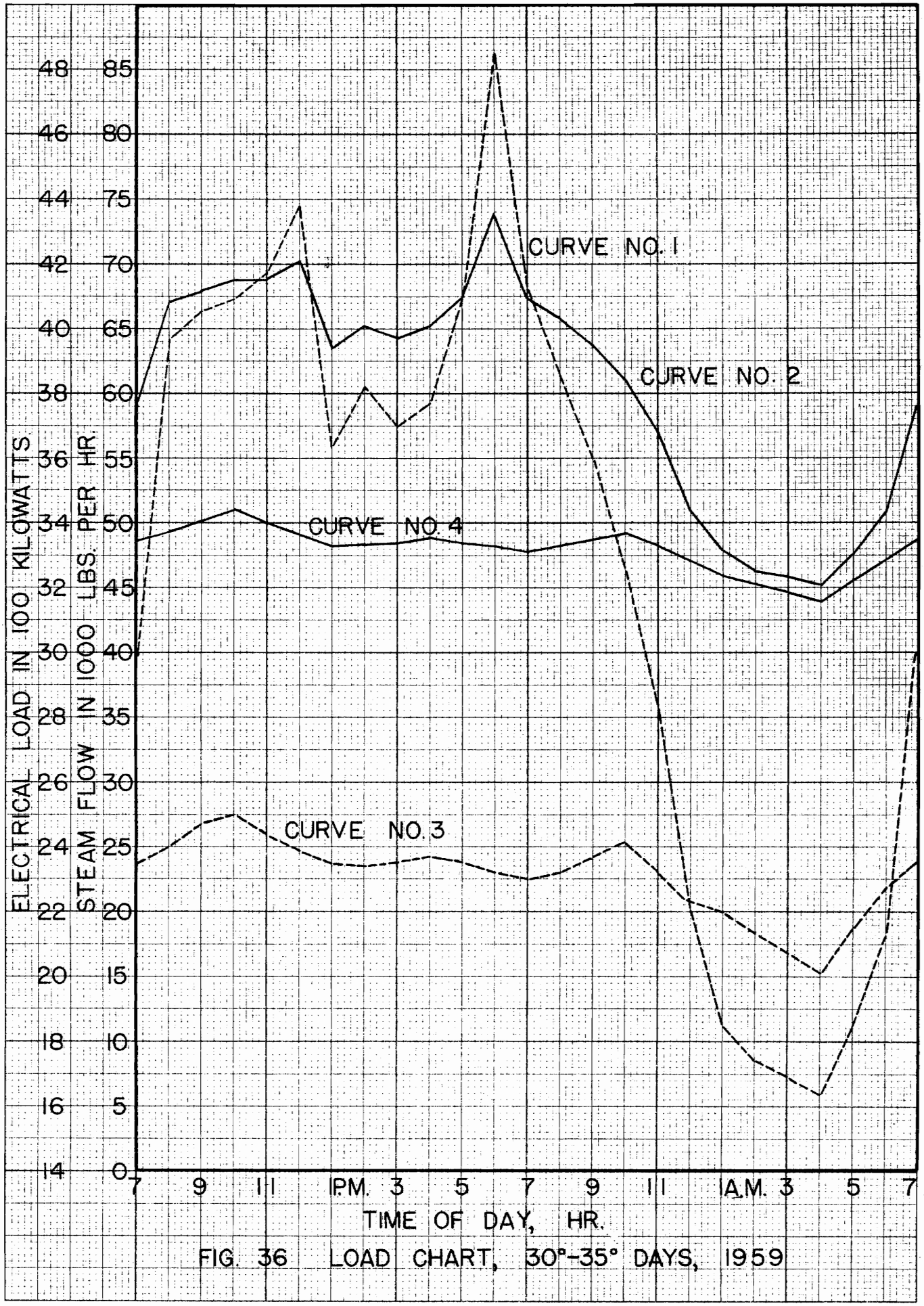


FIG. 36 LOAD CHART, 30°-35° DAYS, 1959

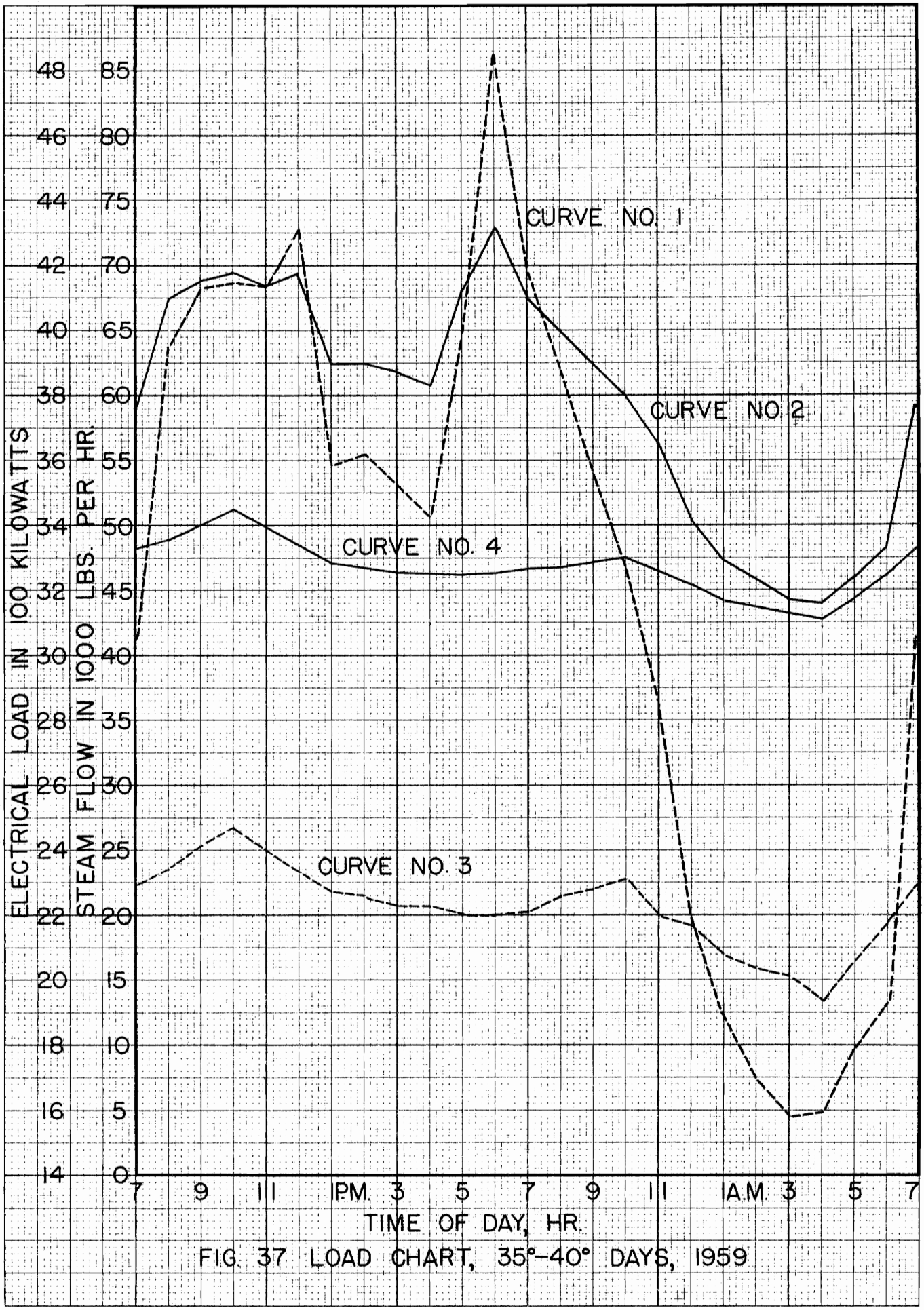


FIG. 37 LOAD CHART, 35°-40° DAYS, 1959

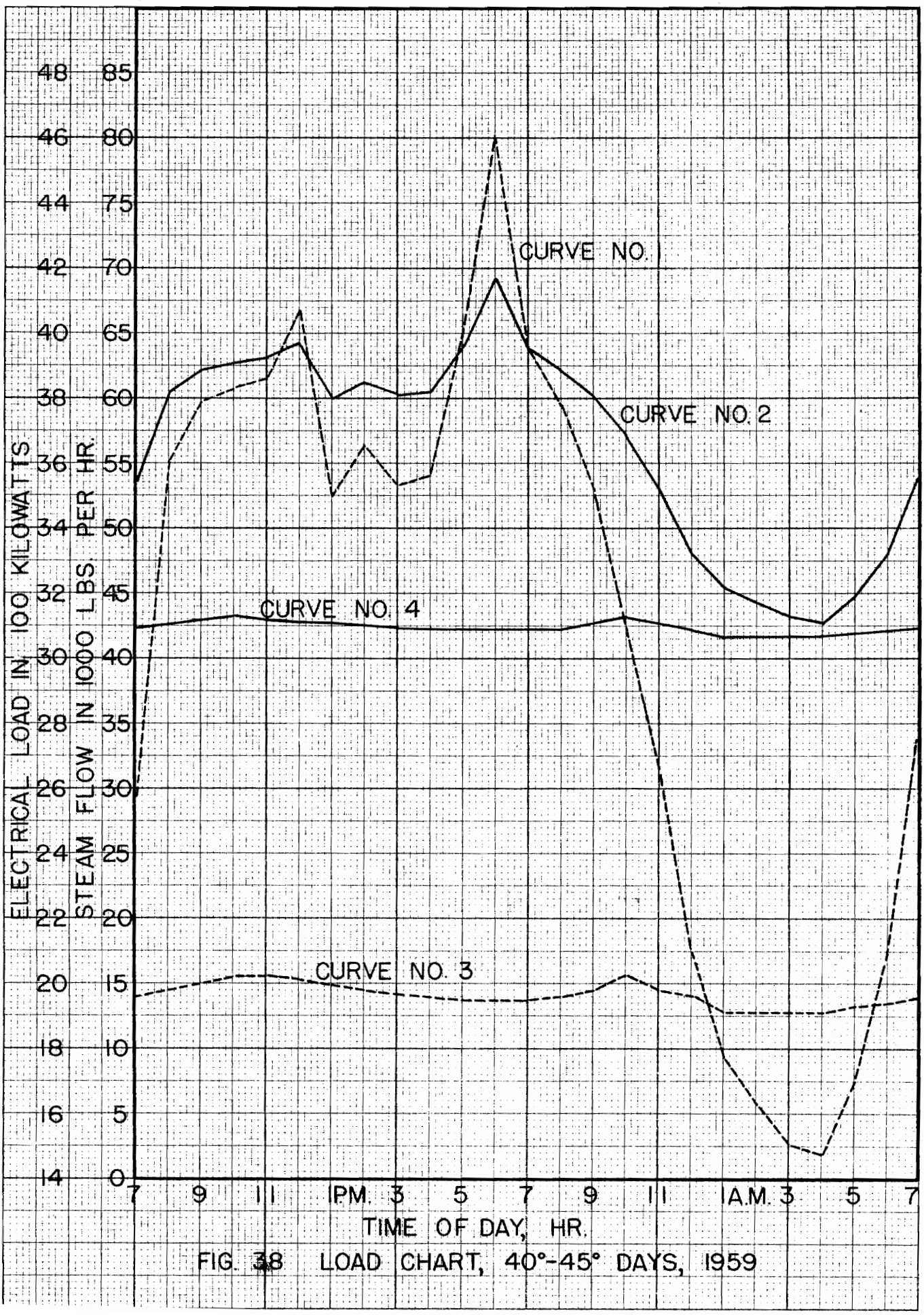


FIG. 38 LOAD CHART, 40°-45° DAYS, 1959

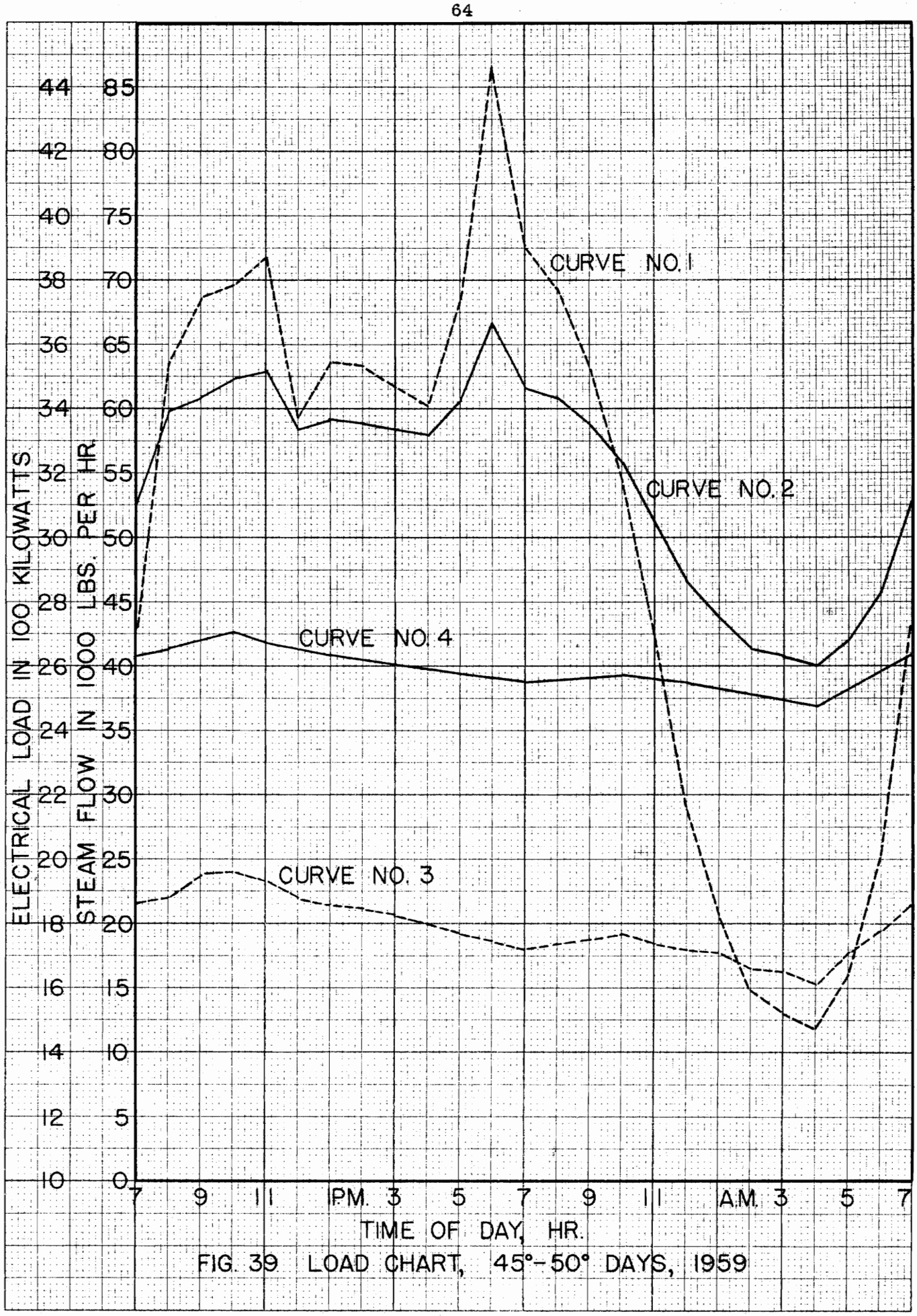


FIG. 39 LOAD CHART, 45°-50° DAYS, 1959

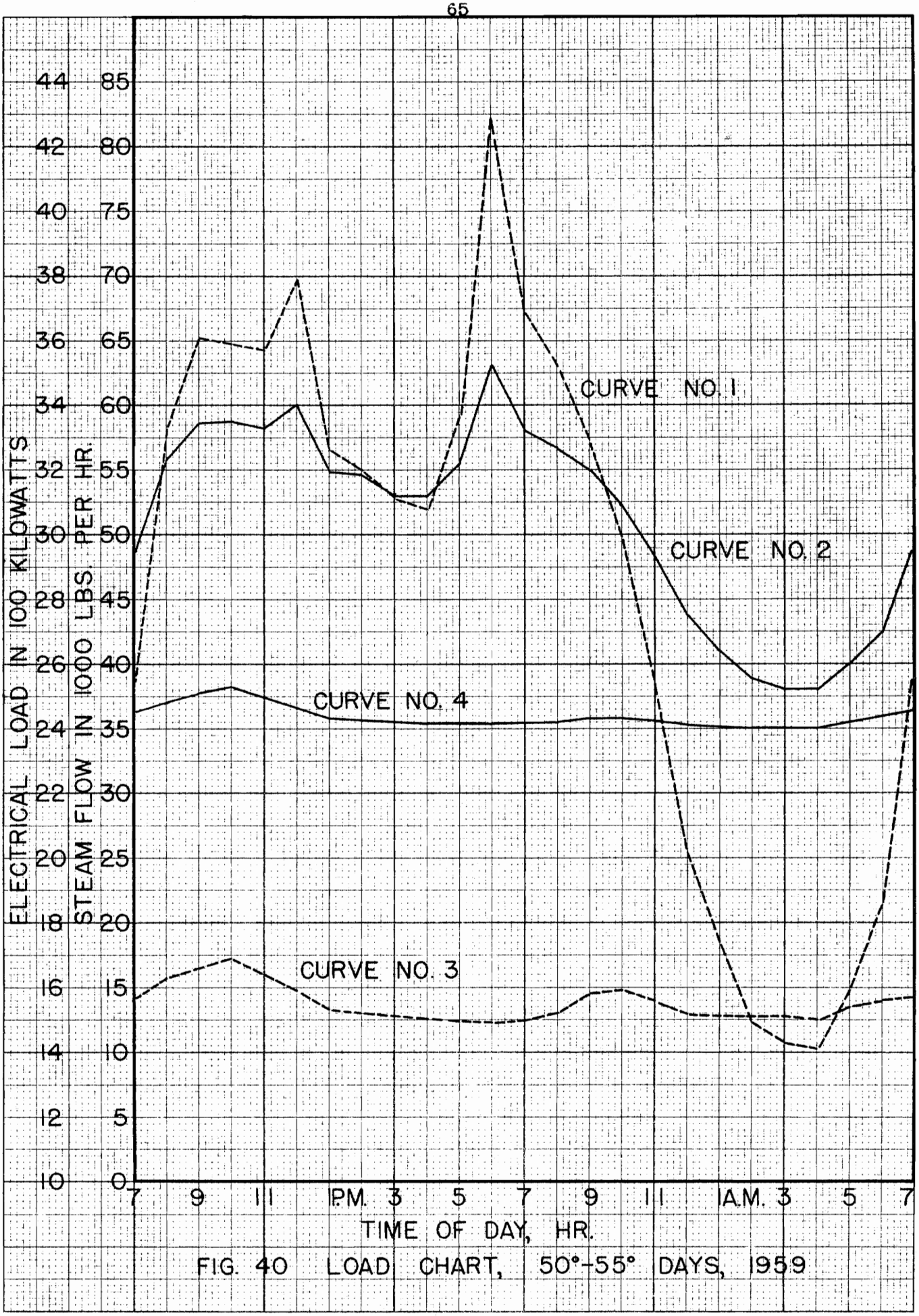


FIG. 40 LOAD CHART, 50°-55° DAYS, 1959

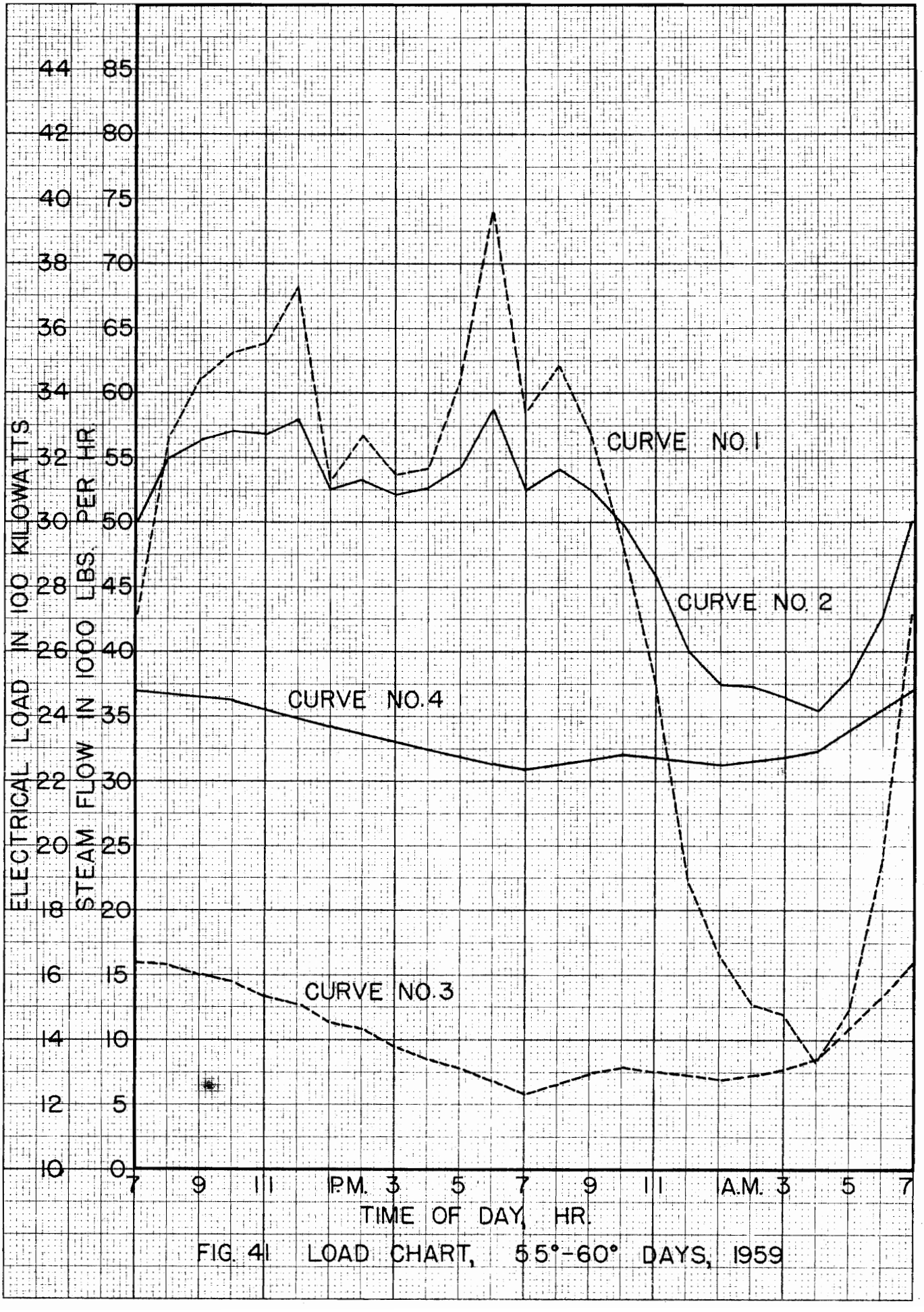


FIG. 41 LOAD CHART, 55°-60° DAYS, 1959

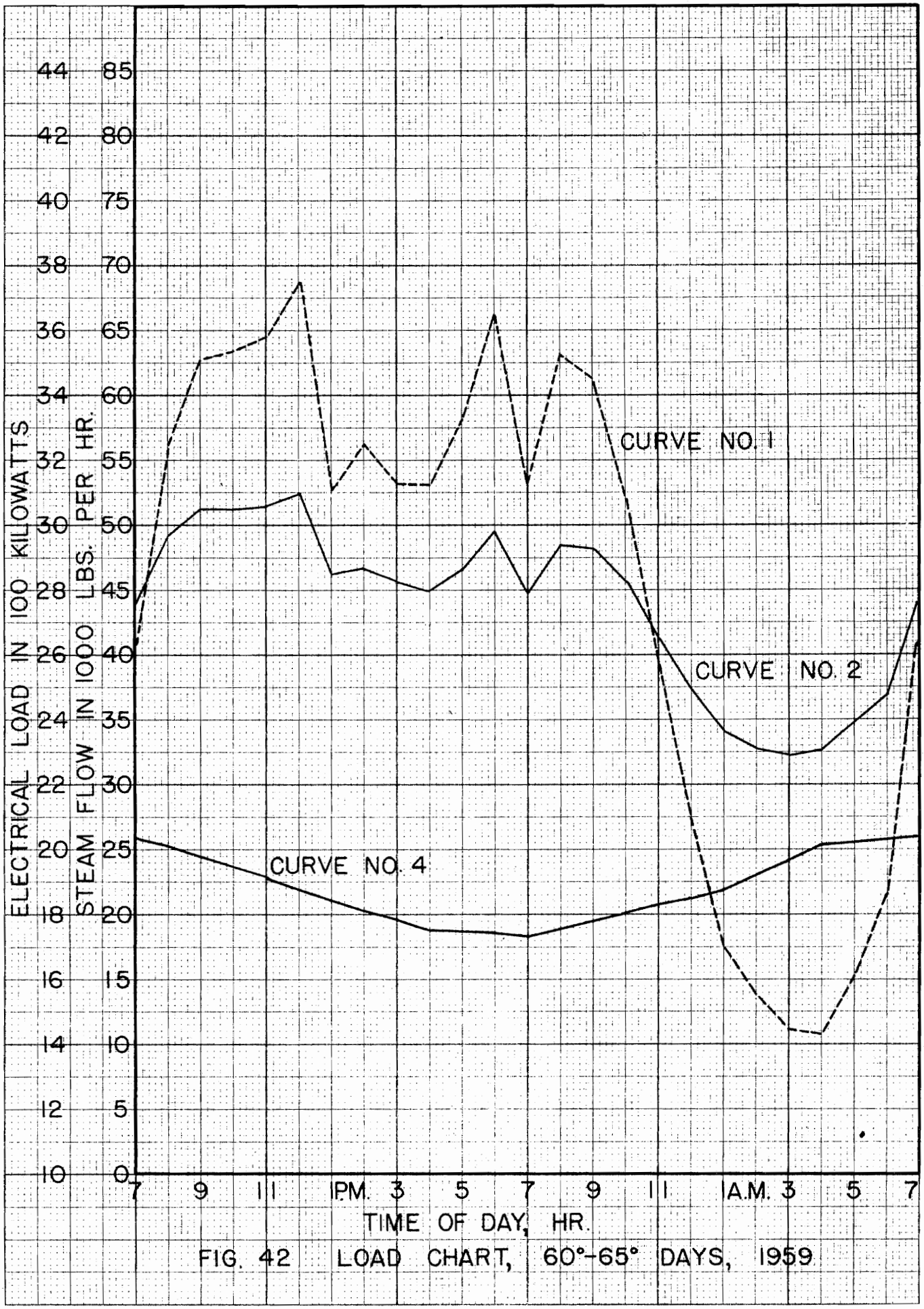


FIG. 42 LOAD CHART, 60°-65° DAYS, 1959

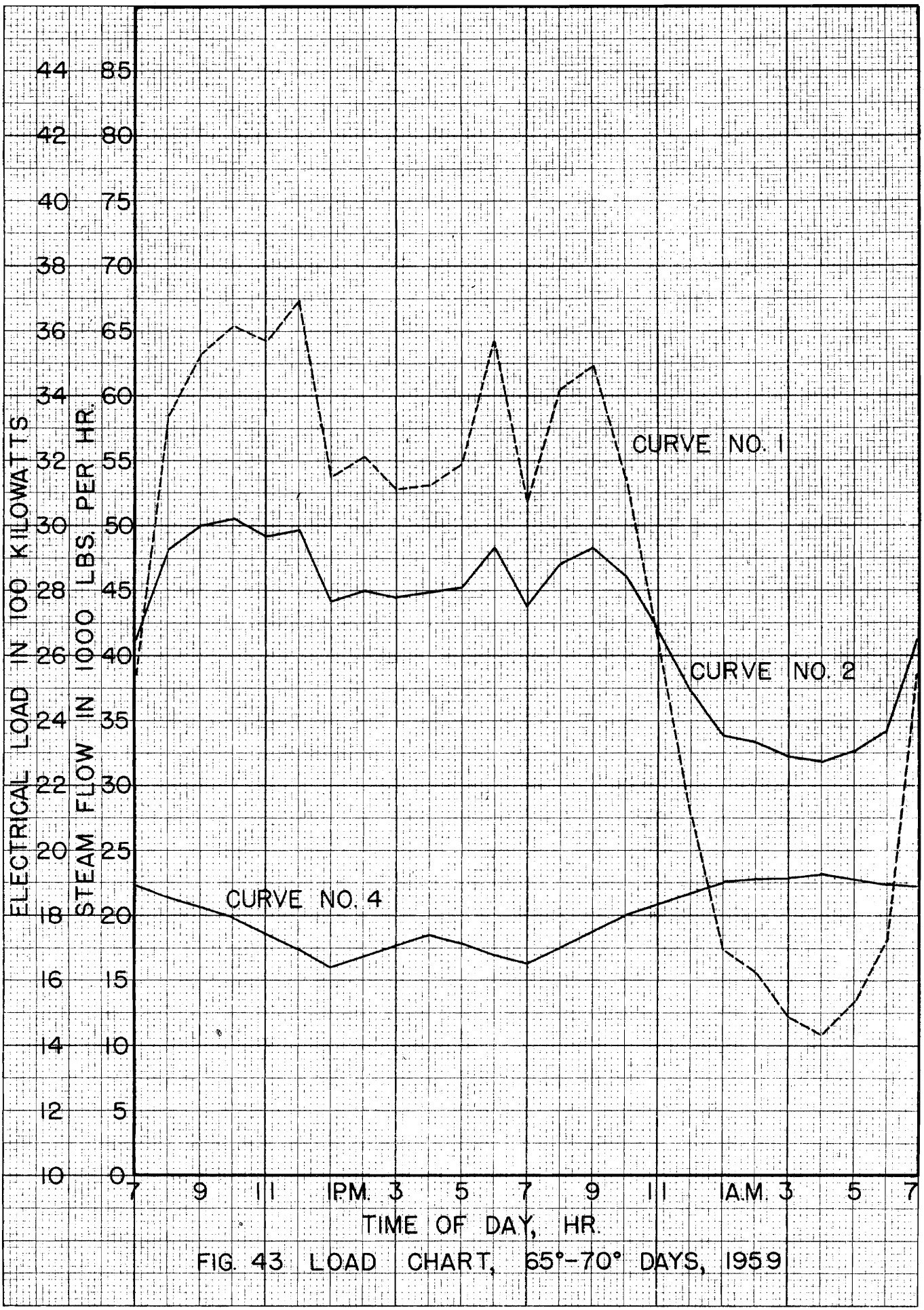


FIG. 43 LOAD CHART, 65°-70° DAYS, 1959

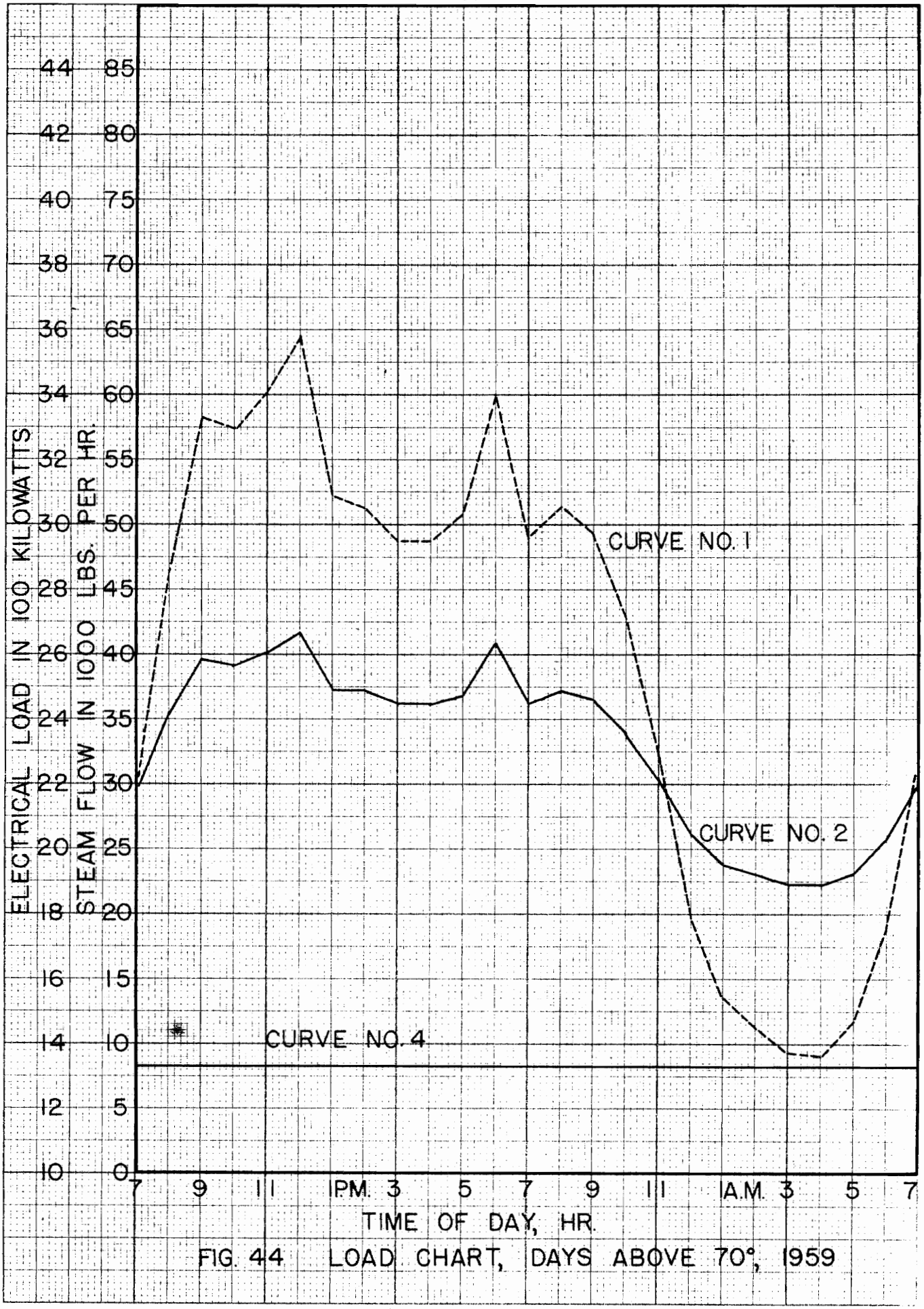


FIG. 44 LOAD CHART, DAYS ABOVE 70°, 1959

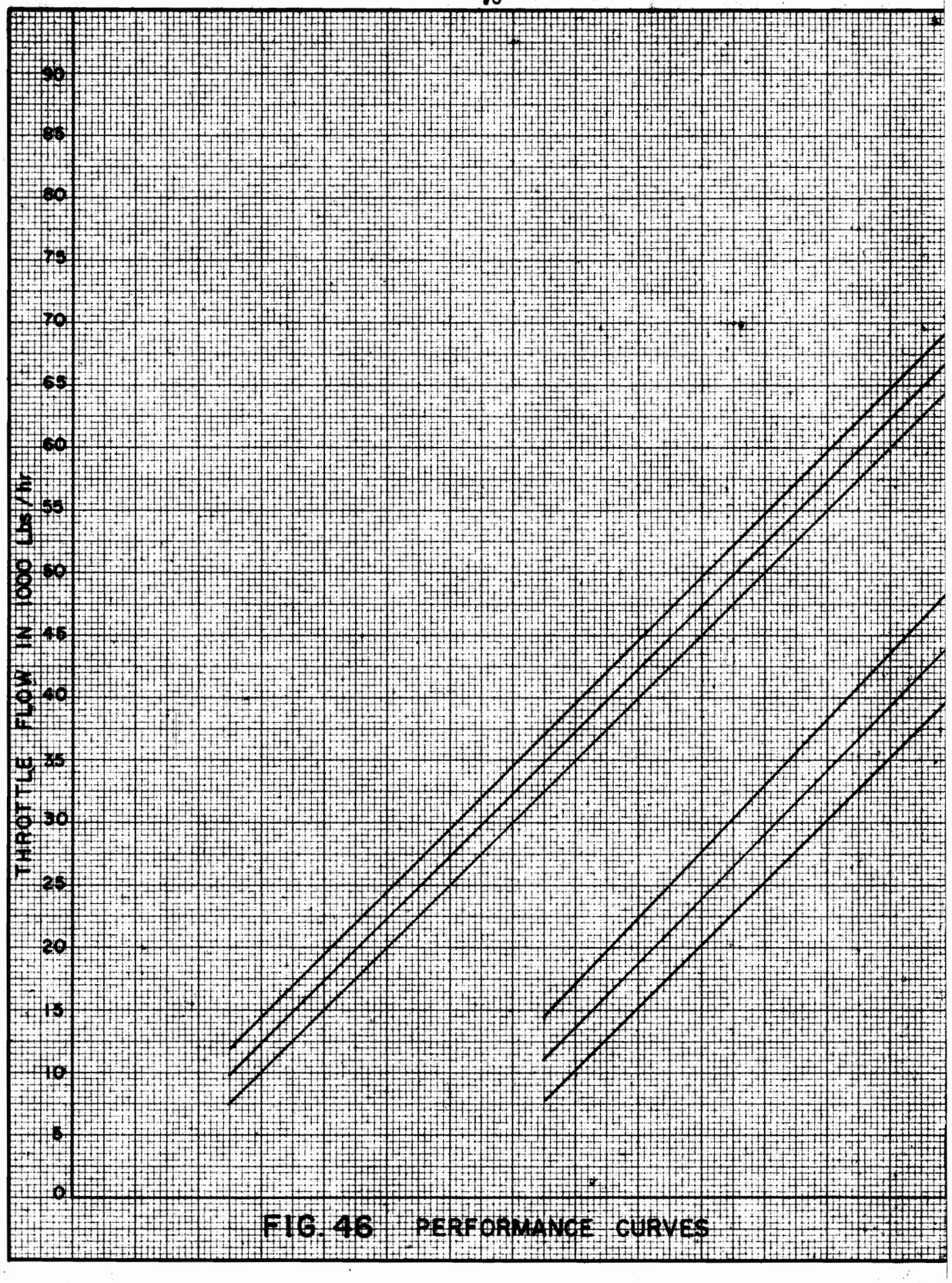
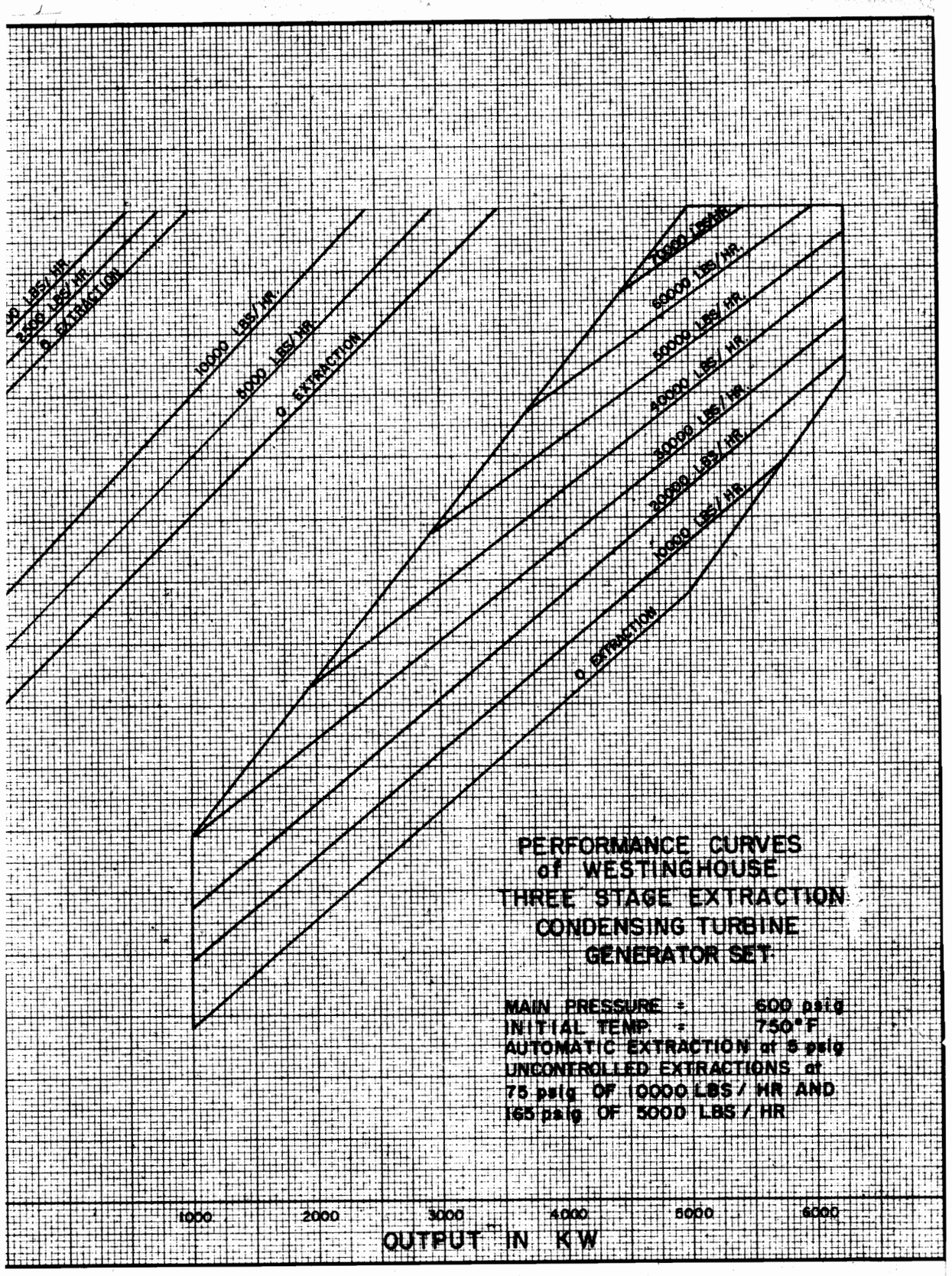


FIG. 46 PERFORMANCE CURVES



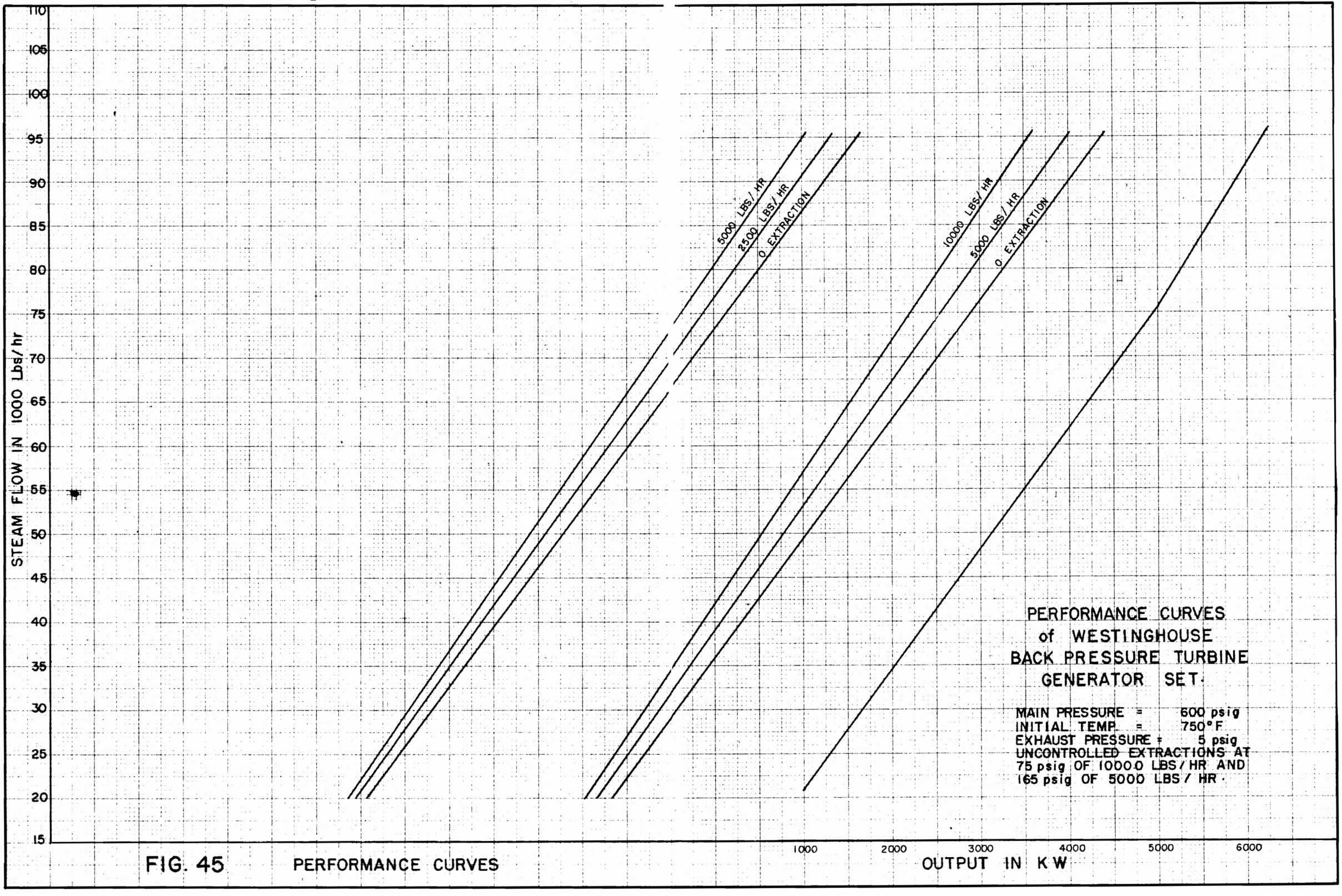


FIG. 45 PERFORMANCE CURVES

VIII

DISCUSSION OF RESULTS

The results of this investigation indicate that the installation of a 5000 Kw three stage extraction condensing turbo-generator in the Virginia Polytechnic Institute Heating and Power Plant would result in a saving of $137,400.00 in 1956, $147,600.00 in 1957, $158,000.00 in 1958, and $171,300.00 in 1959 over the cost to the college of purchasing the electric power from the Appalachian Electric Power Company necessary to carry the total load while meeting the heating and process steam demand. The installation of a 5000 Kw three stage extraction condensing generator would result in a saving of $64,290.00 in 1956, $73,180.00 in 1957, $79,890.00 in 1958, and $93,280.00 in 1959 over the cost to the college of using a proposed 5000 Kw two stage extraction back-pressure turbo-generator.

These results are based on predictions of the electric load and steam demand placed on the plant during the years 1956, 1957, 1958, 1959. These years were chosen because it was estimated that the proposed unit could not be installed before 1956. These predictions were used to determine the daily load curves for the various average outdoor temperature day groups of the years studied.

A study of these curves showed the following information.

1. The most important curve was that which represented the total electric load. This curve was used to determine the cost of purchasing the electric power and also to determine the steam demand when using the extraction condensing turbo-generator. During the early morning hours

the total electric load was less than the electric load that would be generated if the back-pressure turbo-generator was in use. When this situation occurred, the expected electrical output of the back-pressure unit was decreased because of the lack of demand for electrical energy.

2. The very low drop in the total electric load curve created another uneconomical situation. The amount of steam that could be extracted from the extraction condensing unit would not be large enough to meet the 5 psig steam demand during the early morning hours. To cool the last stages of the turbine a minimum flow to the exhaust must be maintained, the flow remaining after the minimum flow to the exhaust has been subtracted from the throttle flow is not large enough to meet the psig steam demand. This situation could be remedied by lowering the steam demand during this period, or by-passing enough steam to meet the demand through a reducing valve.

3. During the heating season both the electric load and the steam loads peak during the same time of day. This is an economical situation and should be maintained. During the $60^{\circ}F$ - $65^{\circ}F$ and $65^{\circ}F$ - $70^{\circ}F$ average outdoor temperature day groups the steam load peaks during the early morning hours, however, at days of this temperature the steam load is not large enough to have any uneconomical effects on the plant operation. The steam load was nearly constant during the off heating season and was considered to be a straight line.

4. The steam load does not peak as much as does the electric load. This is because heating steam is used almost as much at night as in the day. By installing individual building controls a considerable

amount of steam might be saved during the night hours.

The saving created by the installation of an extraction condensing unit increased more rapidly than the saving created by a back-pressure unit. This situation is caused by the more rapid increase of the electric load over the increase of the steam load.

The proposed back-pressure unit would not be operated on days when the average outdoor temperature is above 60°F. This is because the steam demand on these days is not enough to generate the minimum load of 1000 Kw. It is during this time that the extraction condensing unit could be used to the best advantage.

Some assumptions were made in this investigation and must be kept in mind when interpreting the information presented in this thesis. Most of these assumptions have been mentioned previously, but it is felt that they should be repeated since the results of the investigation depend directly upon them. These assumptions were as follows:

1. Business and economic conditions remain constant, that there will be neither inflation nor depression. These conditions affect both the price of fuel and the price of electric power.

2. The total electric load for the college and the community of Blacksburg will increase at a rate of 8 percent per year.

3. The college 5 psig heating steam will increase proportionally to the increase in building radiation. The college building program will continue at the proposed rate and that there will be no unexpected changes in enrollment.

4. The 75 psig heating and process steam demand will not increase.

5. The 165 psig process steam demand will remain at a constant 4000 pounds per hour.

6. The cost of steam to continue at $0.20 per 1000 pounds. This cost should not change much because the increase in efficiency of a new high performance steam generating unit would discount the additional heat added to each pound of steam.

7. The distribution of the average outdoor temperature days will remain the same as for 1952.

This investigation was based on the cost of fuel and the cost of electric power. The other operating costs and overhead costs were not considered to be in the scope of this thesis. A complete study of the purchase cost, operational cost, maintainance cost, and depreciation cost would be undertaken to determine the actual return on the investment.

IX

RECOMMENDATIONS

1. An investigation should be made to find a method of increasing the electric load during the early morning hours on the Heating and Power Plant.

2. An investigation should be made concerning the physical problems of a proposed installation of a 5000 Kw three stage extraction condensing turbo-generator in the present Heating and Power Plant.

3. An economic investigation should be made to determine the optimum operating conditions and cycle of a proposed 5000 Kw three stage extraction condensing turbo-generator for the Heating and Power Plant.

4. An investigation should be made to establish a complete system of filing and recording the operating data of the Heating and Power Plant.

5. An investigation should be made of the heat lost due to the lack of controls on the buildings. This study would cover the economic standpoint as well as better conditions for the students.

6. An investigation should be made to determine the type of steam generator to be used with a proposed 5000 Kw turbo-generator. The location and arrangement of auxiliaries are to be given an important part in the study.

7. An investigation should be made to determine the effect of various weather conditions, such as temperature of preceding day, humidity, cloudiness, wind, and average outdoor temperature, on the electric and steam loads on the Heating and Power Plant.

X

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XI

VITA

Charles Cliffton Wagoner was born in Poughkeepsie, New York on December 12, 1927. Charles attended Hughsonville Grammar School, Arlington Junior High School, and Arlington High School, all in the town of Poughkeepsie. He was graduated from Arlington High School in June 1945

He then entered Virginia Polytechnic Institute for a short while before entering the armed forces. Charles served in the 505th Parachute Infantry Regiment. After receiving his discharge he reentered college as a student of Mechanical Engineering. After a year at Cornell University, he returned to receive his Bachelor of Science Degree in Mechanical Engineering in June, 1952.

Charles Wagoner has been admitted to the Law School of George Washington University in the fall of 1953.

Charles C. Wagoner

XII

APPENDICES

TABLE NO. I

TOTAL ELECTRIC LOAD FOR 1952 IN KILOWATTS

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	1651	1684	1748	1780	1605	1586	1489	1583	1538	1482	1298
8:00 A.M.	2220	2184	2313	2301	2102	2068	1940	1904	1885	1943	1669
9:00 A.M.	2343	2362	2367	2409	2212	2182	2106	2009	2046	2056	1944
10:00 A.M.	2333	2374	2388	2419	2231	2209	2098	2056	2064	2109	1925
11:00 A.M.	2331	2366	2432	2411	2252	2259	2082	2075	2089	2080	1988
12:00 A.M.	2489	2468	2556	2520	2378	1970	2213	2174	2186	2155	2088
1:00 P.M.	2174	2146	2121	2092	2042	2068	1905	1823	1810	1839	1804
2:00 P.M.	2161	2163	2229	2111	2131	2062	1868	1908	1894	1871	1784
3:00 P.M.	2140	2133	2160	2054	2061	2021	1816	1838	1824	1815	1721
4:00 P.M.	2149	2111	2200	1998	2079	1988	1797	1850	1822	1821	1723
5:00 P.M.	2420	2382	2388	2335	2331	2177	1968	2008	1939	1861	1773
6:00 P.M.	2891	2819	2830	2829	2688	2605	2501	2308	2131	2080	1983
7:00 P.M.	2393	2444	2412	2498	2316	2278	2158	1948	1821	1795	1729
8:00 P.M.	2050	2261	2249	2266	2206	2204	2058	2003	2061	1994	1783
9:00 P.M.	2142	2131	2102	2080	2061	2058	1922	1905	2014	2039	1736
10:00 P.M.	1910	1914	1906	1912	1806	1853	1748	1708	1802	1835	1581
11:00 P.M.	1696	1699	1657	1662	1555	1573	1492	1459	1505	1548	1334
12:00 P.M.	1360	1353	1288	1290	1230	1262	1182	1105	1226	1233	1044
1:00 A.M.	1151	1129	1083	1106	1035	1068	1020	969	996	990	903
2:00 A.M.	1060	1011	1017	992	955	931	873	878	908	948	847
3:00 A.M.	997	964	990	924	881	888	834	862	842	868	802
4:00 A.M.	975	956	957	931	863	860	822	776	835	833	795
5:00 A.M.	1065	1062	1076	982	991	958	930	871	942	896	856
6:00 A.M.	1277	1222	1237	1124	1218	1169	1084	1143	1086	1005	1024

TABLE NO. II

EXPECTED TOTAL ELECTRIC LOAD FOR 1956 IN KILOWATTS

Time of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	2247	2289	2378	2420	2181	2159	2025	2152	2091	2015	1766
8:00 A.M.	3040	2971	3148	3130	2860	2810	2639	2589	2562	2641	2369
9:00 A.M.	3169	3210	3218	3273	3018	2969	2863	2731	2781	2794	2643
10:00 A.M.	3173	3229	3247	3259	3035	3003	2852	2797	2809	2869	2619
11:00 A.M.	3170	3119	3309	3280	3062	3070	2851	2821	2840	2889	2702
12:00 A.M.	3384	3354	3474	3427	3232	2879	3010	2958	2971	2930	2839
1:00 P.M.	2958	2919	2886	2847	2778	2811	2590	2479	2461	2500	2452
2:00 P.M.	2940	2942	3060	2871	2900	2803	2540	2595	2578	2544	2424
3:00 P.M.	2910	2902	2938	2792	2805	2750	2470	2500	2480	2469	2340
4:00 P.M.	2921	2871	2991	2718	2825	2702	2443	2515	2478	2477	2342
5:00 P.M.	3291	3241	3248	3175	3171	2980	2677	2730	2638	2531	2411
6:00 P.M.	3935	3832	3850	3843	3654	3542	3401	3139	2900	2829	2698
7:00 P.M.	3258	3324	3280	3398	3149	3098	2934	2850	2478	2441	2350
8:00 P.M.	2789	3075	3057	3080	3000	3000	2799	2766	2803	2711	2423
9:00 P.M.	2779	2899	2859	2829	2790	2798	2614	2591	2739	2771	2380
10:00 P.M.	2611	2616	2591	2600	2457	2520	2378	2382	2451	2496	2180
11:00 P.M.	2308	2310	2253	2259	2113	2139	2029	1964	2048	2091	1814
12:00 P.M.	1850	1840	1751	1754	1672	1715	1607	1508	1666	1676	1420
1:00 A.M.	1565	1535	1473	1504	1407	1462	1387	1318	1355	1348	1228
2:00 A.M.	1442	1374	1384	1349	1299	1266	1186	1194	1235	1290	1152
3:00 A.M.	1356	1311	1346	1256	1198	1208	1134	1172	1145	1161	1090
4:00 A.M.	1326	1300	1301	1266	1174	1170	1118	1056	1136	1134	1081
5:00 A.M.	1449	1444	1464	1336	1348	1304	1286	1185	1281	1219	1164
6:00 A.M.	1736	1661	1682	1529	1656	1576	1474	1555	1476	1366	1392

TABLE NO. III

EXPECTED TOTAL ELECTRIC LOAD FOR 1957 IN KILOWATTS

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	2426	2472	2568	2615	2358	2330	2188	2325	2259	2177	1906
8:00 A.M.	3261	3210	3399	3381	3089	3037	2850	2797	2769	2852	2451
9:00 A.M.	3442	3468	3472	3539	3250	3208	3092	2950	3003	3018	2854
10:00 A.M.	3429	3489	3505	3552	3279	3244	3080	3020	3031	3095	2828
11:00 A.M.	3424	3475	3571	3542	3309	3318	3059	3049	3069	3054	2921
12:00 A.M.	3653	3623	3752	3700	3491	2892	3251	3193	3210	3164	3068
1:00 P.M.	3193	3152	3116	3072	3000	3037	2798	2679	2658	2700	2650
2:00 P.M.	3176	3180	3270	3102	3130	3030	2743	2803	2781	2749	2620
3:00 P.M.	3143	3135	3171	3019	3029	2970	2668	2700	2679	2667	2529
4:00 P.M.	3158	3101	3230	2935	3051	2920	2630	2718	2675	2676	2531
5:00 P.M.	3554	3500	3507	3430	3424	3198	2891	2949	2848	2734	2604
6:00 P.M.	4249	4140	4155	4153	3949	3825	3673	3389	3130	3054	2911
7:00 P.M.	3518	3590	3542	3670	3400	3344	3170	2861	2673	2638	2540
8:00 P.M.	3011	3321	3302	3328	3240	3239	3022	2988	3029	2929	2619
9:00 P.M.	3148	3131	3088	3056	3012	3021	2822	2799	2958	2993	2550
10:00 P.M.	2806	2811	2800	2808	2652	2721	2569	2509	2648	2697	2322
11:00 P.M.	2491	2495	2432	2441	2283	2310	2191	2142	2210	2273	1959
12:00 P.M.	1997	1987	1892	1895	1860	1854	1736	1623	1800	1812	1534
1:00 A.M.	1690	1658	1590	1625	1520	1568	1498	1424	1463	1454	1326
2:00 A.M.	1557	1485	1494	1456	1402	1367	1282	1290	1334	1393	1245
3:00 A.M.	1465	1416	1454	1357	1294	1304	1225	1266	1236	1275	1178
4:00 A.M.	1432	1405	1405	1367	1267	1263	1208	1140	1226	1224	1168
5:00 A.M.	1564	1560	1580	1442	1455	1407	1366	1280	1384	1316	1258
6:00 A.M.	1876	1795	1816	1650	1789	1716	1592	1679	1594	1476	1504

TABLE IV

EXPECTED TOTAL ELECTRIC LOAD FOR 1958 IN KILOWATTS

Time of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	2620	2671	2772	2823	2531	2502	2362	2511	2441	2351	2060
8:00 A.M.	3523	3465	3672	3651	3306	3261	3080	3021	2991	3081	2649
9:00 A.M.	3719	3745	3756	3821	3490	3443	3342	3189	3248	3260	3083
10:00 A.M.	3704	3769	3790	3838	3521	3483	3330	3263	3279	3335	3054
11:00 A.M.	3700	3752	3861	3827	3552	3562	3305	3292	3313	3300	3154
12:00 A.M.	3949	3914	4056	4000	3750	3109	3515	3451	3470	3420	3311
1:00 P.M.	3451	3403	3379	3320	3221	3261	3025	2893	2872	2918	2861
2:00 P.M.	3430	3432	3548	3350	3363	3253	2966	3029	3007	2970	2830
3:00 P.M.	3397	3387	3430	3260	3251	3189	2882	2918	2893	2880	2731
4:00 P.M.	3410	3351	3492	3170	3279	3138	2852	2937	2891	2890	2734
5:00 P.M.	3840	3780	3791	3705	3679	3432	3124	3187	3078	2950	2811
6:00 P.M.	4589	4470	4490	4488	4239	4109	3972	3662	3383	3300	3148
7:00 P.M.	3799	3879	3829	3962	3652	3593	3424	3092	2891	2849	2742
8:00 P.M.	3253	3589	3569	3597	3480	3478	3268	3228	3271	3163	2830
9:00 P.M.	3401	3381	3336	3300	3235	3247	3051	3024	3198	3234	2753
10:00 P.M.	3030	3038	3025	3032	2850	2922	2775	2711	2861	2911	2510
11:00 P.M.	2691	2695	2620	2638	2452	2480	2369	2314	2390	2458	2116
12:00 P.M.	2159	2147	2043	2047	1940	1991	1877	1754	1946	1956	1656
1:00 A.M.	1826	1791	1729	1755	1633	1685	1620	1538	1581	1572	1434
2:00 A.M.	1682	1604	1615	1575	1506	1470	1386	1394	1442	1505	1344
3:00 A.M.	1582	1530	1571	1466	1390	1401	1324	1368	1336	1379	1273
4:00 A.M.	1547	1517	1519	1478	1362	1357	1305	1232	1325	1323	1262
5:00 A.M.	1690	1685	1708	1559	1564	1512	1476	1382	1495	1423	1359
6:00 A.M.	2026	1940	1964	1784	1923	1844	1720	1815	1724	1594	1624

TABLE NO. V

EXPECTED TOTAL ELECTRIC LOAD FOR 1959 IN KILOWATTS

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	2830	2886	2993	3050	2751	2720	2550	2712	2635	2540	2226
8:00 A.M.	3803	3743	3964	3943	3603	3543	3325	3261	3231	3329	2860
9:00 A.M.	4017	4045	4053	4127	3790	3741	3609	3442	3508	3522	3331
10:00 A.M.	4000	4070	4090	4142	3827	3785	3593	3523	3539	3612	3299
11:00 A.M.	3997-	4055	4169	4132	3860	3870	3569	3557	3580	3563	3408
12:00 A.M.	4261	4230	4378	4318	4073	3378	3792	3727	3747	3692	3578
1:00 P.M.	3726	3679	3638	3584	3500	3543	3263	3124	3101	3150	3090
2:00 P.M.	3702	3709	3819	3619	3654	3534	3200	3270	3247	3208	3056
3:00 P.M.	3669	3658	3700	3521	3532	3465	3111	3150	3126	3110	2950
4:00 P.M.	3681	3620	3770	3423	3560	3409	3080	3171	3121	3121	2953
5:00 P.M.	4148	4083	4090	4000	3998	3730	3372	3441	3322	3190	3038
6:00 P.M.	4955	4829	4850	4845	4606	4465	4287	3957	3652	3563	3399
7:00 P.M.	4103	4189	4131	4194	3960	3903	3698	3340	3121	3077	2961
8:00 P.M.	3513	3878	3852	3881	3780	3779	3528	3486	3532	3416	3055
9:00 P.M.	3672	3651	3602	3564	3518	3528	3293	3274	3452	3492	2975
10:00 P.M.	3272	3280	3265	3277	3098	3178	2994	2929	3089	3144	2710
11:00 P.M.	2907	2912	2840	2849	2665	2697	2557	2500	2580	2652	2285
12:00 P.M.	2330	2319	2208	2200	2109	2162	2026	1894	2101	2112	1789
1:00 A.M.	1972	1934	1855	1895	1774	1831	1748	1661	1706	1697	1547
2:00 A.M.	1816	1733	1743	1700	1636	1595	1496	1505	1556	1625	1451
3:00 A.M.	1708	1651	1697	1584	1509	1521	1430	1477	1442	1488	1375
4:00 A.M.	1671	1639	1640	1596	1478	1474	1409	1330	1430	1428	1362
5:00 A.M.	1825	1820	1894	1684	1698	1641	1595	1494	1614	1536	1466
6:00 A.M.	2189	2094	2120	1925	2090	2002	1857	1960	1862	1722	1755

TABLE NO. VI

EXPECTED LOADING OF PROPOSED BACK-PRESSURE UNIT FOR 1956 AND 1957 IN KILOWATTS

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M	2280	2440	2270	2260	1920	1850	1560	1600			
8:00 A.M.	2300	2570	2350	2320	1950	1855	1580	1580			
9:00 A.M.	2320	2670	2410	2340	1990	1900	1620	1550			
10:00 A.M.	2400	2770	2440	2410	2060	1950	1670	1540			
11:00 A.M.	2440	2750	2400	2340	1980	1870	1620	1500			
12:00 A.M.	2500	2700	2310	2290	1960	1860	1570	1450			
1:00 P.M.	2550	2640	2270	2200	1950	1850	1500	1410			
2:00 P.M.	2560	2620	2280	2170	1940	1820	1490	1380			
3:00 P.M.	2590	2600	2300	2150	1920	1780	1470	1320			
4:00 P.M.	2580	2580	2320	2150	1920	1740	1470	1300			
5:00 P.M.	2530	2580	2310	2150	1910	1730	1470	1280			
6:00 P.M.	2480	2580	2250	2150	1910	1700	1470	1210			
7:00 P.M.	2420	2580	2240	2150	1910	1690	1480	1190			
8:00 P.M.	2440	2610	2270	2200	1920	1700	1450	1210			
9:00 P.M.	2490	2620	2340	2270	1950	1710	1470	1250			
10:00 P.M.	2460	2660	2350	2250	1960	1730	1500	1290			
11:00 P.M.	2410	2620	2280	2180	1950	1700	1470	1270			
12:00 P.M.	2300	2530	2200	2100	1910	1680	1460	1240			
1:00 A.M.	2260	2480	2130	2030	1870	1650	1450	1210			
2:00 A.M.	2200	2400	2070	1980	1860	1610	1430	1250			
3:00 A.M.	2080	2350	2040	1970	1850	1590	1430	1280			
4:00 A.M.	1960	2280	2000	1950	1860	1560	1450	1300			
5:00 A.M.	2030	2350	2120	2060	1880	1650	1470	1400			
6:00 A.M.	2200	2410	2210	2180	1910	1730	1500	1520			

TABLE NO. VII

EXPECTED LOADING OF PROPOSED BACK-PRESSURE UNIT FOR 1958 AND 1959 IN KILOWATTS

Time of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	2330	2540	2350	2290	1960	1860	1570	1640			
8:00 A.M.	2350	2660	2400	2340	1980	1880	1630	1630			
9:00 A.M.	2400	2750	2470	2410	2000	1950	1660	1600			
10:00 A.M.	2450	2880	2500	2470	2020	1960	1690	1580			
11:00 A.M.	2500	2830	2440	2400	2020	1930	1640	1530			
12:00 A.M.	2580	2760	2390	2330	2010	1880	1590	1510			
1:00 P.M.	2590	2700	2350	2270	1990	1860	1530	1450			
2:00 P.M.	2590	2650	2340	2260	1980	1850	1520	1430			
3:00 P.M.	2590	2640	2350	2230	1970	1830	1510	1380			
4:00 P.M.	2580	2620	2370	2230	1960	1800	1500	1340			
5:00 P.M.	2540	2590	2350	2200	1950	1770	1490	1310			
6:00 P.M.	2500	2590	2320	2200	1950	1750	1490	1270			
7:00 P.M.	2450	2630	2300	2210	1950	1720	1500	1230			
8:00 P.M.	2450	2650	2320	2260	1960	1740	1520	1260			
9:00 P.M.	2460	2670	2370	2280	1980	1750	1580	1290			
10:00 P.M.	2490	2720	2410	2310	2020	1770	1590	1310			
11:00 P.M.	2420	2640	2320	2200	1980	1740	1560	1300			
12:00 P.M.	2320	2560	2240	2170	1960	1720	1520	1290			
1:00 A.M.	2270	2490	2200	2080	1910	1710	1510	1280			
2:00 A.M.	2220	2430	2140	2040	1910	1660	1510	1290			
3:00 A.M.	2110	2370	2070	2010	1910	1650	1510	1310			
4:00 A.M.	2010	2320	2010	1940	1910	1610	1500	1340			
5:00 A.M.	2120	2390	2150	2060	1930	1710	1540	1440			
6:00 A.M.	2210	2440	2270	2180	1940	1780	1560	1530			

TABLE NO. VIII

5 PSIG STEAM DEMAND FOR 1952 IN 100 POUNDS PER HOUR

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	335	363	338	334	288	272	234	241	142	111	40
10:00 A.M.	354	409	360	357	303	286	250	235	117	82	40
1:00 P.M.	378	389	341	330	294	275	230	218	97	50	40
4:00 P.M.	377	376	344	326	288	264	227	197	84	72	40
7:00 P.M.	356	375	335	322	288	258	230	185	76	55	40
10:00 P.M.	361	389	350	336	299	264	234	197	94	92	40
1:00 A.M.	333	364	319	304	285	253	223	189	112	113	40
4:00 A.M.	299	338	301	289	284	240	225	201	140	120	40

TABLE NO. IX

EXPECTED 5 PSIG STEAM DEMAND FOR 1956 AND 1957 IN 100 POUNDS PER HOUR

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	350	380	353	349	301	285	245	252	148	116	42
10:00 A.M.	369	427	376	373	316	299	261	245	123	86	42
1:00 P.M.	394	406	356	345	307	287	241	227	101	52	42
4:00 P.M.	394	393	359	340	301	276	237	206	88	75	42
7:00 P.M.	372	301	348	337	301	269	240	193	79	57	42
10:00 P.M.	377	406	365	351	312	276	244	208	99	96	42
1:00 A.M.	348	380	333	318	298	265	238	198	117	119	42
4:00 A.M.	312	353	315	302	297	251	235	210	142	126	42

TABLE NO. X

EXPECTED 5 PSIG STEAM DEMAND FOR 1958 AND 1959 IN 100 POUNDS PER HOUR

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F 25°F	25°F 30°F	30°F 35°F	35°F 40°F	40°F 45°F	45°F 50°F	50°F 55°F	55°F 60°F	60°F 65°F	65°F 70°F	Days Above 70°F
7:00 A.M.	358	389	361	357	308	291	250	258	152	119	43
10:00 A.M.	378	437	386	382	312	306	267	251	126	88	43
1:00 P.M.	404	416	365	354	314	294	246	233	104	53	43
4:00 P.M.	403	403	368	348	308	284	243	211	90	77	43
7:00 P.M.	381	401	356	345	308	276	246	198	81	58	43
10:00 P.M.	387	416	374	359	320	283	250	213	101	98	43
1:00 A.M.	357	389	341	326	305	271	244	203	120	121	43
4:00 A.M.	319	362	322	309	304	257	240	215	150	129	43

TABLE NO. XI

AVERAGE 75 PSIG STEAM DEMAND FOR 1952, 1956, 1957, 1958 AND 1959 IN POUNDS PER HOUR

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	8500	8460	8550	8460	7500	7640	7320	7250	6700	6380	
10:00 A.M.	9000	8950	8400	9000	7940	7950	7590	7130	7000	7130	
1:00 P.M.	7920	8140	7700	7710	7390	7360	7140	6880	6700	6630	
4:00 P.M.	8250	8230	8150	7590	7440	7450	7090	7250	5800	6850	
7:00 P.M.	8250	8500	8100	8040	7340	7180	6820	7000	6200	6500	
10:00 P.M.	8090	8230	7900	7630	7230	7090	6770	6880	6000	6250	
1:00 A.M.	7750	8090	7800	7540	7110	7090	6770	6880	6010	6380	
4:00 A.M.	7500	7910	7650	7790	7160	7270	7000	6880	6400	6250	

TABLE NO. XII

EXPECTED STEAM FLOW TO PROPOSED EXTRACTION CONDENSING UNIT FOR 1956 IN 100 POUNDS PER HOUR

Time of Day	Average Outdoor Temperature Day Groups										
	20°F 25°F	25°F 30°F	30°F 35°F	35°F 40°F	40°F 45°F	45°F 50°F	50°F 55°F	55°F 60°F	60°F 65°F	65°F 70°F	Days Above 70°F
7:00 A.M.	520	530	527	532	483	475	437	452	390	367	257
8:00 A.M.	580	595	592	596	545	530	495	495	427	415	301
9:00 A.M.	600	620	628	613	557	550	517	500	447	427	334
10:00 A.M.	598	638	635	624	560	552	521	508	445	430	332
11:00 A.M.	605	623	615	615	562	555	512	502	450	421	342
12:00 A.M.	614	640	624	620	576	518	527	510	455	426	351
1:00 P.M.	595	597	567	560	533	527	482	465	402	385	319
2:00 P.M.	590	597	585	562	545	526	478	472	405	392	316
3:00 P.M.	588	593	575	550	542	520	470	462	392	392	308
4:00 P.M.	589	588	580	542	537	513	465	460	387	390	308
5:00 P.M.	616	620	602	581	563	538	485	472	398	395	315
6:00 P.M.	667	668	652	639	605	585	552	510	425	417	339
7:00 P.M.	612	625	601	602	565	543	510	460	387	374	309
8:00 P.M.	572	608	582	586	552	538	500	476	422	408	316
9:00 P.M.	567	593	570	561	535	520	480	460	415	412	310
10:00 P.M.	552	573	550	540	515	500	465	442	395	397	290
11:00 P.M.	527	542	518	510	482	465	432	404	362	368	264
12:00 P.M.	485	500	466	460	441	425	395	365	334	337	227
1:00 A.M.	455	458	447	436	417	413	374	341	306	312	210
2:00 A.M.	442	437	433	422	410	390	356	328	295	314	203
3:00 A.M.	421	430	430	415	400	372	349	334	298	306	198
4:00 A.M.	415	430	416	416	395	370	346	326	301	301	197
5:00 A.M.	422	447	440	425	410	412	367	349	314	311	204
6:00 A.M.	464	423	463	447	437	420	380	388	328	324	225

TABLE NO. XIII

EXPECTED STEAM FLOW TO PROPOSED EXTRACTION CONDENSING UNIT FOR 1957 IN 100 POUNDS PER HOUR

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	535	547	545	550	500	490	450	417	405	382	270
8:00 A.M.	610	622	623	616	562	546	515	506	450	437	316
9:00 A.M.	623	653	627	632	582	567	539	517	465	450	354
10:00 A.M.	630	666	636	645	588	575	542	522	465	455	352
11:00 A.M.	633	656	640	632	585	574	537	518	467	441	361
12:00 A.M.	653	668	647	642	600	537	546	533	480	446	371
1:00 P.M.	615	620	592	582	553	545	505	484	422	405	336
2:00 P.M.	612	617	607	581	563	543	500	495	426	410	332
3:00 P.M.	611	615	600	572	555	541	454	477	412	400	324
4:00 P.M.	611	605	602	563	556	532	440	476	405	405	326
5:00 P.M.	642	642	623	607	589	555	513	495	421	405	331
6:00 P.M.	694	694	675	666	631	608	578	526	446	438	357
7:00 P.M.	635	645	622	627	585	565	538	476	402	397	326
8:00 P.M.	592	630	607	600	575	561	522	495	437	427	332
9:00 P.M.	602	635	592	580	558	545	506	476	434	435	326
10:00 P.M.	575	595	620	561	527	515	487	455	415	417	307
11:00 P.M.	546	563	535	520	496	483	452	424	382	385	274
12:00 P.M.	500	505	483	472	460	437	412	374	344	346	236
1:00 A.M.	467	476	450	446	428	410	390	350	318	316	220
2:00 A.M.	496	452	440	430	417	390	369	341	308	316	212
3:00 A.M.	435	445	434	422	406	385	367	343	304	302	205
4:00 A.M.	425	444	426	415	401	372	358	334	308	295	204
5:00 A.M.	445	467	445	433	422	397	380	356	324	308	214
6:00 A.M.	476	496	483	457	452	427	400	397	342	316	236

TABLE NO. XIV

EXPECTED STEAM FLOW TO PROPOSED EXTRACTION CONDENSING UNIT FOR 1958 IN 100 POUNDS PER HOUR

Time of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	555	572	568	560	517	508	470	482	421	397	283
8:00 A.M.	630	648	647	648	582	573	539	503	469	459	336
9:00 A.M.	653	683	650	664	600	588	562	542	491	472	373
10:00 A.M.	658	694	661	666	602	593	565	546	487	480	372
11:00 A.M.	658	678	658	661	605	600	560	548	492	466	379
12:00 A.M.	676	696	676	671	620	561	572	556	503	472	395
1:00 P.M.	643	643	615	602	575	573	526	503	440	421	354
2:00 P.M.	638	645	627	603	586	572	522	512	452	430	351
3:00 P.M.	635	638	617	596	578	562	512	504	432	421	341
4:00 P.M.	640	632	627	589	581	556	506	501	426	427	341
5:00 P.M.	668	668	648	631	612	578	532	521	445	426	350
6:00 P.M.	726	727	711	698	658	632	605	560	470	457	380
7:00 P.M.	655	679	650	656	608	588	556	506	426	417	344
8:00 P.M.	612	656	629	627	597	582	546	521	467	450	351
9:00 P.M.	627	647	612	603	578	563	530	502	460	457	345
10:00 P.M.	595	616	607	582	548	535	502	476	432	436	323
11:00 P.M.	565	580	552	546	512	495	467	442	396	401	288
12:00 P.M.	516	532	474	490	467	454	422	387	357	359	248
1:00 A.M.	483	497	467	460	438	426	404	367	327	329	228
2:00 A.M.	462	467	457	437	426	404	378	355	318	321	220
3:00 A.M.	447	460	446	432	418	398	374	362	301	312	215
4:00 A.M.	441	460	442	432	417	386	372	341	320	306	213
5:00 A.M.	457	483	462	447	435	407	389	369	336	318	221
6:00 A.M.	496	502	496	472	465	438	415	417	354	331	245

TABLE NO. XV

EXPECTED STEAM FLOW TO PROPOSED EXTRACTION CONDENSING UNIT FOR 1959 IN 100 POUNDS PER HOUR

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	570	595	590	592	536	527	487	500	440	412	298
8:00 A.M.	656	665	670	673	605	597	557	550	492	481	355
9:00 A.M.	678	701	679	688	666	607	586	562	513	500	396
10:00 A.M.	683	705	688	695	627	623	587	570	512	505	392
11:00 A.M.	680	702	688	685	631	628	581	568	514	492	401
12:00 A.M.	707	716	702	695	642	584	600	580	524	497	417
1:00 P.M.	664	667	635	625	600	593	547	525	462	442	374
2:00 P.M.	662	667	652	625	612	589	546	532	467	450	372
3:00 P.M.	661	660	643	618	602	584	530	521	456	445	362
4:00 P.M.	663	655	652	607	605	580	530	526	450	450	362
5:00 P.M.	698	694	675	680	642	605	555	542	466	452	369
6:00 P.M.	759	756	740	728	693	666	631	587	496	482	409
7:00 P.M.	682	703	674	675	638	616	580	525	447	438	362
8:00 P.M.	631	679	657	650	622	608	568	540	485	470	372
9:00 P.M.	653	666	636	625	601	587	550	525	482	483	365
10:00 P.M.	618	640	610	602	572	557	522	497	456	461	339
11:00 P.M.	580	600	570	563	530	512	483	457	412	420	304
12:00 P.M.	532	545	510	502	481	466	437	400	372	372	261
1:00 A.M.	496	513	478	472	455	438	410	374	341	339	238
2:00 A.M.	474	480	462	457	443	413	389	372	328	334	230
3:00 A.M.	462	472	457	442	431	407	380	365	322	321	223
4:00 A.M.	452	463	451	440	426	400	380	355	326	318	223
5:00 A.M.	470	472	476	460	447	420	400	380	346	326	231
6:00 A.M.	511	521	507	485	480	457	424	426	369	341	258

TABLE NO. XVI

EXPECTED HEATING AND PROCESS STEAM DEMAND FOR 1956 AND 1957 IN 100 POUNDS PER HOUR

Time of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	475	504	478	473	416	400	358	364	255	220	82
8:00 A.M.	482	522	486	483	422	405	362	359	247	210	82
9:00 A.M.	490	539	493	491	430	411	370	357	240	204	82
10:00 A.M.	499	556	500	503	436	418	377	358	233	197	82
11:00 A.M.	502	548	492	490	429	413	370	348	224	186	82
12:00 A.M.	511	539	483	477	424	407	360	342	215	171	82
1:00 P.M.	514	528	473	462	421	402	352	336	208	158	82
2:00 P.M.	514	525	474	460	418	398	350	329	201	168	82
3:00 P.M.	516	520	476	457	416	395	348	324	194	176	82
4:00 P.M.	515	515	480	456	415	391	348	319	186	183	82
5:00 P.M.	508	516	476	456	415	389	348	314	185	177	82
6:00 P.M.	501	515	471	457	415	385	348	307	181	170	82
7:00 P.M.	494	516	469	457	414	382	348	303	181	162	82
8:00 P.M.	497	521	473	461	417	385	346	307	186	175	82
9:00 P.M.	499	524	479	473	420	386	348	311	190	185	82
10:00 P.M.	498	528	484	467	424	389	352	316	199	198	82
11:00 P.M.	489	520	474	456	420	385	348	313	204	206	82
12:00 P.M.	476	509	462	444	415	378	347	309	210	214	82
1:00 A.M.	466	501	453	434	409	375	346	307	217	232	82
2:00 A.M.	453	491	443	429	408	371	344	310	228	225	82
3:00 A.M.	440	482	438	424	407	367	344	314	237	226	82
4:00 A.M.	427	472	431	419	409	363	346	319	246	228	82
5:00 A.M.	443	482	446	436	411	375	348	335	249	226	82
6:00 A.M.	458	493	462	456	414	389	352	351	252	224	82

TABLE NO. XVII

EXPECTED HEATING AND PROCESS STEAM DEMAND FOR 1958 AND 1959 IN 100 POUNDS PER HOUR

Time Of Day	Average Outdoor Temperature Day Groups										
	20°F to 25°F	25°F to 30°F	30°F to 35°F	35°F to 40°F	40°F to 45°F	45°F to 50°F	50°F to 55°F	55°F to 60°F	60°F to 65°F	65°F to 70°F	Days Above 70°F
7:00 A.M.	483	513	487	482	423	408	364	371	259	222	83
8:00 A.M.	490	531	494	490	426	413	371	368	252	214	83
9:00 A.M.	499	547	501	500	429	420	377	365	245	206	83
10:00 A.M.	508	567	510	512	432	426	383	362	236	199	83
11:00 A.M.	512	558	500	498	432	418	375	355	229	186	83
12:00 A.M.	517	549	492	484	430	413	366	348	219	174	83
1:00 P.M.	523	537	482	471	428	408	358	342	211	160	83
2:00 P.M.	523	533	484	467	427	405	356	336	203	168	83
3:00 P.M.	523	529	485	464	425	401	355	330	196	178	83
4:00 P.M.	526	525	489	464	423	398	354	324	188	185	83
5:00 P.M.	519	524	485	462	422	394	353	319	187	178	83
6:00 P.M.	511	524	482	463	422	392	353	313	186	169	83
7:00 P.M.	503	526	477	465	422	387	354	308	183	163	83
8:00 P.M.	504	531	482	467	423	390	355	312	189	175	83
9:00 P.M.	505	535	487	472	426	391	357	316	195	187	83
10:00 P.M.	508	538	493	475	432	394	358	321	201	200	83
11:00 P.M.	497	529	482	465	427	390	356	318	207	209	83
12:00 P.M.	477	519	470	454	422	387	353	315	212	216	83
1:00 A.M.	474	510	459	441	416	382	352	312	220	225	83
2:00 A.M.	462	499	453	437	416	378	351	316	230	227	83
3:00 A.M.	447	490	446	432	416	374	351	319	242	228	83
4:00 A.M.	434	481	439	427	416	369	350	324	254	231	83
5:00 A.M.	451	491	456	443	419	383	356	339	255	227	83
6:00 A.M.	468	503	471	463	421	395	360	355	256	224	83

TABLE NO. XVIII

EXPECTED DAILY COST AND SAVINGS FOR 1956

Average Outdoor Temperature Day Groups	Cost To College If No Power Generated	Cost To College Of Back-Pressure Unit	Cost To College Of Extraction Condensing Unit	Saving Of Plan No.2 Over Plan No.1	Saving Of Plan No.3 Over Plan No.1	Saving Of Plan No.3 Over Plan No.2
20°F-25°F	723.00	304.00	262.00	419.00	461.00	42.00
25°F-30°F	739.00	303.00	272.00	436.00	467.00	31.00
30°F-35°F	721.00	323.00	261.00	398.00	460.00	62.00
35°F-40°F	709.00	326.00	258.00	383.00	451.00	68.00
40°F-45°F	670.00	327.00	250.00	434.00	420.00	77.00
45°F-50°F	646.00	325.00	236.00	321.00	410.00	89.00
50°F-55°F	603.00	323.00	218.00	280.00	385.00	105.00
55°F-60°F	582.00	327.00	209.00	255.00	373.00	118.00
60°F-65°F	529.00	529.00	182.00	0.0	347.00	347.00
65°F-70°F	522.00	522.00	180.00	0.0	342.00	342.00
Days Above 70°F	432.00	432.00	136.00	0.0	296.00	296.00

TABLE NO. XIX

EXPECTED DAILY COST AND SAVINGS FOR 1957

Average Outdoor Temperature Day Groups	Cost To College If No Power Generated	Cost To College Of Back-Pressure Unit	Cost To College Of Extraction Condensing Unit	Saving Of Plan No.2 Over Plan No.1	Saving Of Plan No.3 Over Plan No.1	Saving Of Plan No.3 Over Plan No.2
20°F-25°F	768.00	342.00	272.00	426.00	496.00	70.00
25°F-30°F	775.00	330.00	281.00	445.00	494.00	49.00
30°F-35°F	760.00	355.00	269.00	405.00	491.00	86.00
35°F-40°F	749.00	356.00	265.00	393.00	484.00	91.00
40°F-45°F	709.00	360.00	252.00	349.00	457.00	108.00
45°F-50°F	685.00	359.00	242.00	326.00	443.00	117.00
50°F-55°F	635.00	352.00	227.00	283.00	408.00	125.00
55°F-60°F	618.00	359.00	215.00	259.00	403.00	144.00
60°F-65°F	563.00	563.00	192.00	0.0	371.00	371.00
65°F-70°F	554.00	554.00	187.00	0.0	367.00	367.00
Days Above 70°F	463.00	463.00	144.00	0.0	319.00	319.00

TABLE NO. XX

EXPECTED DAILY COSTS AND SAVINGS FOR 1958

Average Outdoor Temperature Day Groups	Cost To College If No Power Generated	Cost To College Of Back-Pressure Unit	Cost To College Of Extraction Condensing Unit	Saving Of Plan No.2 Over Plan No.1	Saving Of Plan No.3 Over Plan No.1	Saving Of Plan No.3 Over Plan No.2
20°F-25°F	811.00	372.00	282.00	439.00	529.00	90.00
25°F-30°F	827.00	365.00	292.00	462.00	535.00	73.00
30°F-35°F	806.00	384.00	278.00	422.00	528.00	106.00
35°F-40°F	787.00	367.00	272.00	420.00	515.00	95.00
40°F-45°F	748.00	373.00	258.00	375.00	490.00	115.00
45°F-50°F	718.00	382.00	250.00	336.00	468.00	132.00
50°F-55°F	678.00	381.00	236.00	297.00	442.00	145.00
55°F-60°F	656.00	389.00	226.00	267.00	430.00	163.00
60°F-65°F	601.00	601.00	200.00	0.0	401.00	401.00
65°F-70°F	591.00	591.00	196.00	0.0	395.00	395.00
Days Above 70°F	491.00	491.00	150.00	0.0	341.00	341.00

TABLE NO. XXI

EXPECTED DAILY COSTS AND SAVINGS FOR 1959

Average Outdoor Temperature Day Groups	Cost To College If No Power Generated	Cost To College Of Back-Pressure Unit	Cost To College Of Extraction Condensing Unit	Saving Of Plan No.2 Over Plan No.1	Saving Of Plan No.3 Over Plan No.1	Saving Of Plan No.3 Over Plan No.2
20°F-25°F	859.00	413.00	293.00	446.00	566.00	120,00
25°F-30°F	872.00	402.00	300.00	470.00	572.00	102.00
30°F-35°F	855.00	429.00	290.00	426.00	565.00	139.00
35°F-40°F	840.00	429.00	285.00	411.00	555.00	144.00
40°F-45°F	808.00	443.00	269.00	365.00	539.00	174.00
45°F-50°F	770.00	430.00	262.00	340.00	508.00	168.00
50°F-55°F	718.00	421.00	244.00	297.00	474.00	177.00
55°F-60°F	694.00	426.00	236.00	268.00	458.00	190.00
60°F-65°F	642.00	642.00	210.00	0.0	432.00	432.00
65°F-70°F	631.00	631.00	204.00	0.0	427.00	427.00
Days Above 70°F	533.00	533.00	158.00	0.0	375.00	375.00

B. Sample Calculations

1. Future Expected Electrical Load:

$EL_f = EL_p \times IF$

Where: EL_f is the future electrical load in kilowatts.

EL_p is the present electrical load in kilowatts.

IF is the amount of one at compound interest for n periods, where n is 4 for 1956, 5 for 1957, 6 for 1958, 7 for 1959.*

For 1956, 7:00 A.M., 20°F - 25°F Average Outdoor Temperature Day Group.

$EL_f = 1651 \text{ kw} \times 1.360$

$EL_f = \underline{2247 \text{ kw}}$

2. Increase in 5 psig Steam Demand:

It was assumed that the increase in the 5 psig steam demand would be proportional to the increase in building radiation.

$$\text{Factor of proportionality} = \frac{\text{Radiation 1956}}{\text{Radiation 1952}}$$

$$\text{Factor of proportionality} = \frac{276{,}665 \text{ sq. ft.}}{243{,}316 \text{ sq. ft.}} = 1.044$$

As there was no change in building radiation from 1956 to 1957, it was assumed that the 5 psig steam demand was the same for both years.

For 1956 and 1957, 7:00 A.M., 20°F - 25°F Average Outdoor

* Table XXI, pg. 432, Introduction to Engineering Economy, Woods, B. M. and DeGarmo, E. P., The Macmillian Co., New York, 1950.

Temperature Day Group.

$SD_f = SD_p \times FP$

Where: SD_f is the future 5 psig steam demand in pounds per hour.

SD_p is the present 5 psig steam demand in pounds per hour.

FP is the factor of proportionality.

$SD_f = 33,460 \times 1.044$

$SD_f = \underline{34,970 \text{ pounds per hour}}$

3. The expected 5 psig steam demand for 1958 and 1959 was calculated in a manner similar to calculation No.2.

4. The Electrical Load Scale Constant:

$SC_e = Ord_e \times Abs. \times Value$

Where: SC_e is the electrical load scale constant in dollars per square inch.

Ord_e is the scale of the electrical ordinate of the curve sheets, 400 kw per inch.

Abs. is the scale of the abscissa of the curve sheets, 4 hours per square inch.

Value is the dollar value of kilowatt-hour, $0.008 per kilowatt-hour.

$SC_e = 400 \text{ kw} \times 4 \text{ hours} \times \$0.008 \text{ per kw-hr}$

$SC_e = \underline{\$12.80 \text{ per square inch}}$

5. The Steam Demand Scale Constant:

$SC_{sd} = Ord_{sd} \times Abs. \times value$

Where: SC_{sd} is the steam demand scale constant in dollars per square inch.

Ord_{sd} is the scale of the steam ordinate of the curve sheets, 10,000 pound per hour per inch.

Abs is the scale of the abscissa of the curve sheets, 4 hours per inch.

Value is the dollar value of 1000 pounds of steam, $0.20 per 1000 pounds

SC_{sd} = 10,000 pounds per hour x 4 hours x $0.20 per 1000 pounds

SC_{sd} = $8.00 per square inch

6. Daily Cost of Plan No. 1:

$C_1 = (A_1 \times SC_e) + (A_4 \times SC_{sd})$

Where: C_1 is the daily cost of plan No. 1 in dollars.

A_1 is the area under curve No. 1 in square inches.

SC_e is the electrical scale constant, $12.80 per square inch.

A_4 is the area under curve No. 4 in square inches.

SC_{sd} is the steam demand scale constant, $8.00 per square inch.

For 1956, the 20°F - 25°F Average Outdoor Temperature Day Group

C_1 = (38.36 sq. in. x $12.80) + (29.00 sq. in. x $8.00)

C_1 = $723.00

7. Daily Cost of Plan No. 2:

$C_2 = C_1 - (A_3 \times SC_e)$

Where: C_2 is the daily cost of plan No. 2 in dollars.

C_1 is the daily cost of plan No. 1 in dollars.

A_3 is the area under curve No. 3 and curve No. 1 when curve No. 1 goes beneath curve No. 3 in square inches.

SC_e is electrical scale constant, $12.80 per square inch.

For 1956, the 20°F - 25°F Average Outdoor Temperature Day Group.

C_2 = $723.00 - (32.68 sq. in. x $12.80)

C_2 = $304.00

8. The Daily Cost of Plan No. 3:

$C_3 = A_2 \times SC_{sd}$

Where: C_3 is the daily cost of plan No. 3 in dollars.

A_2 is the area under curve No. 2 and curve No. 4 when curve no. 4 goes above curve No. 2 in square inches.

SC_{sd} is the steam demand scale constant, $8.00 per square inch.

For 1956, the 20°F - 25°F Average Outdoor Temperature Day Group

C_3 = 32.73 sq. in. x $8.00

C_3 = $262.00

9. The Daily Saving of Plan No. 2 Over Plan No. 1:

$S_{21} = A_3 \times SC_e$

Where: S_{21} is the daily saving in dollars.

A_3 is the area under curve No. 3 and curve No. 1 when curve No. 1 goes beneath curve No. 3 in square inches.

SC_e is the electrical scale constant, $12.80 per square inch.

S_{21} = 32.68 sq. in. x $12.80

S_{21} = $419.00

10. The Daily Saving of Plan No. 3 over Plan No. 1:

$S_{31} = C_1 - C_3$

Where: S_{31} is the daily saving of plan No. 3 over plan No. 1 in dollars.

C_1 is the daily cost of plan no. 1 in dollars.

C_3 is the daily cost of plan No. 3 in dollars.

S_{31} = $723.00 -$262.00

S_{31} = $461.00

11. The Daily Saving of Plan No. 3 over Plan No. 2:

$S_{32} = C_2 - C_3$

Where: S_{32} is the daily saving of plan No. 3 over plan No. 2 in dollars.

C_2 is the daily cost of plan No. 2 in dollars.

C_3 is the daily cost of plan No. 3 in dollars.

$S_{32} = \$304.00 - \$262.00$

$S_{32} = \underline{\$42.00}$

12. The various annual indicated savings for each Average Outdoor Temperature Day Group were determined by multiplying the daily saving for each Average Outdoor Temperature Day Group by the number of days in the group. The annual indicated saving for 1956, for the 20°F - 25°F group of plan No. 2 over plan No. 1:

$AS_{21} = N \times S_{21}$

Where: AS_{21} is the annual indicated saving of plan No. 2 over plan No. 1 for the 20°F - 25°F Average Outdoor Temperature Day Group in dollars.

N is the number of days in the group.

S_{21} is the daily saving of plan No. 2 over plan No. 1.

$AS_{21} = 11 \times \$419.00$

$AS_{21} = \underline{\$4610.00}$

13. The annual indicated savings for each Average Outdoor Temperature Day were then totaled to get the annual indicated saving.