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INTRODUCTION

The obligation to render adequate service at reasonable and nondiscriminatory rates has long been recognized as a duty of all enterprises affecting public interest. This doctrine, established early as a principle of common law, has its effect on the central heating and power plant of the Virginia Polytechnic Institute. The recent expansion of the plant has made the information available for budget estimates and departmental billings valueless and created the need for more pertinent data.

At present there is no universally accepted method for arriving at cost of power or the other services in question, for each system presents its own intricate problem and requires individual attention. Since the Institute would be forced to buy electrical energy from a public utility, were it without facilities for generating electric energy, it seemed logical to base these service charges on that of purchased electrical energy.

With more construction still in the offing, it was deemed advisable to make the estimate of future service charges for the fiscal year 1940-1941, prior to which all the proposed additions under construction were to be completed.

The basis for the estimate of service charges for the year 1940-1941 was the plant records for the corresponding period of 1938-1939, to which the proposed additional services were added and from which the calculations for the year were made. From these data, and the trend of curves developed, a service charge estimate was derived.

REVIEW OF LITERATURE

The most complete work relating to the topic of power plant service costs investigated by the authors was "Notes on the Design of Steam Power Plants", by O. A. Leutweiler, Professor of Mechanical Engineering Design, University of Illinois. From this treatise the authors obtained information on both the technical and economic side of their problem. This book, published in February, 1938, delves into the investment cost percentages of a number of American steam power stations, giving high, low, and average values pertaining to land, structures, steam generators, electric generators, and miscellaneous equipment. A very valuable table for checking cost estimates is also included.

Since the cost of electrical energy delivered at the switch-board is a standard of judging the design of steam power stations, Professor Leutweiler discusses at length all the terms and items entering into the problem of determining the cost of power, giving average values of percentages in many instances. This is supplemented by tables of data gathered from representative steam power plants in the United States.

In previous years, two theses have been written by Power and Fuel Fellows on topics similar to that being presented in this thesis. Blackman and Lutz wrote "Cost Distribution at the V. P. I. Central Heating and Power Plant for the Year 1937-1938", and Cunningham, Geddie, and Saunders wrote "A Cost Study of the V. P. I. Power Plant for the Calendar Year 1934". These two theses varied in many respects from this thesis.

First, a completely itemized inventory for the power plant is included for the first time. Second, and the major variation, is that previous studies were based on the heat energy per pound of steam, whereas this study presents service charges based on purchased cost of electrical energy. Third, the other studies investigated service charge for a period already in the past, whereas this study attempts to determine cost for a future period based on past data and calculated additions.

"Electrical Power Equipment" by Tarboux, published in 1932 was helpful from two standpoints; namely, regarding presentation of data in a graphical form and as an authority on the economic aspect of the thesis.

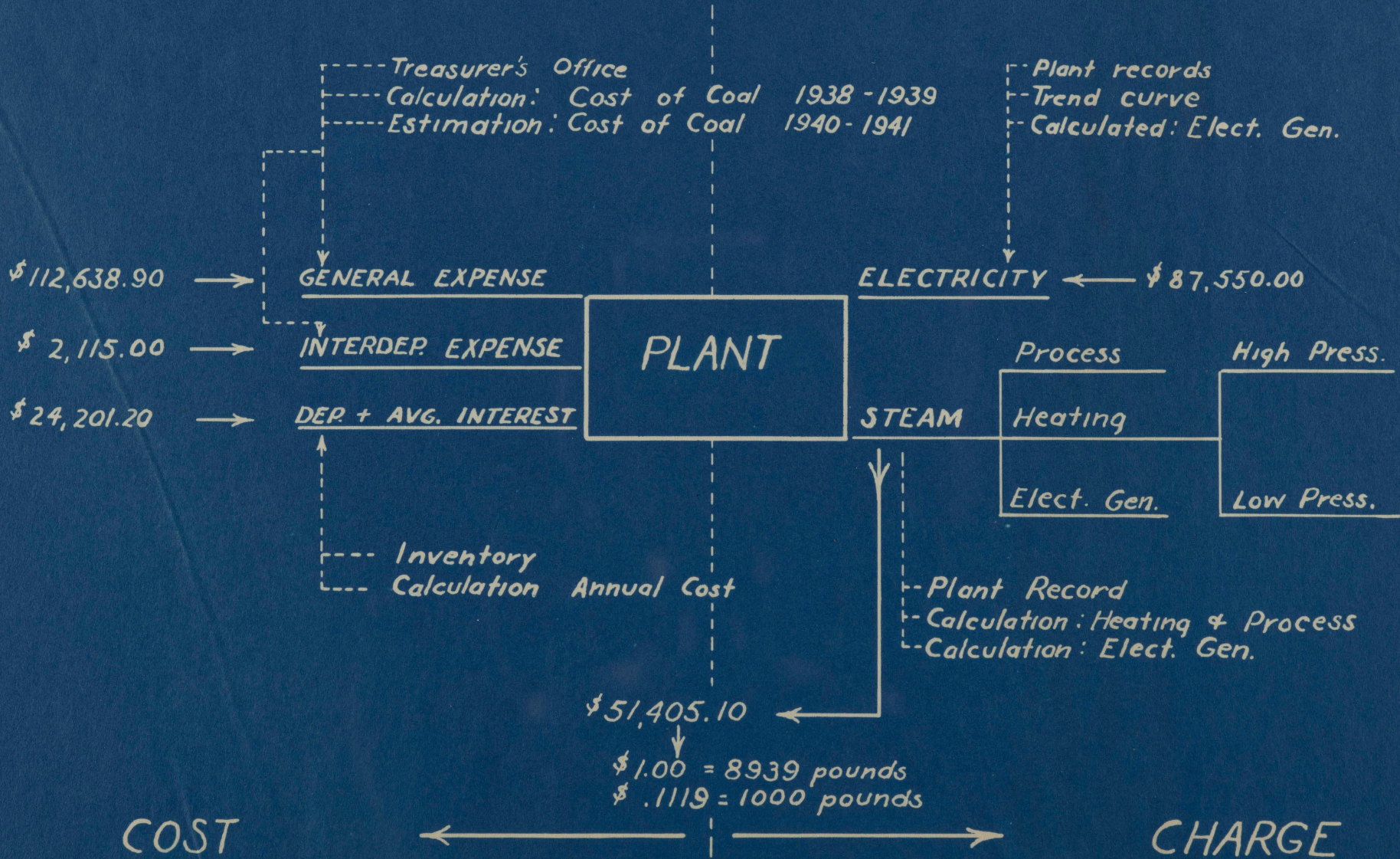
Chapter III of Tarboux discusses the significance of load graphs and factors pertinent to their construction, and the last chapter goes very thoroughly into such items as the principle of rate making, evaluation of property, depreciation, comparison of performance between different types of stations, and rates and methods of selling services.

"Engineering Economics" by Grant was consulted frequently as an authority for figuring most of the cost data.

Supplementary to the foregoing references were two bulletins prepared by the Federal Power Commission. The first of these was entitled, "Rates for Electric Service to Commercial and Industrial Customers". The other was entitled "Cost of Distribution of Electricity". From these the authors obtained an idea of how the Federal Power Commission attacked problems similar to their own.

# ECONOMIC FLOW CHART 1940-1941

## V.P.I. POWER PLANT



POWER PLANT  
VIRGINIA POLYTECHNIC INSTITUTE  
1938-1939

The cost of operating the V. P. I. power plant for the fiscal year 1938-1939:

General Expenditures	\$70,053.79
Interdepartmental Expenditures	1,356.24
Depreciation + Average Interest	19,678.24
	<hr/>
Total	\$91,088.27

Charge for electrical energy for the fiscal year 1938-1939, if purchased from the Appalachian Electric Power Company under rate schedule L. P. :

4,014,060 Kwhs.	58,050.69
-----------------	-----------

Estimated charge for steam generated:

301,579,000 pounds	53,037.58
--------------------	-----------

Total	<hr/> \$91,088.27
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Steam was generated at the estimated rate of 9108 pounds per dollar, or 10.96 cents per thousand pounds.

ESTIMATED EXPENDITURES

Department of Heat and Power

1940-1941

Expenditures:

Salaries.....	\$ 4,800.00
Wages.....	14,600.00
General Repairs (special labor).....	600.00
Traveling.....	200.00
Transportation.....	175.00
Communication.....	110.00
Other Expenses.....	125.00
Fuel	
Hard (local) coal.....	6,000.00
Soft coal.....	75,558.90
Office Supplies.....	75.00
Medical and Laboratory.....	25.00
Laundry, Cleaning, Disinfecting.....	110.00
Other Supplies.....	2,700.00
Other Materials.....	5,000.00
Office Equipment.....	60.00
Other Equipment.....	2,500.00
	<hr/>
	\$112,638.90

Interdepartmental Expenditures:

General Repairs.....	\$ 1,750.00
Other Expenses.....	10.00
Office Supplies.....	20.00
Other Supplies.....	10.00
Other Materials.....	175.00
Other Equipment.....	150.00
	<hr/>
	\$ 2115.00

Grand Total 

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\$114,753.90

ACTUAL EXPENDITURES

Department of Heat and Power

1938-1939

Expenditures:

Salaries.....	\$ 4,248.34
Wages.....	13,304.08
General Repairs (special labor) .....	127.56
Traveling.....	196.82
Transportation.....	172.48
Communication.....	107.63
Other Expenses.....	102.06
Fuel Supplies.....	41,763.87
Office Supplies.....	76.25
Medical and Laboratory Supplies.....	16.20
Laundry and Disinfecting Supplies.....	103.01
Other Supplies.....	2,681.73
Other Materials.....	4,788.82
Office Equipment.....	55.50
Other Equipment.....	2,309.44
	<hr/>
	\$70,053.79

Interdepartmental Expenditures:

General Repairs.....	1,036.64
Other Expenses.....	2.00
Office Supplies.....	16.00
Other Supplies.....	4.60
Other Materials.....	155.00
Other Equipment.....	142.00
	<hr/>
	\$ 1,356.24

Grand Total

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\$71,410.03

ANNUAL DEPRECIATION AND INVENTORY COST SHEET

The straight line method of depreciation calculation was used in this thesis. This method has the approval of the United States Treasury Department with respect to income tax returns and involves fewer difficulties of calculation than the fixed percentage or sinking fund methods.

Average interest was used because of its simplicity and its adaptability to the present problem.

It will be noted in the annual cost sheet that there has apparently been no provision made for salvage value. Machinery such as used in the power plant has a salvage value of approximately 5 per cent of the initial cost. Removal cost will also run about 5 per cent. Then since the amount to be depreciated each year is depreciation plus removal cost minus salvage value divided by the life of the equipment in years, both salvage value and removal costs are included in the calculations.

ANNUAL DEPRECIATION AND INTEREST CHARGES

Sample Calculations

Page 1, Item 1 of Table XVIII

1 Harrisburg Unaflo Steam Engine - 150 hp

Present value = cost - number of years in service x  
yearly depreciation.

$$\$0.00 = \$4,555.50 - (20 \times \$227.77) \text{ approximate}$$

Yearly Depreciation = cost / number of estimated  
years of service.

Average Interest =  $\frac{(n+1) i}{2n}$  (Cost)

$$\$95.66 = \frac{(20+1) .04}{2 \times 20} \times \$4,555.50$$

Total annual cost = yearly depreciation + average  
interest

COST OF COAL

**Explanation**

From test data and experience the evaporation of Steam Generator No. 4, using hard coal, may be taken as seven pounds of steam per pound of coal. Then, knowing the number of pounds of coal fired in 1938-1939, the number of pounds of steam generated during that year was determined.

The summation of all steam generator meter readings during the year gave the total number of pounds of steam generated at the plant. Subtracting the number of pounds of steam generated by the hard coal from this total leaves the number of pounds of steam generated by soft coal. This value divided by the total soft coal used during the year gives the average evaporation from soft coal for the year.

Evaporation for Steam Generator No. 5 will approximate 10.5 pounds of steam per pound of coal as shown by the experiments of DeBusk and Diamond conducted during the winter of 1939-1940. It is therefore safe to assume that 10.2 pounds of water per pound of steam will be a conservative estimate for the over-all average evaporation from soft coal during the year 1940-1941.

Since Steam Generator No. 4 is the only unit burning hard coal, and it is in continuous use, then it can be expected to burn approximately the same number of pounds of coal in 1940-1941 as it did in 1938-1939. It follows that the steam generated from hard coal in 1940-1941 will equal the approximate number of pounds of hard coal used in 1938-1939 multiplied by the average evaporation of the steam generator.

The total steam from soft coal is equal to the estimated steam for the year 1940-1941 (as calculated in another section of this thesis)

minus the steam from hard coal. Then the steam from soft coal divided by the evaporation of steam multiplied by 2000 gives the total number of tons of coal.

The cost of hard coal was taken at \$1.00 per ton including the trucking charge, and the cost of soft coal at \$4.10. These figures represent current prices.

The total cost of coal is finally found by adding the cost of hard and soft coal as shown in the following sheet of calculations.

ESTIMATION OF COST OF COAL

FISCAL YEAR

1940-1941

Year 1938-1939

Steam from hard coal:

Local coal in tons from Table XII x 2000 x evaporation  
per pound of coal

$$6,595,895 \times 2000 \times 7 = 92,342,530 \text{ pounds}$$

Steam from soft coal:

Total steam from Table V minus steam from hard coal

$$301,379,000 - 92,342,530 = 209,036,470 \text{ pounds}$$

Pounds of steam per pound of soft coal:

Total steam from soft coal divided by the number of  
tons of soft coal from Table XII x 2000

$$209,036,470 / 2,048,570 = 10.2 \text{ pounds per}$$

pound of soft coal.

Year 1940-1941

Steam to be generated by hard coal:

Hard coal evaporation x approximate number of tons  
of hard coal used in 1938-1939 x 2000

$$7 \times 6000 \times 2000 = 84,000,000 \text{ pounds}$$

Total steam from soft coal

Estimated steam for year - steam from hard coal

$$459,963,068 - 84,000,000 = 375,963,068 \text{ pounds}$$

Total soft coal;

Steam from soft coal divided by the product of the  
evaporation of steam per pound of soft coal x 2000

$$\frac{375,963,068}{10.2 \times 2000} = 18,429 \text{ tons}$$

Total cost of coal 1940-1941:

Tons of hard coal x cost per ton + tons of soft  
coal x cost per ton

$$6000 \times \$1.00 + 18,429 \times \$4.10 = \$81,558.90$$

EXPLANATION OF EXPENDITURES

FISCAL YEAR

1940-1941

It will be seen from the comparison of the 1940-1941 expense sheet with that from 1938-1939, which was supplied by the treasurer's office, that the major change is in cost of fuel. This was based on the following points:

There has been no change in the plant personnel.

Repairs to the latest additional unit will be a minimum.

Repairs to the old units will be substantially less.

Since fuel cost varies considerably, a detailed explanation of this item is included in Estimation of Cost of Coal for Fiscal Year 1940-1941.

ESTIMATED ELECTRICAL CHARGES AND PRODUCTION

FISCAL YEAR

1940-1941

The electrical load for the fiscal year 1940-1941 was estimated by the use of a kilowatt hour trend curve, Figure 1. Data for this curve covering the period from November, 1934, through 1939 was taken from the daily plant reports and represents a tabulation of all reliable information since the organization of the report system. Data for the continuation of the curve through September, 1942, was obtained by adding the expected abnormal load due to the addition of new buildings to the normal increase from the trend curve.

The accuracy of this estimate depends upon the diversity factor of the new buildings and whether or not the recent expansion has materially affected the trend of electrical production. The authors believe that after this year normal growth will be restored both in the electrical load and steam consumption.

Peak load estimates were made on the basis of probable increase in electrical cooking and lighting loads as based on information as to enrollment and new building projects. It was found that there are several factors contributing to electrical peaks and that previous records cannot be used as an indication of further conditions. This point is covered under recommendations for electric service.

The charges for electric energy were taken from the rate L. P. of the Appalachian Electric Power Company. Other rates were

investigated but for the type of load and loading conditions encountered at the V. P. I. power plant the rate L. P. proved to be the most economical. Thus with the cost of electrical energy established at the bus bars, it is possible to work back through the various units and obtain the cost of steam.

ACTUAL CHARGE FOR POWER

1938-1939

Appalachian Electric Power Company

Rate L. P.  
(Large power)

<u>Month</u>	<u>Peak (kw)</u>	<u>Load (kw-hrs)</u>	<u>Charge</u>
July .....	760	258,160	\$3841.60
August .....	712	259,880	3798.89
September.....	880	298,560	4395.60
October .....	980	327,660	4811.60
November .....	1060	339,700	5032.00
December.....	1060	352,300	5158.00
January .....	980	380,400	5339.00
February .....	1020	354,700	5132.00
March .....	1000	379,900	5359.00
April .....	980	366,000	5195.00
May .....	1020	383,000	5415.00
June .....	900	313,800	4573.00
			<hr/>
			\$58,050.69

ESTIMATED CHARGE FOR POWER

1940-1941

from

Appalachian Electric Power Company

Rate L. P.  
(Large power)

<u>Month</u>	<u>Peak (kw)</u>	<u>Load (kw-hrs)</u>	<u>Charge</u>
July .....	1100 .....	450,000 .....	\$6,185
August .....	1100 .....	450,000 .....	6,185
September .....	1300 .....	450,000 .....	6,435
October .....	1400 .....	540,000 .....	7,440
November .....	1600 .....	530,000 .....	7,595
December .....	1700 .....	560,000 .....	8,005
January .....	1700 .....	570,000 .....	8,100
February .....	1700 .....	530,000 .....	7,720
March .....	1600 .....	570,000 .....	7,975
April .....	1400 .....	570,000 .....	7,725
May .....	1300 .....	570,000 .....	7,600
June .....	1100 .....	490,000 .....	6,585
		<b>Total</b>	<b>\$87,550</b>

APPALACHIAN ELECTRIC POWER COMPANY

Tariff Large Power

Availability of Service:

Available to power users contracting for a definite amount of electrical capacity but not less than 50 kilowatts.

Rate:

Primary Portion: For each kilowatt of integrated monthly maximum demand,  
\$1.25 per kilowatt to which will be added

Secondary Portion: First 10,000 kw-hrs used in any month 2.0 cents/kw-hr  
Next 30,000 kw-hrs used in any month 1.5 cents/kw-hr  
Next 60,000 kw-hrs used in any month 1.1 cents/kw-hr  
Next 400,000 kw-hrs used in any month 1.0 cents/kw-hr  
Next 500,000 kw-hrs used in any month .95 cents/kw-hr  
Next 500,000 kw-hrs used in any month .85 cents/kw-hr  
All over 1,500,000 kw-hrs used in any month .80 cents/kw-hr

CO. PARISON OF RATE SCHEDULES

Sample Calculations

Appalachian Electric Power Company

Tariff C.S.  
(Commercial Service)  
500,000 Kw-hrs.

Kilowatt hours equal to sixty times the kilowatts of monthly  
billing demand

1700 x .05	=	\$ 85.00	(Peak)
1000 x .03	=	30.00	
2000 x .02	=	40.00	
495,300 x .015	=	7429.00	
		<u>\$7584.50</u>	

Note: See rate schedule for detailed information

Tariff L.P.  
(Large power)  
500,000 Kw-hrs.

For each kilowatt of integrated 15 minute maximum demand  
\$1.25 per kilowatt

1700 x \$1.25	=	\$2125.00
10000 x 0.02	=	200.00
30000 x 0.015	=	450.00
60000 x 0.011	=	660.00
400000 x 0.010	=	4000.00
		<u>\$7435.00</u>

Note: A detailed rate schedule for this rate is included  
in this thesis. This was the most economical rate found.

Rates Investigated

Tariff C. S.

Tariff C.L.P.

Tariff L. P.

Tariff C. P.

EXPECTED WEATHER CONDITIONS

In a perusal of the United States Department of Agriculture Weather Bureau Reports for Blacksburg, Virginia, it was found that the year 1938-1939 was slightly warmer than the normal year since 1890, but an average for the past ten years showed 1938-1939 to approximate the normal for that period. Table III shows the condensed weather report for 1938-1939 and figure 4 depicts its relationship to the normal year. The authors believe that this year had a typical heating season.

From these records, it was realized that seldom are there heating seasons that vary greatly from the normal. The heating season of 1939-1940 was unusual so it was reasonable to expect that the 1940-1941 would approach the normal.

STEAM GENERATION FOR 1940-1941

In making estimates for the amount of steam generated during the fiscal year 1940-1941, the authors took plant records for a similar period during 1938-1939, and added to the totals for that year the amounts of steam needed to supply additional steam demand on the Virginia Polytechnic Institute campus and to the turbines at the V. P. I. power plant due to increased electrical load.

For the fiscal year 1938-1939, the monthly steam totals for each steam generator were tabulated, along with the total amount of steam generated by all four steam generators in Table V. Using this total as a base figure to which could be added the steam required by additional equipment in the power plant and new buildings on the campus, the next step was to calculate the additional steam requirements.

In calculating the amount of additional steam necessary to supply the increased demand on the V. P. I. plant for electrical energy, the trend curve for past and future monthly kilowatt-hour totals was used as a base. Taking the number of kilowatt-hours per month in 1938-1939 and the amount of steam used by the turbines in supplying that load, a relationship was derived which was used to calculate the amount of steam necessary for supplying the projected electrical demand for the fiscal year 1940-1941. In view of the fact that another turbo-generator has been added since 1938-1939, its water rate had to be considered in relation to those machines previously installed in order to arrive at a reliable method for calculating steam requirements. From

a previous thesis, water rates at different conditions of load and vacuum for the Westinghouse turbo-generator were obtained. When compared under expected operating conditions of load with results from the latest turbo-generator unit, in its present condition, the difference in water rates is so small that a correction factor is of little value. In view of this, it was decided to consider water rate on the latest unit the same as the previous condensing unit.

Calculating the steam demand for July, 1940, we have from page 22 an estimated 450,000 kilowatt-hours for that period. For July, 1938, the kilowatt-hours totaled 258,160, page 21, and the corresponding amount of steam for that electrical generation was 7,304,570 pounds. Now, since the water rates are close enough under present conditions to use the same for the condensing units, a straight proportionality to figure the new steam demand for the estimated electrical load can be used.

In the same manner, steam quantities for all the months under consideration are calculated and totaled as shown on page 34. This total represents the number of pounds of steam necessary for electrical generation during the fiscal year 1940-1941.

To this figure must be added the steam for heating, which has been calculated as the total heating steam used in 1938-1939, plus the steam necessary for the added radiation in the form of new buildings. In order to differentiate clearly between old buildings and those just recently added to the physical plant of the college, the authors have prepared a campus map which is included in the attached pocket on the back cover of this thesis. All buildings as of May 1, 1940, were shown

as either old radiation or new with the location of connecting steam lines. In 1938-1939 the total number of pounds of steam for heating was divided by the number of square feet of radiation to obtain a factor for calculating steam consumption of the new buildings. Table XI shows the buildings, numbered according to our campus map, with their respective radiations as is recorded by Wiley and Wilson, Consulting Engineers. Calculation and addition of these two items showed a total steam requirement for heating of 226,275,554 pounds per year. It was estimated that 60,000,000 pounds of this heating steam would be supplied by the back-pressure and bleeding turbines, leaving 166,275,554 pounds to be supplied directly by the steam generators.

The next item added to steam generation requirements was that for plant auxiliaries. To the total auxiliary steam for 1938-1939 was added the steam required by the Nuveyor ash conveyor system. A test was run on this apparatus to determine steam demand, and, as shown on page 35, it revealed an average consumption in operation of 3960 pounds per hour. This apparatus is in use an average of four hours per day throughout the year, shown on page 36, making a total steam consumption of 5,785,250 pounds per year. Adding this to the 1938-1939 auxiliary figure gives 32,897,950 pounds steam per year chargeable to auxiliaries.

The last item included in the steam generation requirements was that for the college laundry and pressing shop. Since the water on that line was not in operation during the 1938-1939 period, it was necessary to estimate the quantity of steam for that period, as well as the period of 1940-1941. By taking the latest reliable data available and using the total number of resident students during the three periods as an index to

steam consumption, the value 7,459,000 pounds was derived for 1938-1939, and 8,832,000 pounds for 1940-1941.

Totaling these four items, a figure of 413,966,761 pounds of steam was obtained to which must be added 45,996,307 pounds, or 11.11 per cent for meter errors and losses as determined in the year 1938-1939, giving a grand total of 459,963,068 pounds of steam to be generated in 1940-1941.

With a heating system of this size, the meter errors and losses are approximately ten per cent of the generated steam. If ten per cent of the generated steam was not metered in 1938-1939, then  $1 \div 0.9 = 11.11$  per cent had to be added to the estimated metered steam in 1940-1941 to get the estimated generated steam.

In order to find the steam required for heating during 1938-1939, it was necessary to go through a series of calculations as well as add the year's monthly totals, as is tabulated on pages 37, 38, and 39. By taking the total steam generated, page 37, and subtracting ten per cent for meter errors and losses a value of 271,241,100 pounds of steam per year was obtained. This was the corrected metered steam for 1938-1939. Adding the yearly totals of the Westinghouse turbine, the Allis-Chalmers turbine, the auxiliaries, and the laundry and pressing shop resulted in a grand total of 166,655,740 pounds per year for purposes other than heating. This subtracted from 271,241,100, the corrected metered steam, netted 104,585,360 pounds per annum, supplied for heating by the steam generators.

Steam amounting to 60,337,000 pounds went through the building heating meter but 2,836,000 pounds of this was supplied by high pressure steam into the exhaust heating header. This left 57,701,000 pounds per year supplied by the exhaust of the turbines and auxiliaries. The

addition of the high pressure steam for heating and the exhaust steam for heating resulted in 162,286,360 pounds per year for all heating purposes.

To find the steam condensed or exhausted to the atmosphere by the turbines, it was first necessary to know the steam required for heating the feedwater. Average inlet and outlet feedwater temperatures were known as well as the amount of water heated so a relation, as is shown in the sample calculations, was set up and a value, 21,170,037 pounds per year, was computed. The total of all the steam into the exhaust heating header minus all the metered steam leaving gave the steam condensed or exhausted to the atmosphere. This, in 1938-1939, was 66,950,403 pounds.

STEAM GENERATION

Sample Calculations

Taking the ratio consisting of the estimated kilowatt-hours for July, 1940, divided by the actual kilowatt-hours for July, 1938, and multiplying that by the steam used for the kilowatt-hours generated in July, 1938, the result is the amount of steam required for July, 1940.

$$\frac{450,000}{258,160} \times 7,304,570 = 12,732,596 \text{ pounds of steam for July, 1940}$$

To obtain the number of pounds of steam used per square foot of radiation in 1938-1939, divide the total number of pounds of heating steam by the number of square feet of radiating surface.

$$\frac{162,286,360}{183,375} = 884.998 \text{ pounds steam per square foot of radiation}$$

For 1940-1941, multiply total square feet of radiation by radiation factor to get total heating steam.

$$255,679 \times 884.998 = 226,275,554 \text{ pounds steam for heat during 1940-1941}$$

Auxiliary steam for 1940-1941 equals 1938-1939 value plus average pounds per hour for ash ejector multiplied by the hours per day in use and the days per year.

$$27,112,700 \quad (3960 \times 4 \times 365) = 32,879,950 \text{ pounds aux. steam for 1940-1941}$$

Laundry and Pressing shop steam consumption. Multiply pounds of steam per year for last year showing reliable data by the ratio

of the number of students (resident) on the campus in 1938-1939 or estimated to be on the campus during 1940-1941 divided by the number of students during the year from which the data were taken.

1937-1938 ..... 2578 students  
1938-1939 ..... 2760 students  
1940-1941 (estimated)..... 3160 students

$$1938-1939 \quad \frac{6,380,520 \times 2760}{2578} = 7,459,000 \text{ pounds steam}$$

$$1940-1941 \quad \frac{6,380,520 \times 3160}{2578} = 8,532,000 \text{ pounds steam}$$

The figure 6,380,520 is the total amount of steam in pounds metered out to the laundry and pressing shop during the fiscal year 1937-1938.

STEAM GENERATION

1940-1941

	<u>Est. Kw-hrs</u>	<u>1938-1939 Steam</u>		<u>Total Steam</u>
		<u>West.</u>	<u>Allis C.</u>	
July	450,000	7,304,570		7,304,570
August	450,000	7,026,500	767,100	7,793,600
September	450,000	6,589,960	2,901,420	9,491,380
October	540,000	5,695,590	5,181,930	10,877,880
November	530,000	6,784,310	4,782,010	11,566,320
December	560,000	7,875,660	4,644,660	12,520,320
January	570,000	8,162,730	5,313,300	13,476,030
February	530,000	7,134,140	5,343,160	12,477,290
March	570,000	7,316,470	5,438,670	12,755,140
April	570,000	6,951,410	5,310,170	12,261,480
May	70,000	7,265,700	4,734,210	11,999,910
June	490,000	5,761,190	3,798,930	9,560,120
				<hr/>
				132,084,040 lb

CALCULATED MONTHLY STEAM TOTALS

1940-1941

July	$\frac{450,000}{258,160}$	x	7,304,570	=	12,732,596 pounds
August	$\frac{450,000}{259,880}$	x	7,793,600	=	13,494,618 pounds
September	$\frac{450,000}{298,560}$	x	9,491,380	=	14,305,408 pounds
October	$\frac{540,000}{327,660}$	x	10,877,880	=	17,926,746 pounds
November	$\frac{530,000}{339,700}$	x	11,566,328	=	18,045,784 pounds
December	$\frac{560,000}{352,300}$	x	12,520,320	=	19,901,048 pounds
January	$\frac{570,000}{380,400}$	x	13,476,030	=	20,192,483 pounds
February	$\frac{530,000}{354,700}$	x	12,477,290	=	18,643,567 pounds
March	$\frac{270,000}{379,900}$	x	12,755,140	=	19,137,812 pounds
April	$\frac{570,000}{366,000}$	x	12,261,480	=	19,094,802 pounds
May	$\frac{570,000}{383,000}$	x	11,999,910	=	17,856,266 pounds
June	$\frac{490,000}{313,800}$	x	9,560,120	=	14,928,127 pounds
					<hr/>
			Total		206,261,257 pounds

CONVEYOR ASH EJECTOR TEST

Meter Reading	Time
64 .....	0' - 00"
74 .....	1' - 45"
Ash Removal from Steam Generator No. 4	
84 .....	3' - 30"
94 .....	5' - 05"
4 .....	6' - 45"
14 .....	8' - 20"
24 .....	9' - 55"
Ash Removal from Steam Generator No. 3	
34 .....	11' - 30"
44 .....	13' - 00"
54 .....	14' - 35"
64 .....	16' - 10"
Ash Removal from Steam Generator No. 5	
74 .....	17' - 50"
84 .....	19' - 25"
94 .....	21' - 00"
4 .....	22' - 35"
14 .....	24' - 15"
24 .....	25' - 45"
34 .....	27' - 15"
44 .....	28' - 45"

STEAM CONSUMPTION OF ASH REMOVAL SYSTEM

Calculation

Steam Generator	Quantity (pounds)	Time (Min. and Sec.)
No. 4	400	6 - 25
No. 5	700	9 - 25
No. 3	300	4 - 40
	<hr/>	
	1400	20 - 30
Previous to test	400	6 - 45
	<hr/>	
	1800	27 - 15

1800 pounds steam divided by 27.25 minutes  
equals 66 pounds steam per minute of operation.

66 x 60 minutes = 3960 pounds steam per hour

No. 4 averaged 62.5 pounds per minute = 3750 per hour

No. 5 averaged 72.9 pounds per minute = 4374 per hour

No. 3 averaged 65.2 pounds per minute = 3912 per hour

12,036

Dividing 12,036 by three for an average, the result is 4,012  
pounds per hour which checks very closely the above figure.

3960 x 4 x 365 = 5,785,250 pounds steam per year to  
ash ejector

4 hours per 24 hour day average use, and 365 days per year.

HEATING SYSTEM

Sample Calculations

Total steam generated.....	301,379,000 lb
Meter errors and losses (ten per cent) .....	-30,137,900
	<hr/>
Corrected metered steam .....	271,241,100
Steam used by:	
Westinghouse turbine .....	83,868,590
Allis-Chalmers turbine .....	48,215,450
Auxiliaries .....	27,882,700
Laundry and Pressing Shop .....	7,459,000
	<hr/>
Total steam for purposes other than heating.....	166,655,740
Corrected metered steam .....	271,241,100
Total steam for purposes other than heating .....	-166,655,740
	<hr/>
High pressure heating steam .....	104,585,360
Exhaust steam for heating .....	57,701,000
	<hr/>
Total steam required for heating purposes.....	162,286,360
Steam required for heating feedwater:	
$t_{in} = 147^{\circ} F; t_{out} = 219^{\circ} F; \text{heat available} = 953 \text{ Btu}$	
Feedwater to be heated = 301,379,000 lb	
$(301,379,000 - X) (219 - 147) = 953 X$	
Steam required for feedwater heating = X =	21,170,037 lb
Steam supplied by auxiliary exhaust.....	27,112,700 lb
Steam required for feedwater heating.....	-21,170,037
	<hr/>
Steam supplied by auxiliaries to heating.....	5,942,663
Steam supplied by make-up line for heating.....	2,636,000
	<hr/>
Steam for heating not supplied by turbines.....	8,578,663 lb

Steam supplied to exhaust heating header.....	74,712,300 lb
Steam for heating not supplied by turbines.....	-8,578,663
	<hr/>
Steam supplied by turbine exhaust.....	66,133,637
Steam supplied to turbines.....	132,084,040
Steam exhausted into heating system.....	- 66,133,637
	<hr/>
Steam condensed or exhausted to atmosphere.....	66,950,403 lb

STEAM TOTALS

	<u>1938-1939</u>	<u>1940-1941</u>
Steam for Heating	162,286,360	226,275,554
Exhaust Steam used for Heating	<u>57,701,000</u>	<u>60,000,000</u>
Steam from Steam Generator to Heating System	104,585,360	166,275,554
Steam to Laundry	7,459,000	8,532,000
Steam to Turbo-generator	132,084,040	206,261,257
Steam for Auxiliaries	<u>27,112,700</u>	<u>32,897,950</u>
Total	271,241,100	413,966,761
Add 11.11% for Meter Errors and Losses	<u>30,137,900</u>	<u>45,996,307</u>
Grand Totals	301,379,000 lb	459,963,068 lb

SOFT WATER

In this thesis there has been no separate consideration of the cost of supplying soft water to the plant and campus. Depreciation charges on the equipment used in the process are included in the "Annual Depreciation and Inventory" sheet, while the salt and chemicals are included under general expenditures in the "Estimated Expenditures 1940-1941" sheet.

The steam used in heating the soft water is accounted for in the steam exhausted by the turbines and auxiliaries. Power required for pumping is included in general electrical charges.

Soft water is supplied for the power plant steam generators, laundry, and other domestic services on the campus.

This service has its cost absorbed by the other services because of the diversity of its utility.

RECOMMENDATIONS FOR ELECTRIC SERVICE

Two-thirds of the electrical energy generated at the power plant goes to supply V. P. I. and the remaining third supplies the town of Blacksburg. This gives a very peculiar load curve as a result of the following points:

Practically all the electrical load is lighting and/or cooking, which has a very high power factor.

Peak loads at 12 N and 6 PM from cooking.

Rapid changes in load from the Dining Hall.

Heavy loading from laboratories during certain seasons of the year.

To aid operating conditions, the following is suggested:

First: A study of existing laboratory schedules with the idea of shifting heavy electrical loads to fall or spring quarters and scheduling courses between 1-4 PM.

Second: Formulation of rules governing the time and method of connecting the Dining Hall load.

Third: A study of the trends of electrical peaks in order to determine their origin and duration.

Fourth: A determination of the cost of electrical distribution to insure that all rate schedules are paying their way.

Fifth: The offering of a low rate for power or water heating in the early morning hours so as to fill in the daily load curve and give a more constant load.

RECOMMENDATIONS FOR STEAM SERVICE

As a result of this survey covering services supplied by the Central Heating and Power Plant, the following recommendations relative to steam generation and distribution are made:

1. All meters on both 250 pound pressure and 165 pound pressure steam lines should be kept in a state of repair such that the readings that they show will be an accurate record of the steam generated and distributed.

2. All steam lines should be metered in order that a check may be kept of distributed steam against generated steam. This method is the only positive way of checking excessive loss due to leaks and other irregularities of operation.

3. Condensed steam should be measured by condensate meters or some other competent method in order that a relationship may be calculated between the steam exhausted to the atmosphere and that condensed.

VIRGINIA POLYTECHNIC INSTITUTE  
POWER PLANT  
STATION ELECTRICAL LOAD

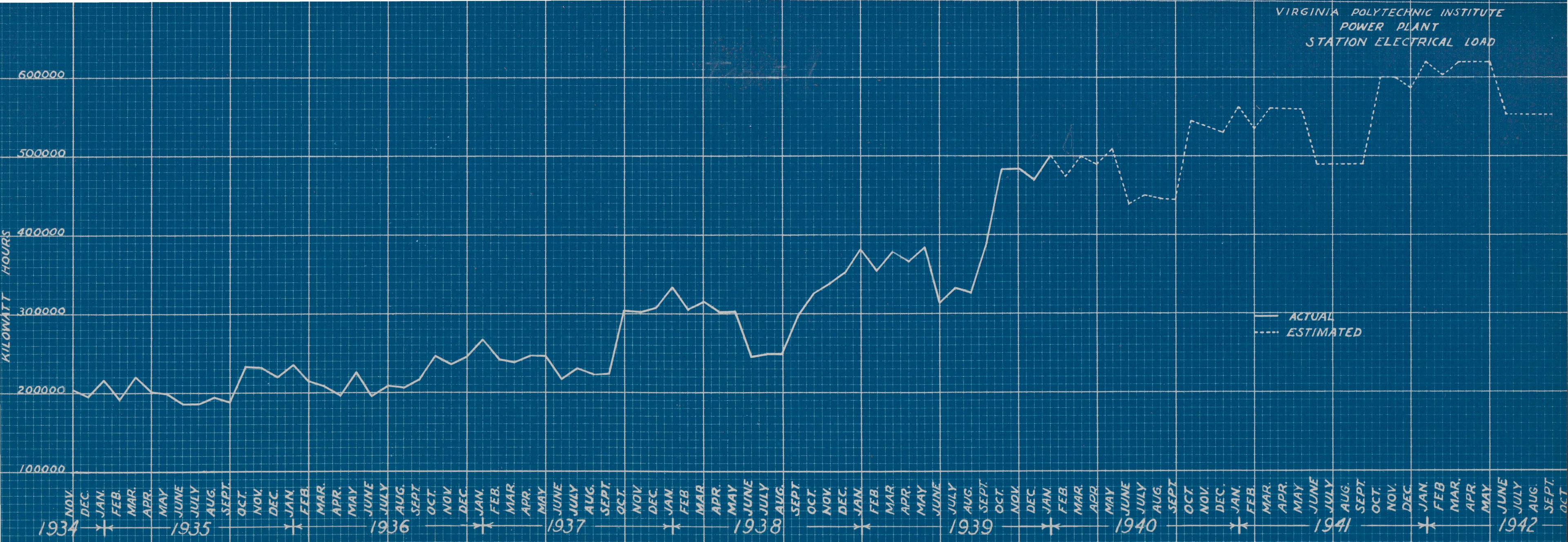


Figure 1

ELECTRICAL DISTRIBUTION  
 VIRGINIA POLYTECHNIC INSTITUTE  
 FEEDER CIRCUITS

1.- PLANT	5.- SERIES
2.- BARRACKS	6.- CAMPUS #2
3.- TOWN #1	7.- TOWN #2
4.- CAMPUS #1	

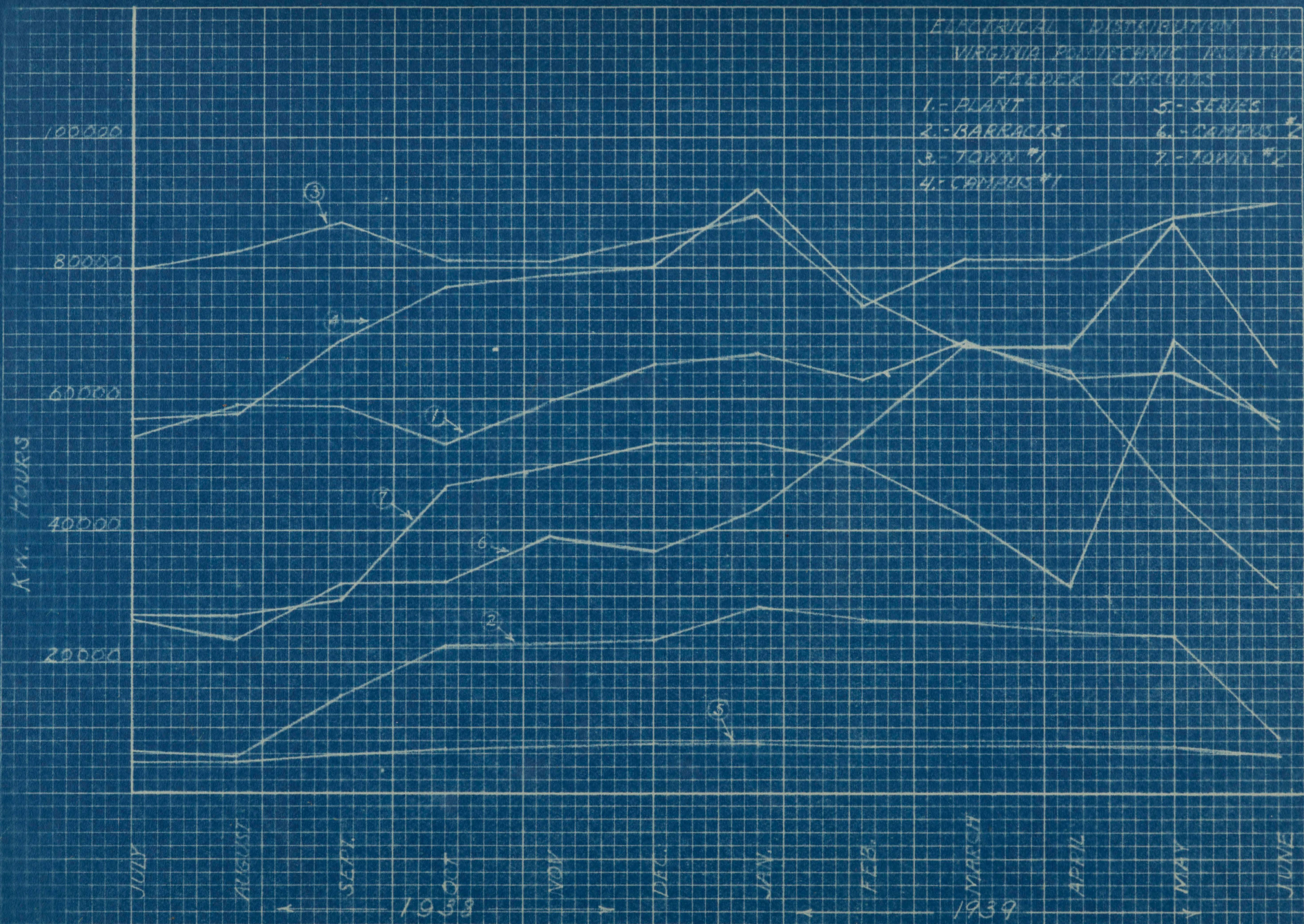
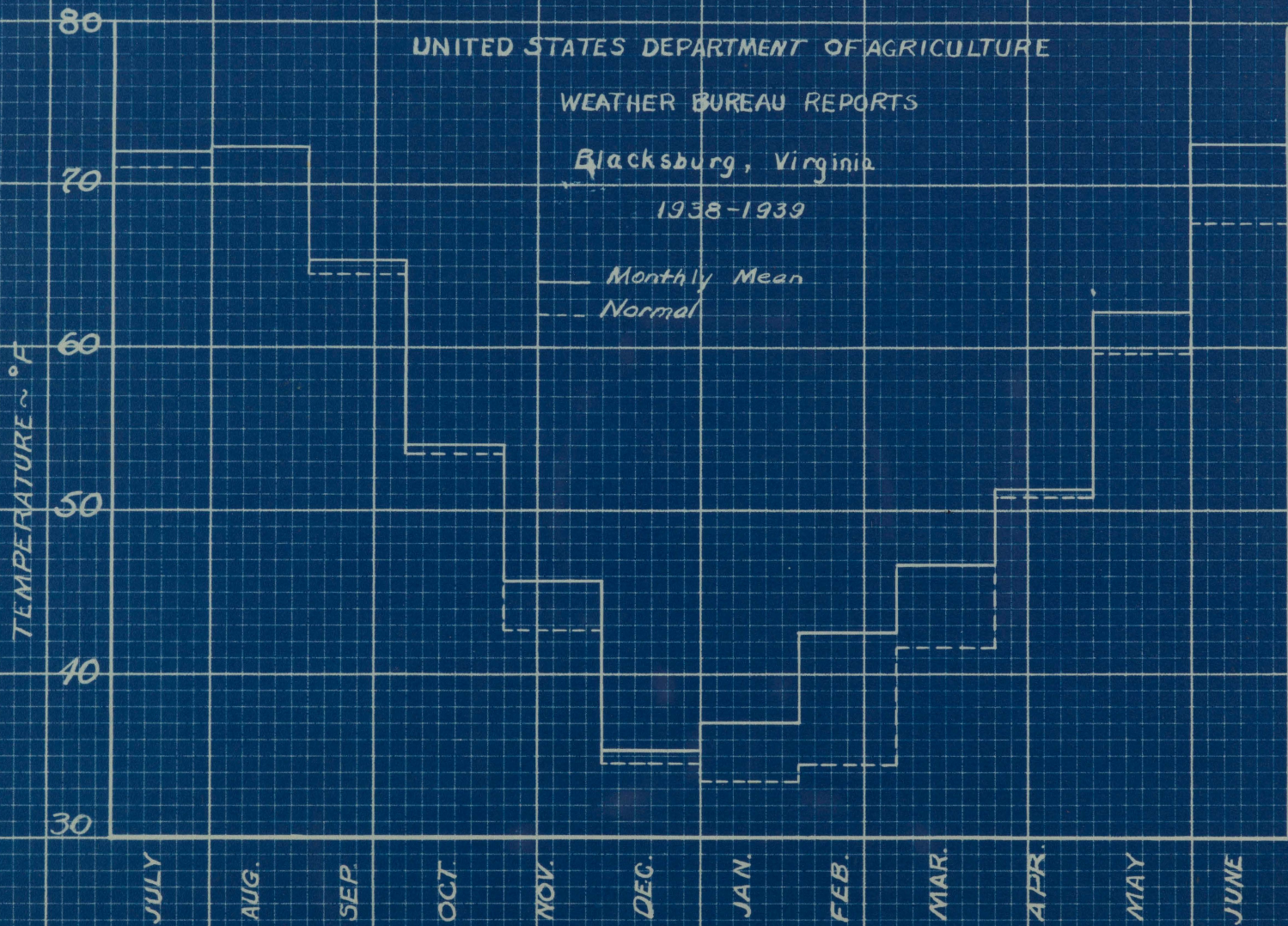


Fig. 2

Table III

UNITED STATES DEPARTMENT OF AGRICULTURE												
WEATHER BUREAU REPORTS												
Blacksburg, Virginia												
1938-1939												
Month	Mean Maximum	Mean Minimum	Mean	Normal	Departure from normal	Maximum	Minimum	Precipitation ( inches )	Rainy days	Clear days	Partly cloudy	Cloudy
July	81.2	62.8	72.0	71.0	+1.0	88	54	8.42	18	10	9	12
Aug.	84.3	60.5	72.4	70.0	+2.4	89	51	1.12	7	21	8	2
Sept.	74.4	54.8	65.1	64.6	+0.5	86	42	2.14	10	6	7	17
Oct.	69.8	38.4	54.1	53.4	+0.7	86	42	0.41	2	22	4	5
Nov.	58.8	32.7	45.8	42.6	+3.2	75	11	3.62	9	14	6	10
Dec.	43.4	27.2	35.3	34.6	+0.7	55	10	1.79	10	10	4	17
Jan.	47.0	27.0	37.0	33.3	+3.7	63	10	3.30	9	9	6	16
Feb.	54.0	30.5	42.5	34.5	+8.0	72	10	4.41	11	12	3	13
Mar.	58.7	34.7	46.7	41.7	+4.0	77	19	2.58	10	11	11	9
Apr.	63.3	39.2	51.3	50.9	+0.4	79	26	1.78	13	10	12	8
May	74.8	49.3	62.1	59.9	+2.2	85	31	1.28	6	14	10	7
June	83.0	62.0	72.5	67.7	+4.8	88	54	5.14	13	13	10	7



1938-1939

Fig 4

## HIGH PRESSURE STEAM GENERATION - Lbs

1938 - 1939

Steam Generators					
Month	No. 1	No. 2	No. 3	No. 4	Total
July	2,770,000	4,487,000	-----	7,122,000	14,388,000
Aug	2,179,000	4,190,000	3,956,000	4,538,000	14,863,000
Sept.	2,590,000	753,000	7,647,000	7,663,000	18,653,000
Oct.	4,506,000	-----	11,398,000	8,708,000	24,612,000
Nov.	4,066,000	3,559,000	11,976,000	9,116,000	28,717,000
Dec	5,306,000	7,258,000	10,525,000	9,045,000	32,134,000
Jan.	4,583,000	8,743,000	10,998,000	9,357,000	33,681,000
Feb	3,872,000	8,453,000	9,839,000	8,606,000	30,770,000
March	3,852,000	8,411,000	11,191,000	7,973,000	31,427,000
April	3,700,000	5,703,000	11,578,000	7,323,000	28,304,000
May	3,579,000	2,789,000	10,291,000	7,178,000	23,837,000
June	-----	3,303,000	10,629,000	6,061,000	19,993,000

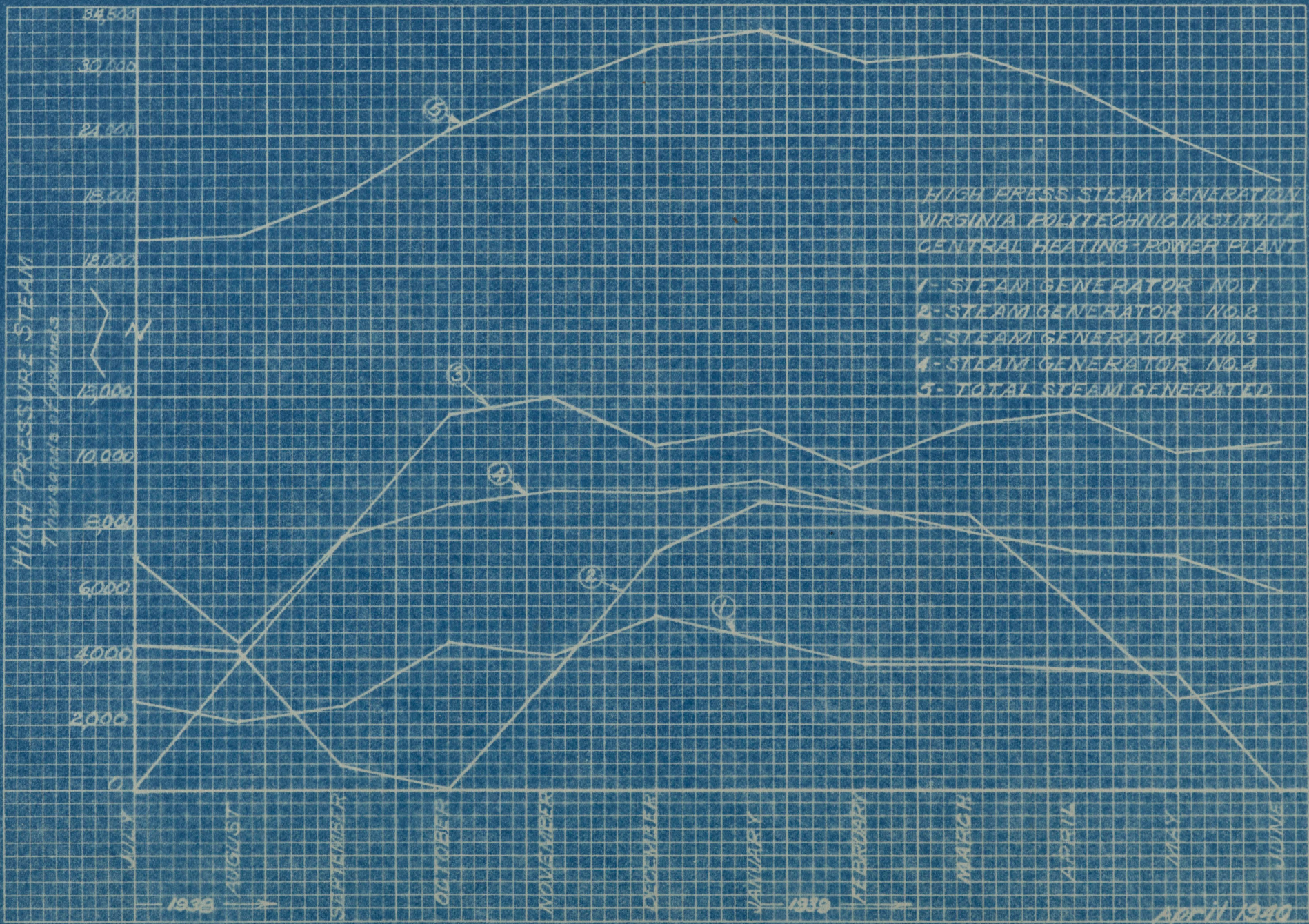


Fig. 6

Table XI

HEATING REQUIREMENTS

No.	Building	1938-1939 Radiation sq ft EDR	1938-1939 Line Loss sq ft EDR	Added Radiation sq ft EDR	Added Line Loss sq ft EDR	Total Radiation sq ft EDR	1938-1939 Steam Flow lb	Added Steam Flow lb
1	Power Plant	112				112	99,120	
2	B. T. U. Club	534	106			640	566,399	
3	Utilities Bldg.	3,000	600			3,600	3,185,993	
4	M. E. Laboratory	1,000	200			1,200	1,061,998	
5	Mining Building	345	69			414	366,389	
6	Pressing Shop	475	95			570	504,450	
7	Pipe Shop Bldg.	409	82			491	434,535	
8	Barracks No. 7	4,755	950			5,705	5,048,919	
9	Barracks No. 4	1,704	340			2,044	1,808,940	
10	Barracks No. 2	1,704	340			2,044	1,808,940	
11	Barracks No. 1	2,604	520			3,124	2,764,740	
12	First Academic	2,428	485			2,913	2,578,005	
13	Military Garage	1,200	240			1,440	1,274,400	
14	Commandant's Home	500	100			600	531,000	
15	Old Mess Hall	2,092	400			2,492	2,205,420	
16	Mr. Owen's House	302	60			362	320,370	
17	Infirmery	2,379	475			2,854	2,525,790	
18	Barracks No. 6	3,845	769			4,614	4,083,384	
19	Barracks No. 5	2,144	428			2,572	2,276,220	
20	Barracks No. 3	1,712	340			2,052	1,816,020	
21	Military Building	1,742	350			2,092	1,851,420	
22	Second Academic	2,989	597			3,586	3,173,610	
23	Library	5,000	1,250			6,250	5,531,250	
24	Student Activity <sup>1</sup>	12,000	1,800			13,800	12,212,968	
25	Faculty Apts. <sup>1</sup>	6,600	1,650			8,250	7,301,250	
26	Dining Hall			24,200	6,050	30,250		27,682,737
27	East Dormitory	3,812	953	5,560	1,640	12,965	4,216,915	7,256,984
28	War Memorial Bldg.	13,000	3,500			16,500	14,602,400	
29	West Dormitory	4,588	1,147	3,690	990	10,685	5,075,464	4,380,740
30	New Agriculture Bldg.			7,200	1,800	9,000		7,964,982
31	Natural Science			4,400	800	5,200		4,601,989
32	Extension Division	1,760	440			2,200	1,947,000	
33	Agricultural Hall	5,132	1,533			6,665	5,898,525	
34	Greenhouse	1,500	375			1,875	1,659,375	
35	Agr. Engr. Lab.	8,000	2,000			10,000	8,849,980	
36	Dairy Husbandry	4,812	1,203			6,015	5,323,262	
37	Girls Dormitory			4,620	1,155	5,775		5,110,863
38	Davidson Hall	15,326	3,831			19,157	16,953,906	
39	McBryde Building	4,044	800			4,844	4,286,930	
40	Mineral Ind. Bldg.			6,583	1,316	7,899		6,990,599
41	Patton Hall	8,196	2,049			10,245	9,066,754	
42	Old Admn. Bldg.	1,240	313			1,553	1,374,401	
43	T and A Building	16,000	4,000			20,000	17,699,910	
TOTALS		148,965	34,390	57,523	13,751	255,679	162,286,360	63,988,894
GRAND TOTAL FOR 1940-1941						255,679	226,275,554	

1. Cookers in terms of radiation.

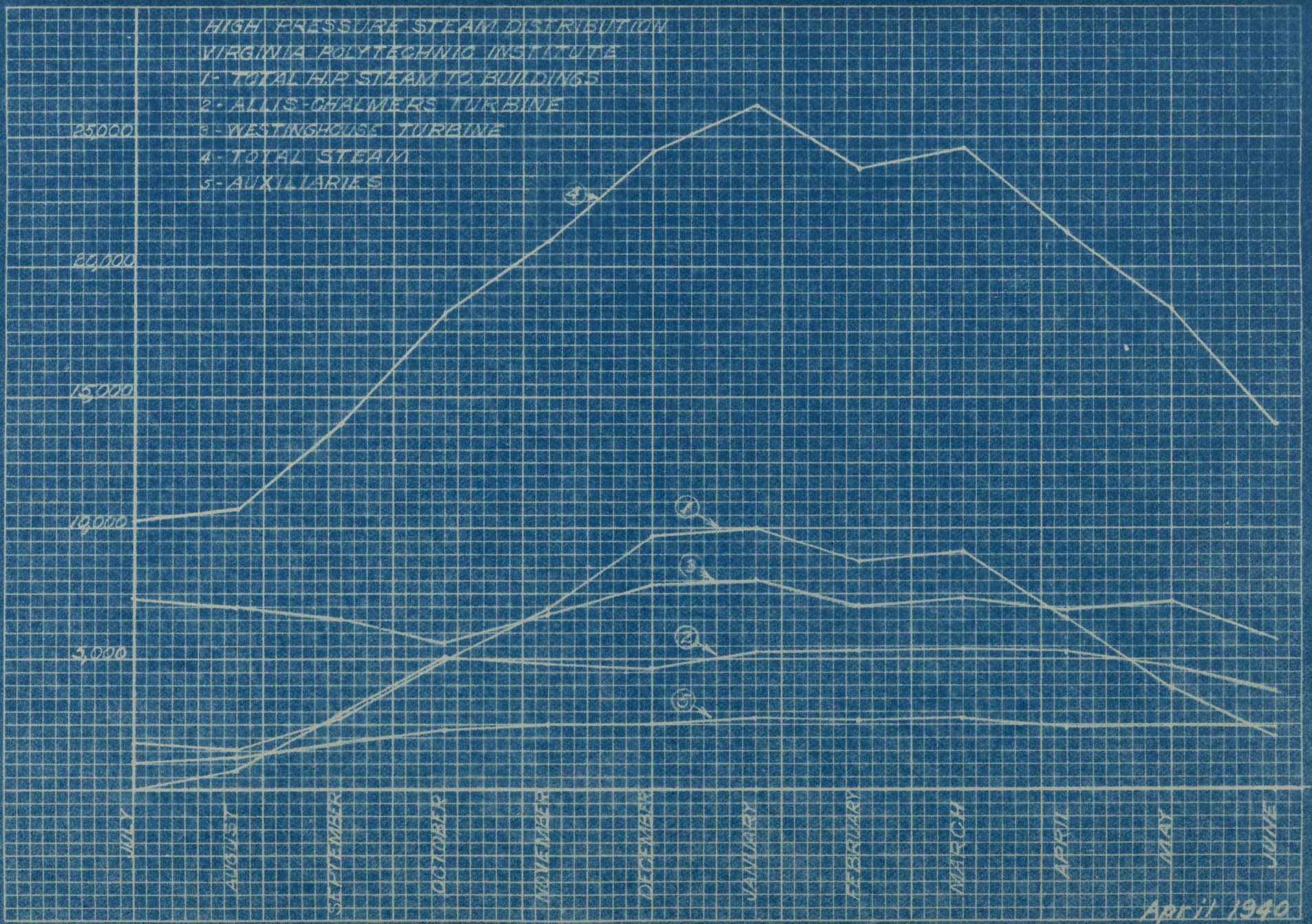


Fig. 8

Table IX

LOW PRESSURE STEAM - Lbs.			
1938-1939 Month	Building Heating	Water Heating	Total
July	3,343,000	584,400	3,927,400
Aug.	3,176,000	522,800	3,698,800
Sept.	3,136,000	1,040,400	4,176,400
Oct.	4,767,000	1,557,600	6,324,600
Nov.	5,851,000	1,345,200	7,196,200
Dec.	7,550,000	1,122,000	8,672,000
Jan.	7,665,000	1,441,200	9,106,200
Feb.	6,546,000	1,454,400	8,000,400
March	6,375,000	1,536,800	7,911,800
April	5,271,000	1,512,000	6,783,000
May	3,624,000	1,603,200	5,227,200
June	3,033,000	655,300	3,688,300

LOW PRESSURE  
STEAM DISTRIBUTION  
VIRGINIA POLYTECHNIC INSTITUTE  
1-WATER HEATING  
2-BUILDING HEATING  
3-TOTAL L.P. STEAM

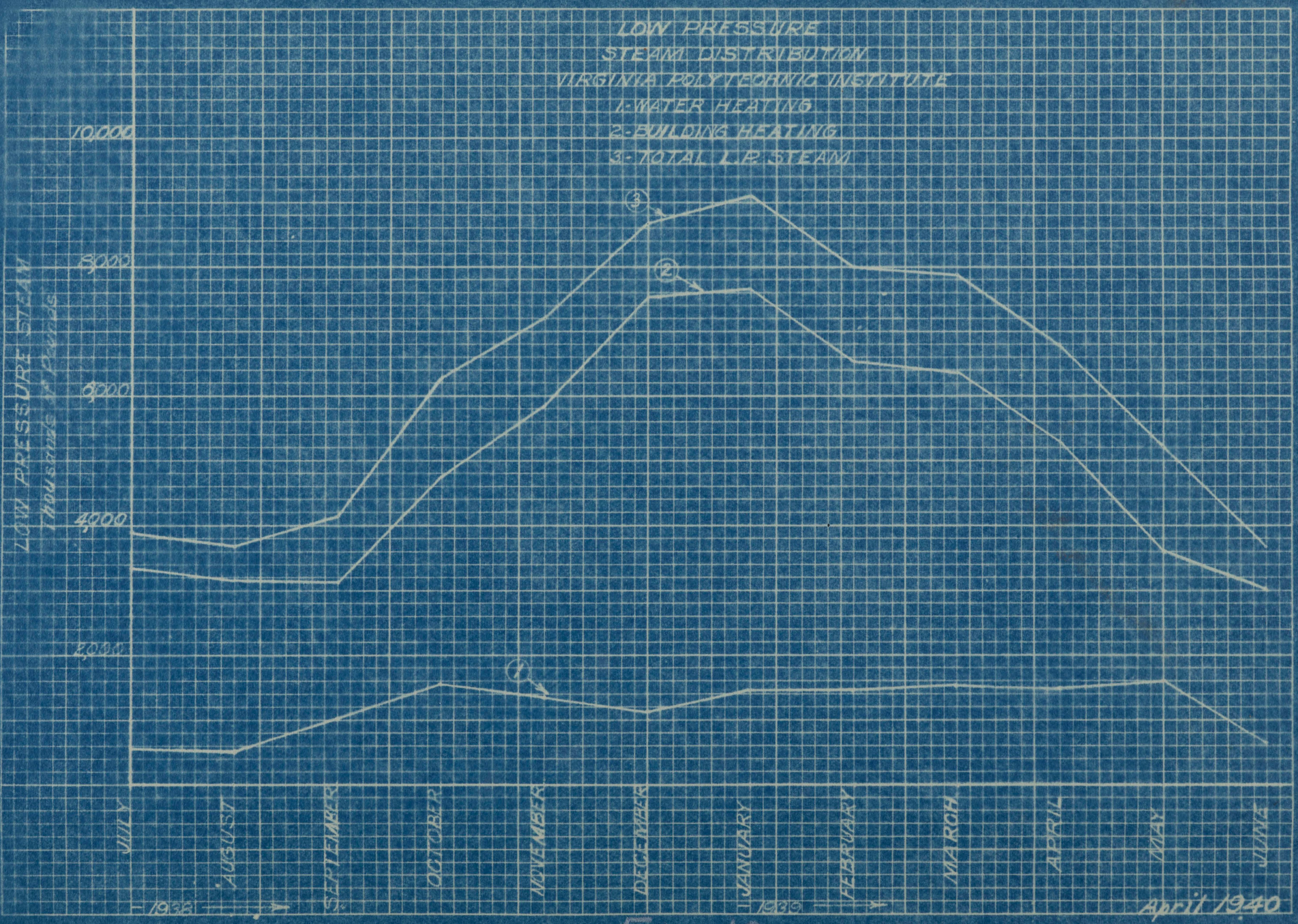


Fig. 10

Table VII

HIGH PRESSURE STEAM DISTRIBUTION  
1938-1939

Month	Aux.	Mech. Lab.	Mess Hall	McBryde Bldg.	Hi Press. Lines 1-2	Low Press. Makeup	Westinghouse	Allis-Chalmers	Total
July	1,179,300	8,960	428,160	312,250	1,076,000		7,304,570		10,309,240
Aug.	1,289,600	5,210	321,750	322,220	926,000		7,026,500	767,100	10,658,380
Sept.	1,806,400	15,130	413,440	448,970	1,874,000		6,589,960	2,901,420	14,049,320
Oct.	2,301,000	11,700	779,300	425,400	3,834,000	2,000	5,695,950	5,181,930	18,231,280
Nov.	2,540,000	4,500	711,000	522,200	5,670,000	6,000	6,784,310	4,782,018	21,020,028
Dec.	2,526,300	300	887,400	579,800	7,894,000	298,000	7,875,660	4,644,660	24,454,120
Jan.	2,743,100	7,500	886,800	629,300	7,832,000	644,000	8,162,730	5,313,300	26,218,730
Feb.	2,640,000	6,800	890,900	514,400	6,875,000	460,000	7,134,140	5,343,150	23,864,390
March	2,746,000	37,800	918,300	534,400	6,486,000	1,154,000	7,316,470	5,438,670	24,631,640
April	2,438,000	15,000	807,860	415,400	5,294,000	72,000	6,951,410	5,310,070	21,303,740
May	2,475,000	8,900	666,800	404,800	2,886,000		7,265,700	4,734,210	18,441,410
June	2,428,000	3,200	434,000	254,900	1,326,000		5,761,190	3,798,930	14,006,220

Table XI (a)

## HEATING CHARGES FOR 1940-1941

Building	Total Rad'n	Steam Flow	Per Cent Radiation	Building Charges
1. Power Plant	112	99,120	.0438	\$11.09
2. B. T. U. Club	640	566,399	.2503	63.38
3. Utilities Bldg.	3,600	3,185,993	1.4080	356.51
4. M. E. Laboratory	1,200	1,061,998	.4693	118.84
5. Mining Building	414	366,389	.1619	41.00
6. Pressing Shop	570	504,450	.2229	56.45
7. Pipe Shop Bldg.	491	434,535	.1920	48.62
8. Barracks No. 7	5,705	5,048,919	2.2313	564.97
9. Barracks No. 4	2,044	1,808,940	.7995	202.42
10. Barracks No. 10	2,044	1,808,940	.7995	202.42
11. Barracks No. 1	3,124	2,764,740	1.2218	309.35
12. First Academic	2,913	2,578,005	1.1393	288.46
13. Military Garage	1,440	1,274,400	.5632	142.60
14. Commandant's Home	600	531,000	.2347	59.42
15. Old Mess Hall	2,492	2,205,420	.9747	246.79
16. Mr. Owen's Home	362	320,370	.1416	35.85
17. Infirmary	2,854	2,525,790	1.1162	282.61
18. Barracks No. 6	4,614	4,083,384	1.8046	456.91
19. Barracks No. 5	2,572	2,276,220	1.0060	257.24
20. Barracks No. 3	2,052	1,816,020	.8026	203.21
21. Military Building	2,092	1,851,420	.8182	207.16
22. Second Academic	3,586	3,173,610	1.4025	355.10
23. Library	6,250	5,531,250	2.4445	618.93
24. Student Activity	13,800	12,212,968	5.3974	1,366.60
25. Faculty Apts.	8,250	7,301,250	3.2267	816.98
26. Dining Hall	30,250	27,682,737	12.2321	3,097.70
27. East Dormitory	12,965	11,473,899	5.0708	1,283.90
28. War Memorial Bldg.	16,500	14,602,400	6.4534	1,633.97
29. West Dormitory	10,685	9,456,204	4.1791	1,058.13
30. New Agricul're Bldg.	9,000	7,964,982	3.5200	891.25
31. Natural Science	5,200	4,601,989	2.0373	515.83
32. Extension Division	2,200	1,947,000	.8605	217.87
33. Agricultural Hall	6,665	5,898,525	2.6068	660.03
34. Greenhouse	1,875	1,659,375	.7333	185.66
35. Ag. Engr. Hall	10,000	8,849,980	3.9112	990.30
36. Dairy Husbandry	6,015	5,323,262	2.3526	595.66
37. Girl's Dormitory	5,775	5,110,863	2.2587	571.89
38. Davidson Hall	19,157	16,953,906	7.4916	1,896.84
39. McBryde Building	4,844	4,286,930	1.8946	479.40
40. Mineral Ind. Bldg.	7,899	6,990,599	3.0894	782.22
41. Patton Hall	10,245	9,066,754	4.0070	1,014.55
42. Old Admin. Bldg.	1,553	1,374,401	.6074	153.79
43. T. and A. Bldg.	20,000	17,699,910	7.8217	1,980.42
TOTALS	255,679	226,275,554	100.0000	\$25,322.82

Table XII

Coal - Tons			
Month	Soft	Local	Total
July	361.025	531.880	892.905
Aug.	491.545	325.985	817.530
Sept.	533.190	553.980	1087.170
Oct.	739.475	626.775	1366.250
Nov.	919.450	644.185	1563.635
Dec.	1135.355	620.755	1756.110
Jan.	1206.060	606.760	1812.820
Feb.	1115.935	543.650	1659.585
March	1169.120	578.300	1747.420
April	1040.025	561.600	1601.625
May	872.505	537.875	1410.380
June	662.600	464.150	1126.750

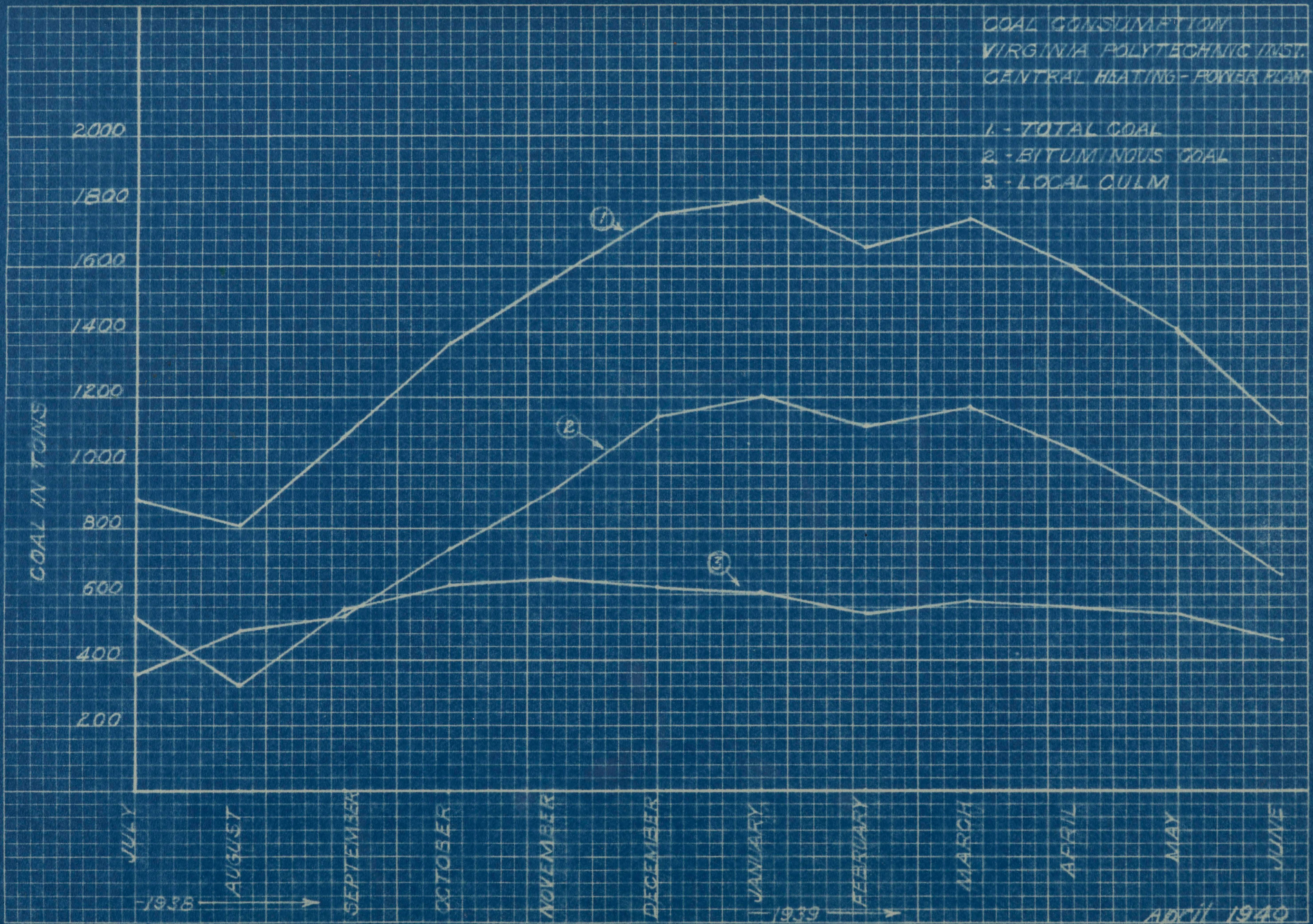


Fig. 13

Table XIV

WATER - Gals.			
Month	Softened Water	Raw Water	Total
July	2,276,100	284,330	2,560,430
Aug.	2,548,400	296,035	2,844,435
Sept.	3,082,700	359,340	3,442,040
Oct.	3,687,000	436,090	4,123,090
Nov.	3,370,200	402,115	3,772,315
Dec.	3,367,700	397,245	3,764,945
Jan.	3,591,700	447,010	4,038,710
Feb.	3,453,100	433,410	3,886,510
March	3,913,900	483,835	4,397,735
April	3,963,200	509,085	4,472,285
May	4,251,700	533,192	4,784,892
June	3,017,300	392,850	3,410,150

WATER CONSUMPTION  
 VIRGINIA POLYTECHNIC INSTITUTE  
 CENTRAL HEATING-POWER PLANT  
 1- RAW WATER  
 2- SOFTENED WATER  
 3- TOTAL WATER

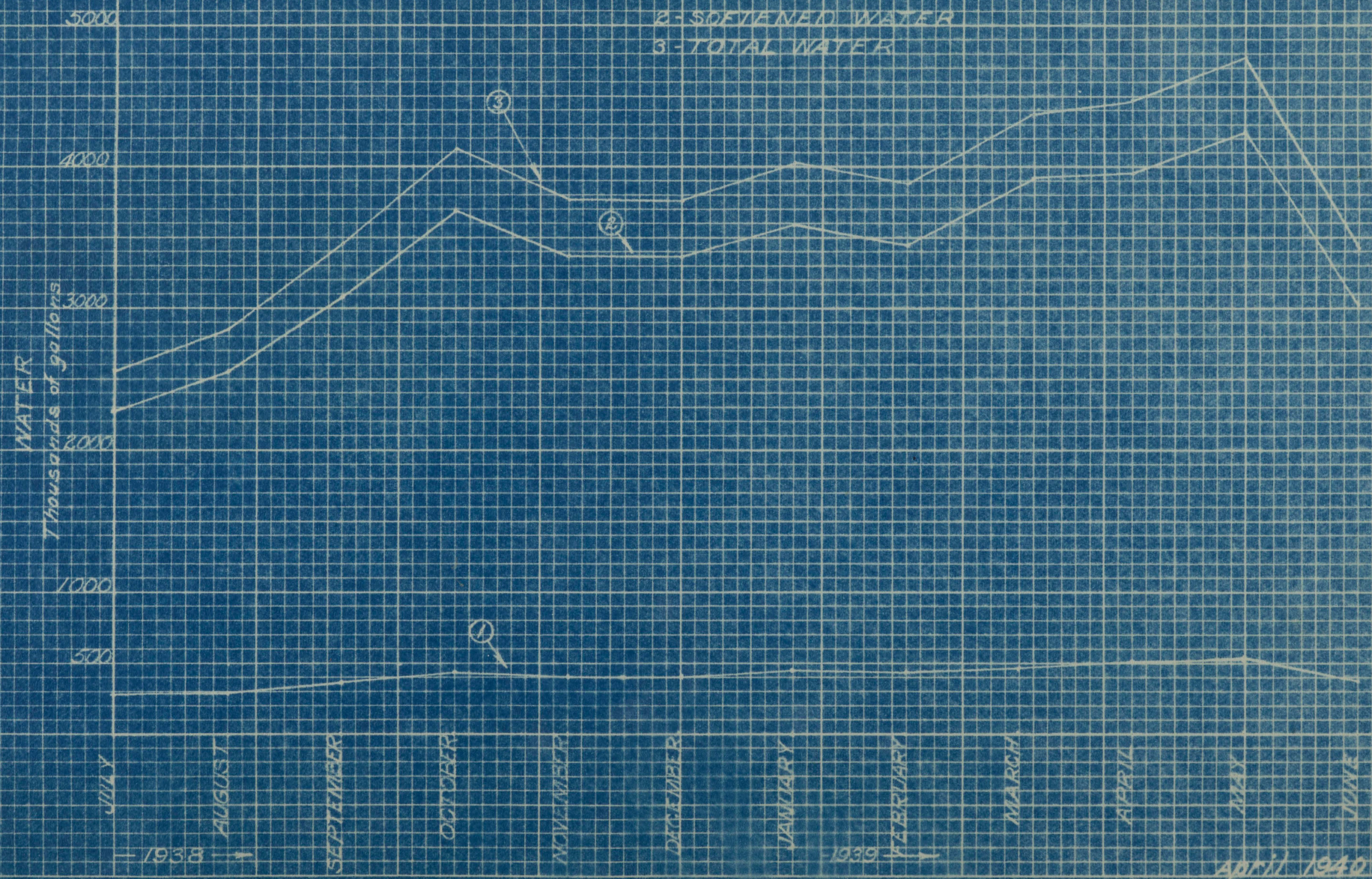


Fig. 15





V. P. I. POWER PLANT

INVENTORY

Annual Depreciation and Interest Charges

	Purchase Date	Purchase Price	Life	Age	Present Value	Yearly Deprec.	Average Interest	Total Annual Cost
1 Westinghouse continuous ash discharge underfeed stoker - 5 retort and 25 hp fan motor	1939	\$9,943.00	15	1	\$9,280.14	\$662.86	\$210.79	\$873.65
1 Clarage fan type W, size 2	1938	850.00	15	2	736.68	56.66	18.02	74.68
1 Cochran deaerating feedwater heater, 85,000 pounds per hour	1938	3,320.00	15	2	2,877.34	221.33	70.38	291.71
1 Hays Eye-Hi water level gage	1939	250.00	10	1	225.00	25.00	5.50	30.50
Nuveyor ash disposal system	1939	8,996.00	15	1	8,396.27	599.73	190.72	790.45
Steel frames	1939	146.00	30	1	141.14	4.86	3.07	7.93
1 Bailey flowmeter	1939	319.00	10	1	287.10	31.90	7.02	38.92
1 American thermometer	1939	135.84	10	1	122.26	13.58	2.98	16.56
1 Air leakage meter	1939	164.50	10	1	148.05	16.45	3.62	20.07
Steam traps	1939	38.60	10	1	34.74	3.86	0.85	4.71
Water level warning whistles	1939	5.52	10	1	4.97	0.55	0.12	0.67
Rockwood standard drive base	1939	29.00	10	1	26.10	2.90	0.64	3.54
1 High Pressure gage glass and gaskets	1939	15.94	10	1	14.35	1.59	0.35	1.94
1 Heat exchanger for continuous blowdown	1939	250.00	15	1	233.34	16.66	5.30	21.96
2 Foster Wheeler cooling towers	1938	3,240.00	15	2	3,024.00	216.00	68.68	284.68
2 Foster Wheeler cooling towers	1939	3,240.00	15	1	2,808.00	216.00	68.68	284.68
1 General Electric feedwater pump	1938	976.00	15	2	845.88	65.06	20.69	85.75
1 Dayton-Dowd pump 155 gpm	1938	486.00	15	1	2,807.66	200.54	63.77	264.31
		<u>68,520.96</u>						
<b>Piping in Plant</b>								
Piping in 1928	1928	41,000.00	20	12	16,400.00	2,050.00	861.00	2,911.00
Water piping in boiler room	1928	1,668.00	20	12	667.20	83.40	35.03	
250 lb/in <sup>2</sup> steam line in 1939	1939	302.00	20	1	286.90	15.10	6.34	21.44
Power plant piping and apparatus	1938	12,524.00	20	2	11,271.60	626.20	263.00	889.20
Cooling tower piping	1938	103.48	20	2	93.14	5.17	2.17	7.34
Air cooler piping	1938	36.16	20	2	32.56	1.80	0.76	2.56
New cooling tower pipe	1938	421.53	20	2	379.39	21.07	8.85	29.92
Control system piping	1938	48.22	20	2	43.40	2.41	1.01	3.42
		<u>56,103.39</u>						
						<u>\$17,156.44</u>	<u>\$7,044.76</u>	<u>\$24,201.20</u>



- POLE
- MANHOLE
- PULL BOX
- UNDERGROUND CABLE
- OVERHEAD LINE



ELECTRIC SERVICE  
CAMPUS  
VIRGINIA POLYTECHNIC INSTITUTE  
BLACKSBURG, VIRGINIA

Porter, Bock,  
Freeman 1940

Scale 1" = 200'