A STUDY OF DIESEL POWER GENERATION FOR SUMMER USE AT THE MICHIGAN STATE COLLEGE PLANT

Thesis for the Degree of M. S.

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Michael Delich

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This is to certify that the

thesis entitled

A Study of Diesel Power Generation
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presented by

Michael Delich

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G. W. Hobbs
Major professor

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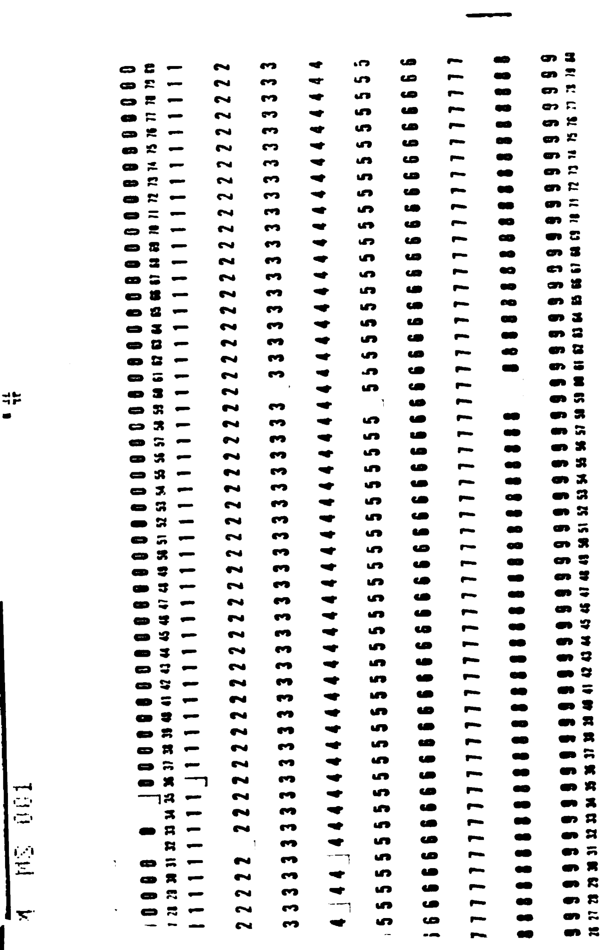

A STUDY OF DIESEL POWER GENERATION FOR SUMMER USE AT THE MICHIGAN STATE COLLEGE PLANT

By

Michael Delich

A THESIS

Submitted to the School of Graduate Studies of Michigan
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The author is deeply grateful to his dear wife, Dorothy Delich, for providing inspiration and encouragement.

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INTRODUCTION

The recent large scale expansion of power plant commitments at Michigan State College has introduced operational problems. In particular, the summer operating condition presents some disturbing features.

It was recommended that the author investigate the possibility of meeting summer generating requirements with adoption of a Diesel generating plant. The project resolved itself into five major phases: (1) electrical energy requirements, (2) cost of the required Diesel proposal, (3) process steam requirements, (4) cost of the required package boiler, (5) comparison of present and proposed costs.

Data on items 1 and 3 was obtained through perusal of existing power plant records and by actual measurement. Items 2 and 4 required calculation of data associated with information received through correspondence, personal interview, and reference material.

Results of the study indicated that a Diesel electric generating plant would require an increase in present costs. However, the increase would represent relatively small investment for the advantage the installation would provide.

It was concluded that the Diesel proposal offered a favorable solution to the summer operational problem.

OBJECT OF INVESTIGATION

The year 1946 represented the beginning of a tremendous expansion in campus facilities at Michigan State College. These changes have affected the college power plant obligations. The major function of this plant is to provide process steam. Of a secondary nature, the plant supplies steam for power generation. Figure 1 illustrates the effect campus expansion has had on steam requirements and electrical energy demand.

Under the circumstances of having to provide steam for process and power generation, it is possible to have an arrangement that involves exceedingly high thermal efficiency operation. Steam can be produced for power generation and then immediately re-used for process requirements. That is, the same quantity of steam serving a dual purpose accounts for the high thermal efficiency operation of the plant.

This desirable combination does not seem to prevail, however, during the summer months. The demand for process steam drops off while electrical energy demand remains comparatively high. Hence, for this period, high thermal efficiency operation of the plant is not anticipated. The summer operating period is defined as June 10th thru September 15th.

The summer condition is further aggravated by the following: High electrical load with low process demand implies that large quantities of condenser cooling water are needed. It is during the summer months that a minimum supply of condenser cooling water will exist. At the same time the condenser cooling water supply will have a relatively high temperature. Appendix I illustrates how unfavorably condenser cooling water supply compares with amounts required during the summer period. Appendix II demonstrates how high temperature condenser cooling water results in unsatisfactory turbine operation.

The substantial year-around electrical load leaves no time allowance for major repair and maintenance responsibilities that must be scheduled for the summer period. Likewise, problems are encountered relative to vacation scheduling for power plant personnel.

The accumulation of difficulties associated with summer operation has become of major concern to Professor J. M. Campbell, power plant superintendent. In his approach toward a solution for this situation, he cites the following possibilities as meriting serious consideration:

(a) Augment condenser cooling water supply by installation of equipment such as a cooling tower and continue the present method of operation.

(b) Install a gas turbine electric generating plant and include a package boiler installation for process steam requirements.

(c) Adopt a Diesel electric generating plant along with a package boiler unit.

It was suggested that the author investigate the details involved in possibility 'c' and present the results of that investigation in thesis form. Thus, this paper represents the results from an investigation undertaken to determine whether or not a Diesel electric generating plant along with package boiler equipment can fulfill satisfactorily the summer phase of college power plant operation.

ELECTRICAL ENERGY REQUIREMENTS

The consideration of this alternate method of summer operation involved the following:

(a) Establishment of the present electrical energy requirements.
(b) Selection procedure and cost data associated with a Diesel plant proposal.
(c) Establishment of the present process steam requirements.
(d) Selection procedure and cost data associated with a package boiler unit.
(e) Comparison of new proposal costs and present charges.

As noted, it was necessary to establish first the electrical energy demands on the present plant installation for the period in question. In the present arrangement, power output of each steam turbine driven generator is denoted by its respective indicating wattmeter. Likewise, the distribution of power generated can be accounted for through wattmeter readings of the various circuits being supplied.

Turbine room procedure includes an hourly recording of all wattmeter readings. Thus, electrical power data accumulates in the form of turbine room log sheet records. A study of these records is offered as being representative of what power requirements must be fulfilled.

The author preferred to present these figures on electrical demand graphically and, in particular, on a load duration basis. Load duration curves are developed by grouping all the hours during a particular operating period when a particular load occurred, and then by starting with the largest value of load, hours are accumulated for all preceding larger load values. Thus for each load value plotted on the load duration curve, the time corresponding to that load is the summation of all the hours at which this load as well as larger loads occurred. Since the abscissa of the duration curve represents time and the ordinate represents power, the area under the curve represents energy output. Figure 2 shows load duration data for the college plant (in relation to summer operation) as of 1946 thru 1950. The data results from log sheet information appearing in the appendix portion of this treatise.

DIESEL PLANT PROPOSAL

To establish figures for the required Diesel plant, attention was first given to the problem of plant location. In this instance it was thought that there were two locations to be considered.

The plant could be located adjacent to the present turbine room and possess these desirable features: "The present distribution switchgear could be utilized most economically and a tie-in with the present condenser cooling water system could be effected most advantageously."

The alternate choice would be a South Campus location. The advantage here would show as follows: "Objections to noise and vibration would be less likely to occur. Appearance of the building would be less critical. Fuel storage and fuel delivery would be less apt to create undesirable situations. From a long range point of view, the power plant installation would be located eventually on South Campus."

It was decided that the North Campus location should be selected. The disadvantages associated with noise, vibration, etc., could be overcome more readily through additional financial outlay as compared to investment required for proper inter-connecting facilities from Diesel plant to present distribution system. Also, the cost of a cooling water system is an item of considerable magnitude and should not be slighted.

Selection of Diesel engine size and number of units would not follow in terms of the 1950 load duration data since campus expansion is still continuing. The author suggested that a predicted 1952 load curve (Figure 3) would represent a maximum for the 1950-1960 period. This opinion was based on a study of the load duration data presented in Figure 2 and prospective building plans.

The foregoing influenced Diesel engine selection:

1. Quotation from Fernald & Orrok, "Engineering of Power Plants",

   "A station with high load factor should have few units and large ones and the most economical apparatus will quickly pay for itself. A low load factor will mean smaller units and a large number of them and the economy of at least half the apparatus is of no great consequence, since it is only used a few hours every year."

2. Quotation from Morse, "Power Plant Engineering and Design",

   "It must be remembered that the investment cost per KW of capacity increases as the capacity of the unit decreases. Probably duplicate units will not meet load requirements as well as units of dissimilar capacities, but, on the other hand, there is to be considered the saving in first cost brought about by duplication of sizes and dimensions of pipes, foundations, wires, insulators, etc., when duplicate units are installed."

The 1952 load duration curve represents high load factor and thereby item 1 was involved. From Figure 3 it can be seen that the smallest unit would be approximately 2000 KW in size. Correspondence with the Cooper Bessemer Corporation revealed that their standard engine generator units in this range involved 1950 KW and 2620 KW. A study of the estimated 1952 load duration data indicated that two 2620 KW units or three 1950 KW units offered possibilities. Hence an estimated Diesel plant installation cost was prepared in terms of these combinations (See page 8). Likewise, similar data was compiled for a combination involving four Nordberg radial engines. Also, a cost list was prepared

ESTIMATED DIESEL PLANT INSTALLATION COST

	Proposal No. 1	Proposal No. 2	Proposal No. 3	Proposal No. 4
1. Standard eng. equip.	485,200	640,000	564,000	509,764
2. Fuel system	7,116	4,224	7,504	7,224
3. Lube oil system	19,730	-	9,000	7,000
4. Starting air system	2,000	-	1,200	1,200
5. Cooling water system	20,390	-	25,000	20,000
6. Intake and exh. system	8,050	-	-	-
7. Electrical equipment	31,600	39,150	39,150	31,600
8. Buildings	75,000	60,000	65,000	60,000
9. Foundations	28,512	6,000	20,000	16,000
10. Miscellaneous	74,236	45,000	74,236	60,000
TOTAL ESTIMATED COST	751,834	794,374	805,090	712,788
Est. cost per KW	151	170	138	136

Proposal No. 1 - Two SEHCO Twin 8's (2486 KW each), 4972 KW Total, Worthington Pump & Mach. Corporation.
Proposal No. 2 - Four RTSG-11 Radial Engine Units (1170 KW each), 4680 KW Total, Nordberg Manufacturing Corporation.
Proposal No. 3 - Three LSV-12T (1950 KW each), 5850 KW Total, Cooper Bessemer Corporation.
Proposal No. 4 - Two LSV-16T (2620 KW each), 5240 KW Total, Cooper Bessemer Corporation.

for a plant having two sets of twin-engine generator units of Worthington design.

Appendix 3 illustrates more complete, detailed information pertaining to the ten items that comprise "estimated plant cost."

The data on estimated cost favored proposals 3 and 4. A study of the predicted load duration curve indicated better performance on the side of proposal number 4. The three 1950 KW combination would seem to represent more reliability, but it was believed that would be offset because of the present 2500 KW tie-in with the city power system. It was concluded that the installation involving two-2620 KW, LSV-16T, Cooper Bessemer, generator units represented the most desirable selection. To insure against under-estimation of total investment cost, it was assumed that $750,000 represent the installation charge.

The total investment cost was used to estimate fixed charges for the proposed installation. Appendix 4 contains explanatory material relative to this item. Fixed charges represent one phase of total operating cost.

For this proposal an itemization on total operating charges would consist of the following:

1. Fuel	
(a) Natural gas..........	$24,220.
(b) Diesel oil...........	6,540.
2. Lubrication oil..............	1,640.
3. Labor & superintendence......	12,250.
4. Repairs & miscellaneous......	8,350.
5. Fixed charges................	65,500.
Total Operating Charge.	$118,500.

Ordinarily, taxes and insurance should be taken into consideration as factors affecting operating cost. In this instance, taxes were not involved because state property is not subjected to taxation. It was assumed that insurance cost could be neglected. Appendix 4 offers detailed calculations for the aforementioned items comprizing total operating charge.

PROCESS STEAM REQUIREMENTS

As previously noted, the third major factor in this investigation involved establishment of the present process steam requirements. Figure 9 describes steam flow of the present plant arrangement. Steam moves from the boiler to the turbines and a reducing station. The reducing station can be used to deliver 100 psig process steam directly from the 300 psig boiler supply. A more economical procedure exists when 100 psig steam is provided through extraction from the turbine. Low pressure (5 psig) process steam must be obtained by extraction from the turbine. The process steam is used for heating purposes and other applications throughout the campus. Some of this process steam is lost to the atmosphere but the major portion returns to the condensate receivers as illustrated in Figure 9. Note that the steam that had passed completely through the turbine also entered the condensate receivers. The make-up water represents liquid that must be added from time to time to compensate for losses throughout the system. Condensate returns to the boiler by way of the de-aerator and storage tank.

Flowmeter equipment on each boiler provided a means of measuring steam flow on the output side of the boilers. The make-up water line also contained a meter and hence that flow was measurable. However, this amount of instrumentation was insufficient for direct establishment of process steam flow. Since it was impossible to obtain or install flowmeters in the process steam lines, the following scheme was proposed. Insert a hot water meter after the condenser. Then the difference between the boiler flow meter reading and the installed hot water meter reading should represent the process steam flow. The results obtained by this method appear in tabular form on enclosed data sheets denoted "Calculated Process Steam Flow".

Another proposal was suggested as a means of obtaining check data on process steam flow. It had been noticed that the make-up water readings compared with boiler flow readings in the order of one part to seventy-five. This was interpreted as meaning that the losses in the system represented a small fraction of the flow involved. Thus, an assumption was introduced, namely, that the heating condensate entering the condensate receivers (See Figure 9) was approximately equal to the process steam flow. That is, measurement of heating condensate flow into the receivers would represent approximately the process steam flow.

It was possible to operate the receiver equipment such that heating condensate would flow into one receiver and the turbine condensate plus make-up water entered the other. Heating condensate would be allowed to collect in its receiver and then pass on in intermittent fashion. The time interval associated with a predetermined accumulation of heating condensate would be translated into a flow reading as follows. A gage glass on the heating condensate receiver was marked such that the difference between two levels indicated was representative of 400 pounds of liquid. This calibration was established by actual weight measurement of the liquid involved. The discharge valve of the receiver would be closed and accumulation of condensate would begin. An initial time reading would be recorded as the level reached the first prescribed mark.

A second time reading would be denoted as the liquid level arrived at the upper mark. The weight of 400 pounds divided by the elapsed time interval would determine a rate of flow into the receiver. A series of ten readings would be taken and the average value used to determine the flow for that period. A tabulation of flow values as computed by this alternate method is listed on an enclosed data sheet entitled "Heating Condensate Data."

On the basis of the results from the two methods of determining process steam flow, it was concluded that approximately 40,000 pounds per hour represented maximum process steam requirements.

Having selected a process steam value, the author proceeded to investigate the fourth phase of the problem; namely, package boiler selection and cost. Initial consideration of this topic involved delving into the possibilities offered by waste heat recovery from the Diesel installation. The net results in this direction were as follows:

> The steam pressure involved restricts the extent to which waste heat recovery could be applied. Mr. G. C. Boyer[1] states that, "Waste heat utilization to be successful requires a careful study of the characteristics of the machine producing the heat as well as the means for reclaiming it."

The factors such as limitations due to pressures involved, characteristics of the machine, and investment in equipment suggested a major project in itself. Hence, subsequent procedure was undertaken on the premise that package boiler equipment would provide all heat energy required for process steam production.

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1 G. C. Boyer, "Diesel & Gas Engine Power Plants", McGraw-Hill Book Company, 1st Edition, 1943.

PACKAGE BOILER DATA

The factors that exert the most influence on the selection of fuel burning and steam generating equipment are: (1) Fuel characteristics, (2) Capacity and steam conditions, (3) Space conditions, (4) Cost, and (5) Individual preference.

In this instance it was decided that the package boiler be of a natural gas fired design. This decision was influenced by the following:

(1) A consideration of comparative price differentials of the available fuels favored the natural gas.

(2) Natural gas is piped direct from suppliers' mains, through metering and regulating equipment, to the burner for use; as a result, there are no handling costs.

(3) For periods other than the summer, the gas fired package boiler would represent some protection for emergency use in case of outages on the part of present coal fired units.

(4) There is no refuse resulting from its use.

It was decided that desirable location for this unit would be in the North Campus boiler room. At present an air compressor installation exists in the area desired. This particular site offered building enclosure and chimney facilities.

Correspondence with Mr. Carl Stripe* provided information on package boilers; namely,

"The cost of the 40,000 lbs per hour unit complete with setting materials, burner windbox, gas burners, forced draft fan and drive, combustion control, and including the services of a superintendent would be $31,500. The cost of the labor required for installation would be an additional $15,400. The efficiency with natural gas firing at 40,000 lb of steam per hour is 76.1 percent based on 212 degree feedwater temperature and 150 lb

* Manager, Industrial Division, Combustion Engineering-Superheater, Inc.

operating pressure, saturated. The estimated maintenance of the unit for the first ten year period of operation would be approximately 5 percent of the delivered cost and superintendence ($31,500) or $1575.

The information on package boilers has been incorporated with the Diesel plant data as shown on page 19. Appensix V offers explanation on package boiler operating and fixed cost calculations.

PRESENT PLANT COSTS VERSUS NEW PROPOSAL COSTS

Data on the package boiler installation would furnish the final detail for enumeration of operating cost of the proposal. Page 19 lists the information that presents a comparison of present and alternate method costs pertaining to summer operation. In relation to this data, items as steam plant labor, superintendence, repairs, maintenance, and fixed charges have been assumed directly proportional to the corresponding annual charges. A resume of annual steam power plant cost appears on page 18. Data on summer fuel cost for the present arrangement is based on existing power plant records.

For the alternate method compilation of costs, it should be noted that this method would be charged with present fixed costs. Adoption of the alternate method would not eliminate automatically the present fixed charges. Likewise, it is important to consider that steam plant personnel of unemployed status with respect to Diesel plant operation cannot be arbitrarily omitted from the payroll for the summer period. In this instance it was assumed that this group would be engaged primarily in major maintenance procedure that would be possible with advent of the Diesel proposal. This expense would be involved regardless of the mode of operation and thereby no discredit should be given to the Diesel plant.

It cannot be expected that steam plant personnel could undertake immediate operation of the Diesel installation. The author's preference for meeting this situation would be to engage experienced Diesel plant personnel. This would introduce the problem of what happens to the added group when the summer period is over. Hence, an estimate for this expense has been denoted for the alternate method.

ANNUAL STEAM POWER PLANT COST (FISCAL YEAR 1949-50)

Operating Cost	
1. Superintendence	$18,800.00
2. Boiler labor	
(a) Craneman & helper	6,989.00
(b) Fireman, assistants	27,518.00
(c) Tech., elect., utility	12,803.00
(d) Miscellaneous	5,241.00
3. Turbine labor	
(a) Operator & helper	29,518.00
(b) Firemen	13,561.00
(c) Repairmen	17,992.00
(d) Miscellaneous	15,549.00
4. Fuel	453,000.00
5. Repairs & miscellaneous	58,540.00
TOTAL ANNUAL OPERATING COST	$659,511.00

Fixed Cost		
1. Equipment cost		
(a) No. 3 Turbo-generator	$83,300.00	
(b) No. 3 Condenser	11,305.00	
(c) No. 4 Turbo-generator	91,800.00	
(d) No. 4 Condenser	14,500.00	
(e) Traveling water screen	3,745.00	
(f) Pumps	3,066.00	
(g) Switchgear	80,167.00	
(h) Boilers No. 1 & 2 (South Campus)	344,716.00	
	632,599.00	
Annual payment including interest		$55,100.00
2. Building cost		
(a) South Campus plant(1948)	506,000.00	
(b) Additions & alter.(1940)	500,000.00	
(c) Pump house	7,000.00	
	$1,013,000.00	
Annual payment including interest		88,400.00
TOTAL ANNUAL FIXED COST		$143,500.00

COMPARATIVE SUMMER PERIOD COST (FISCAL YEAR 1949-50)

Present Method		Alternate Method	
1. Operating Cost		1. Operating Cost	
(a) Superintendence	$4,840.00	(a) Diesel Fuel	$30,760.00
(b) Boiler labor	14,100.00	(b) Diesel lube oil	1,640.00
(c) Turbine labor	19,700.00	(c) Diesel labor & superv.	12,250.00
(d) Fuel	71,000.00	(d) Diesel repair & misc.	8,350.00
(e) Repairs & misc.	15,080.00	(e) Package boiler fuel	4,540.00
		(f) Package boiler main.	41.00
2. Fixed charges	36,900.00	2. Fixed charges (Diesel)	65,500.00
TOTAL COST PER SUMMER	$161,620.00	3. Fixed charges (Package boiler)	4,970.00
		4. Fixed charges (present plant)	36,900.00
		5. Steam plant labor (unemployed)	00.00
		6. Diesel plant labor (unemployed)	15,000.00
		TOTAL COST PER SUMMER	$180,951.00

NOTE: It is assumed the summer period involves 5,580,000 KWHR (Gross) energy output and a gross steam generation of 67,750,000 pounds.

Also, it was assumed that package boiler labor was included in the figures on Diesel plant labor.

DISCUSSION AND CONCLUSION

It is necessary to note that adoption of the Diesel installation would promote economy relative to cost of purchased energy. Appendix 6 illustrated how the proposal could effect a saving of $3200 per summer period on cost of purchased energy.

It should be remembered that the author preferred to engage experienced Diesel plant personnel. This probably represented the most expensive procedure available. It is quite conceivable that steam plant personnel could be trained for Diesel plant operation and hence considerable economy effected.

Another factor influencing analysis of the problem has been described by Mr. F. A. Woolman.* He has written:

> "With loss of the electric curcuit which feeds the plant or the complete loss of all campus circuits the plant is automatically secured because all auxiliaries except one boiler feedwater pump are electrically driven. Also, if the north campus house circuit fails, the plant is without a source of feedwater since all water pumps (both feedwarer and raw water) are in the north campus plant. The only south campus feedwater reserve is a 50,000 lb. storage tank which is a half hour supply at the most. It must also be kept in mind that while the turbines may be out of service the heating load is still in demand. This may cause a serious condition as this demand for heating steam may draw the boiler pressures down to the danger point before electrical supply is resumed. At the present time there is no auxiliary lighting circuit."

Investment in power plant equipment on the basis of summer operation alone would be undesireable. Since the prime purpose of the

* F. A. Woolman, "A study to determine the best operating and maintenance procedure for a 200,000 pounds per hour steam generating plant," M. S. Thesis, Michigan State College, 1950.

college plant is generation of process steam, it would be necessary to establish how effectively a particular proposal could contribute in that direction. Because of the prevailing circumstances, the author deemed that attention to the aforementioned was beyond the scope of this investigation.

As seen on page 19 the proposed installation would require an investment of $18,330 over the present charges.

The following advantages would accrue with the Diesel installation:

1) Boiler and turbine equipment would be available for major maintenance procedure each summer.

2) Vacation scheduling for plant personnel would present no difficulty.

3) Cooling water shortage conditions would be eliminated.

4) Reliability of the plant would be increased.

5) More flexibility of operation would be available.

6) More economic operation could prevail, particularly in the matter of purchased energy.

7) Educational facilities in the Diesel engine field would be increased.

8) Further expansion of campus facilities would not act to upset the required balance between steam and electrical load.

9) Process steam capacity would be increased by 40,000 pounds per hour.

10) Electrical load capacity would be enlarged by 5240 kilowatts.

The author concluded that the results of this investigation showed, "A Diesel generating plant along with package boiler equipment would fulfill satisfactorily the summer phase of college power plant operation. It would mean additional expense but the return on the investment would justify the cost aspect.

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APPENDIXES

APPENDIX 1

Figure 4 depicts the results of measurements taken relative to turbine condensate. This data applies to the August 25th-September 20th portion of the summer period for the year 1950. The higher values indicate a turbine condensate flow of approximately 40,000 pounds per hour.

Assuming the steam is to be condensed at a pressure of 2 inches of mercury absolute, each pound will reject approximately 1000 btu of heat energy to the cooling water. Thus, heat energy will be absorbed by the cooling water at the rate of (40,000)(1000) or 40,000,000 btu per hour. If each pound of cooling water is to undergo a twenty degree change in temperature and thereby absorb 20 btu, 40,000,000 over 20 or two million pounds of water per hour will be required. Since water weighs approximately 8.33 pounds per gallon, there will be required (2,000,000) over (8.33)(60) or 4000 gallons of water per minute.

The Red Cedar river flowing thru the campus provides the supply of condenser cooling water. Records on stream flow as compiled by the U. S. Geological Survey, Water Resources Branch, were consulted. This information has been presented in Figure 5. It can be seen that a flow of 4000 gallons per minute was not available in six instances over the period 1931-1949. In addition, there were five situations when supply was very slightly over 4000 gallons per minute. It was concluded that ample condenser cooling water is not available during the summer period.

APPENDIX II

In a low vacuum surface condenser the temperature of the cooling water may range from 10-25 degrees below that corresponding to the total pressure in the condenser.

Assuming the condenser cooling water discharge temperature to be 100 degrees, Fahrenheit, and that a 10 degree temperature differential exists between condensate and cooling water, the condensate temperature would be 110 degrees, Fahrenheit. A 110 degree Fahrenheit saturation temperature corresponds to a saturation pressure of 2.6 in. Hg. absolute. Under these circumstances the turbine design conditions of 2.0 in. Hg. absolute would not be available. Figure 6 shows that a loss in generator output of 50 KW would result. Likewise, a cooling water discharge temperature of 105 degrees Fahrenheit would mean a loss in generator output of approximately 90 KW.

Undesirable discharge temperature of condenser cooling water results from high inlet temperatures. The operator is forced to operate the equipment at other than design conditions when cooling water supply temperature is high.

Figure 10 denotes cooling water discharge temperatures of 100 degrees Fahrenheit or greater obtained for the summer period of 1950.

APPENDIX III

It was decided that a complete Diesel plant installation consists of the classification:

(1) Standard engine equipment
(2) Starting air system
(3) Fuel system
(4) Lubricating oil system
(5) Intake and exhaust system
(6) Electrical equipment
(7) Cooling water system
(8) Buildings
(9) Foundations
(10) Miscellaneous

Items 2, 3, 4, 5, 6, 7, and 10 appear in detailed form (See following pages).

Data on costs was made available through the co-operation rendered by persons associated with Diesel plant work. Specific information on standard engine equipment was obtained thru Mr. D. E. Levering of the Cooper Bessemer Corporation. Mr. V. M. Holmes of the Worthington Pump and Machinery Corporation provided an estimating data and cost sheet. The Nordberg Manufacturing Company, thru its representative, Mr. H. W. Dow, Jr., contributed information on cost of equipment. A personal interview with Mr. J. H. Keen of the Wolverine Electric Co-op served to further verify cost data.

STARTING AIR SYSTEM	No. Req'd per Engine	No. Req'd per Plant	Remarks
1. Compressor	-	1	Included in eng. bid
2. Compressor motor & drive	-	1	" " " "
3. Auxiliary compressor	-	1	" " " "
4. Aux. compressor engine & drive	-	1	" " " "
5. Air cleaner	-	2	" " " "
6. Relief valves	-	4	" " " "
7. Globe valves	-	14	" " " "
8. Receivers	-	3	" " " "
9. Receiver support	-	1	" " " "
10. Pressure gauge	-	4	" " " "
11. Piping	-	1	" " " "

FUEL SYSTEM			
1. Fuel oil tank	1	3	Included in eng. bid
2. Filter	1	3	" " " "
3. Meter	1	3	" " " "
4. Thermometer	1	3	" " " "
5. Condenser pump	1	3	" " " "
6. Gas reservoir	1	3	" " " "
7. Pressure regulator	1	3	" " " "
8. Pressure gauge	-	-	" " " "
9. Globe valve	-	-	" " " "
10. Check valve	-	-	" " " "
11. Surge bottle	1	1	" " " "
12. Transfer pump	-	2	" " " "
13. Booster pump	1	3	" " " "
14. Transfer pump motor	-	1	" " " "
15. Transfer pump engine	-	1	" " " "
16. Relief valve	-	-	" " " "
17. Storage tank	-	1	" " " "
18. Unloading pump	-	1	" " " "
19. Unloading pump motor	-	1	" " " "
20. Purifier	-	1	" " " "
21. Purifier pump	-	1	" " " "
22. Purifier pump motor	-	1	" " " "
23. Gas scrubber	-	1	" " " "
24. Filling tank	-	1	" " " "
25. Gas meter	1	3	$ 1500
26. Piping	-	1	" " " "

COOLING WATER SYSTEM	No. Req'd per Engine	No. Req'd per Plant	Remarks
1. Motor driven cent. pump	1	3	Included in eng. bid
2. Heat exchanger	1	3	" " " "
3. Temperature regulator	1	3	" " " "
4. Temperature alarm contactor	1	3	" " " "
5. Surge tank	1	3	" " " "
6. Thermometer	2	6	" " " "
7. Gate valve	9	27	" " " "
8. Check valve	1	3	" " " "
9. Rubber expansion joint	1	3	" " " "
10. Raw water pump	-		Incl. in cooling equip. bid
11. Raw water pump motor	-		" " " " "
12. Solenoid operated valve	-		" " " " "
13. Gate valve	-		" " " " "
14. Check valve	-		" " " " "
15. Piping	-	1	" " " " "

MISCELLANEOUS			
1. Pyrometer	1	3	Included in eng. bid
2. Thermocouples	-		" " " "
3. Indicator cock on each cyl.	-	-	" " " "
4. Backfire relief valve	1	3	" " " "
5. Complete set of tools	1	1	" " " "
6. Rigging and hauling	-	1	$8200
7. Labor	-	1	$37,000
8. Erection superintendence	-	1	$7500

LUBE OIL SYSTEM	No. Req'd per Engine	No. Req'd per Plant	Remarks
1. Sump tank	1	3	Included in eng. bid
2. Filter	2	4	" " " "
3. Motor driven pump	1	3	" " " "
4. Heat exchanger	1	3	" " " "
5. Filter	2	6	" " " "
6. Temperature regulator	1	3	" " " "
7. Purifier pump	-	3	" " " "
8. Purifier	1	3	" " " "
9. Storage tank	-	1	" " " "
10. Dirty oil tank	-	1	" " " "
11. Transfer pump	-	1	" " " "
12. Transfer pump drive	-	1	" " " "
13. Pressure regulating valve	1	3	" " " "
14. Relief valve	2	6	" " " "
15. Thermometer	2	6	" " " "
16. Pressure gauge	2	6	" " " "
17. Globe valve	4	12	" " " "
18. Gate valve	18	54	" " " "
19. Pressure alarm contactors	1	3	" " " "
20. Check valve	2	6	" " " "
21. Waste filter	-	1	" " " "
22. Flexible connection	2	6	" " " "
23. Piping	-	1	" " " "

INTAKE AND EXHAUST SYSTEM			
1. Air filter	1	3	Included in eng. bid
2. Turbocharged air cooler	1	3	" " " "
3. Air silencer	1	3	" " " "
4. Exhaust silencer	1	3	" " " "
5. Intake flexible connection	1	3	" " " "
6. Exhaust flexible connection	1	3	" " " "
7. Exhaust stack	1	3	$2100
8. Support for piping	-	3	Included in eng. bid
9. Piping	-	1	" " " "

ELECTRICAL EQUIPMENT	No. Req'd per Engine	No. Req'd per Plant	Remarks
1. Generator (complete with damper windings, generator field rheostat and field resistor)	1	3	Included in eng. bid
2. V-belt driven exciter	1	3	" " " "
3. Exciter drive	1	3	" " " "
4. Exciter guard	1	3	" " " "
5. Synchronizing motor on governor	1	3	" " " "
6. Conduit and wiring on engine	1	3	" " " "
7. Alarm circuit switch	1	3	" " " "
8. Main and auxiliary wiring between machines and switch gear auxiliary transformer	-	1	Included in elec. bid
9. Generator panel	1	3	" " " "
10. A. C. ammeter	1	3	" " " "
11. A. C. voltmeter	1	3	" " " "
12. A. C. voltmeter switch	1	3	" " " "
13. D. C. ammeter	1	3	" " " "
14. D. C. voltmeter	1	3	" " " "
15. D. C. voltmeter switch	1	3	" " " "
16. 3 phase ammeter switch	1	3	" " " "
17. Synchronizing switch	1	3	" " " "
18. Governor control switch	1	3	" " " "
19. Indicating wattmeter	1	3	" " " "
20. Watthour meter	1	3	" " " "
21. Frequency indicator	1	3	" " " "
22. Unit type voltage regulator	1	3	" " " "
23. Oil circuit breaker	1	3	" " " "
24. Circuit breaker support	1	3	" " " "
25. Current and voltage transformer	1	3	" " " "
26. Synchroscope	-	1	" " " "
27. Synchroscope bracket	-	1	" " " "
28. Complete distribution panel for station auxiliaries	-	1	" " " "
29. Erection of switch gear equipment and distribution panel	-	1	" " " "
30. Station lighting fixtures	-	1	" " " "

APPENDIX IV

Explanation of items comprising "operating cost for Diesel plant"

Since the abscissa of the load duration curve represents time and ordinate represents power, the area under the curve represents energy output. For the predicted 1950 load curve, it is seen that one square inch of area is equivalent to 338,000 kilowatt hours. From planimeter readings, it is found that the area under the curve was 16.5 square inches. Thus the total energy output per season would be (338,000) 16.5 or 5,580,000 kwhr.

The LSV-16T engines operate on four percent Diesel pilot fuel. Hence, four percent of the total energy output (223,000 kwhr) would come from Diesel oil and ninety six percent (5,350,000 kwhr) would be furnished by a natural gas supply.

Figure 7 expresses the economy performance of the LSV-16T engine. The engines would be operated between 50-100% of full load in this instance. The 50% full load condition would give minimum economy, and from Figure 7, it is seen that the fuel rate for this situation is approximately 6700 btu per hphr of engine output. It was necessary to multiply this value by 1.39 to account for generator efficiency and a change in units. That is, at 50% full load operation, the fuel rate would be 9300 btu per kwhr of generator output. Similarly, at 50% full load operation on oil fuel, (.36)(1.39) or .500 lbs. of Diesel oil per kwhr of generator output would be required.

Assuming the heating value of natural gas to be 1000 btu per cubic foot, the volume required per season would be (5,350,000)(9300) over (1000) or 49,800,000 cubic feet. If the Diesel oil weighs approximately 6.82 lbs. per gallon, the volume required per season would be (223,000) over (.500)(6.82) or 65,400 gallons.

A personal interview with Mr. Chester Alder, Consumers Power representative, served to confirm the belief that his company could take on the task of supplying 49,800,000 cu. ft. of natural gas during the period June 10th to September 15th. Also, it was pointed out that the price schedule for this fuel would read as follows:

4,000,000 cu.ft.	$ 2400.00
6,000,000 cu.ft. @ 52¢ per 1000 cu.ft......	3120.00
39,800,000 cu.ft. @ 47¢ per 1000 cu.ft......	18700.00
Total cost............	$24,220.00

Information received at the Portland, Michigan R. E. A. Diesel plant indicated that Diesel oil would cost approximately 10 cents per gallon. Hence, the cost of Diesel oil for the season would be (65,400)(.10) or $6540 dollars.

Mr. G. C. Boyer, "Diesel and Gas Engine Power Plants," reports that for estimating lubrication oil consumption in connection with economic studies, one can usually assume 2000-3000 rated hphr per gallon of lubricating oil. Mr. Boyer arrived at this figure through interpretation of data presented by the 1937 ASME report on "Oil Engine Costs".

It was interesting to note data from the D. E. U. A., "Report on Heavy Oil Engine Working Costs, 1940-41". Page 33 lists lubricating oil data from this report. Page 34 shows a more up-to-date picture on lubricating oil economy.

It was concluded that the figure 2000-3000 rated hphr per gallon of lubricating oil represents a reasonable value for estimating purposes.

Data from D. E. U. A. "Report on Heavy-Oil Engine Working Costs, 1940-41":

TABLE II LUBRICATING OIL ECONOMIES

Year	% Stations with More than 2380 bhphr per gallon	All Stations Average bhphr per gallon
1922-23	29	1330
1923-24	25	1390
1924-25	22	1455
1925-26	33	1615
1926-27	36	1470
1927-28	32	1490
1928-29	25	1345
1929-30	23	1385
1930-31	24	1720
1931-32	32	2010
1932-33	44	2365
1933-34	37	2190
1934-35	44	2150
1935-36	43	2185
1936-37	47	2275
1937-38	40	1870
1938-39	48	2030
1939-40	40	2140
1940-41	43	2120

Data from ASME, "Report on Oil Engine Power Costs, 1948":

TABLE III ENGINE DETAILS AND OPERATING INFORMATION

Plant No.	Engine No.	Rated Eng. bhp	Rated hphr per Gallon (new lube oil)
82	4	3300	5370
82	5	3300	3471
82	6	3060	3088
82	7	3850	2640
686	1	2250	5131
686	2	3850	7882
686	6	3850	9121
52	4	2865	6442
52	5	2865	6739
52	6	3000	8105
1381	1,2,3,4	4 @ 3060	4115
109	5	2250	7229
109	6	3200	2829
111	6	3000	2410
42	2	2250	2842
42	3	2250	2789
1280	4	2000	3274
289	6	2150	5791
46	1	2250	1453
129	2	2250	2489
831	1	2250	2630

From the preceding, total engine output would equal (5,580,000) (1.39) or 7,750,000 hphr. Assuming a value of 2600 hphr per gallon, the lubricating oil requirements per season would be (7,750,000) over (2600) or 2980 gallons. Mr. J. H. Keen of the Wolverine Electric Co-op remarked that 55 cents per gallon would represent a current price for lube oil. Hence, the estimated cost for lubricating oil would be (2980)(.55) or 1640 dollars.

The estimate on plant labor was based on the following: Mr. G. C. Boyer, in his "Diesel and Gas-Engine Power Plants", presented a graphical illustration of plant labor data using information from the 1937 ASME Report on Oil Engine Cost. This information appears in Figure 8. With reference to Figure 8, it is seen this data indicates that a capacity of 6900 bhp would require 4 man-hours per installed brake horsepower per year. The foregoing would mean (6900)(4) or 27,600 man-hours per year. For a season of 94 days, the labor requirement would be (94) (27,600) over 365 or 7100 man-hours.

Figure 8 also illustrates Mr. Lee Schneitter's interpretation of plant labor statistics for 1937. In terms of his graphical presentation, a plant of 5000 KW capacity would require 25,000 man-hours per year. For a 94 day period this would mean a total of 6520 man-hours.

A study of the 1948 Report on Oil Engine Cost revealed that six plants listed had essentially the engine size in question. Data on these stations is offered.

Plant No.	Total KW Capacity	Kwhr per man-hour
82	11,622	862
686	8,976	861
52	8,379	1084
1381	8,220	1267
109	6,831	663
42	4,096	814

The average kwhr per man-hour for this group is 925.

Since this proposal involves 5,580,000 kwhr per season, the man-hours per season would be 5,580,000 over 925 or 6030.

It was concluded that 7000 man-hours should be used for estimating purposes. The probable average wage rate to be paid in this locality would be approximately $1.75 per hour. Hence, estimated plant labor cost will equal (7000)(1.75) or $12,250 dollars.

Fixed charges for power producing machinery are determined generally on the basis that an equal payment will be made each year covering both the interest on the outstanding indebtedness as well as a portion of the principal. The annual fixed charges required to spread the investment cost over a period of twenty years was determined through use of an equal annual payment table.* For a total investment of $750,000 and assuming a 6% interest rate, the annual payment would equal (750,000)(.0872) or 65,500 dollars.

To establish repair and miscellaneous costs, the ASME "Report on Oil Engine Cost, 1948" was used as follows. There were six plants listed whose installations involved engines approximately of the size under consideration. A tabulation for these stations was made.

---

1 Footnote on payment table.

REPAIR AND MISCELLANEOUS COSTS

	Plant No. 52	Plant No. 82	Plant No. 109	Plant No. 686	Plant No. 1381	Plant No. 1352
1943	1.14	-	-	0.49	0.27	0.96
1944	1.11	-	-	0.83	0.47	2.48
1945	1.67	-	-	0.27	0.56	1.35
1946	1.56	-	-	1.00	0.53	2.99
1947	2.45	2.29	0.43	1.00	0.47	-
1948	1.22	2.45	0.53	0.79	0.64	-

The author concluded that 1.5 mills per net kwhr would be a representative value to use for estimating purposes. Hence, this item would involve a total of (5,580,000)(.0015) or 8350 dollars.

APPENDIX V

ESTIMATED PACKAGE BOILER COST DATA

Fixed Charges--

(1) Cost of a (VU-10)16B, Combustion Engineering-Superheater, Inc., boiler complete with setting materials, burner windbox, gas burners, forced draft fan and drive, combustion control, and including the services of a superintendent........$31,500.00

(2) Cost of labor required for installation........... 15,400.00

(3) Cost of alterations to North Campus boiler room... 10,000.00

Total investment cost..............$56,900.00

The annual fixed charges required to spread this investment cost over a period of twenty years was determined through use of an equal annual payment table. For a total investment of $56,900 and assuming a 6% interest rate, the annual payment would equal (56900)(.0872) or 4970 dollars.

Operating cost--

(1) The estimated maintenance cost would be $1575 over 10 or 157.5 dollars per year. Since the unit would be expected to operate only 94 days of the year, the maintenance cost would be (157.5)(94) over 365 or 41 dollars.

(2) It will be assumed that package boiler labor can be considered as part of the Diesel plant labor costs.

(3) An estimate on fuel cost was obtained as follows:

Assume an average flow of 30,000 lb. per hour for 94 days. This would total (30000)(24)(94) or 6,775,000 pounds of process steam. Assume a liquid at 140 degrees Fahrenheit entering the boiler and a saturated vapor at 100 psi gage leaving. This would require addition of heat energy at the rate of approximately 1082 btu per pound. Since the heating value of natural gas is about 1000 btu per cubic foot and assuming overall boiler efficiency to be 76.1 percent, the volume of gas required is (6,775,000)(1082) over (1000)(.761) or 9,640,000 cu. ft. Applying the data in Appendix IV (cost of natural gas), the boiler fuel cost would be (9,640,000)(.47) over (1000) or 4540 dollars.

APPENDIX VI

The data on "electrical energy bought and sold" denotes that $4531 was the purchase price for 181,000 kwhr in the period June 10 - September 15, 1950. This would represent a unit cost of 25 mills per kwhr.

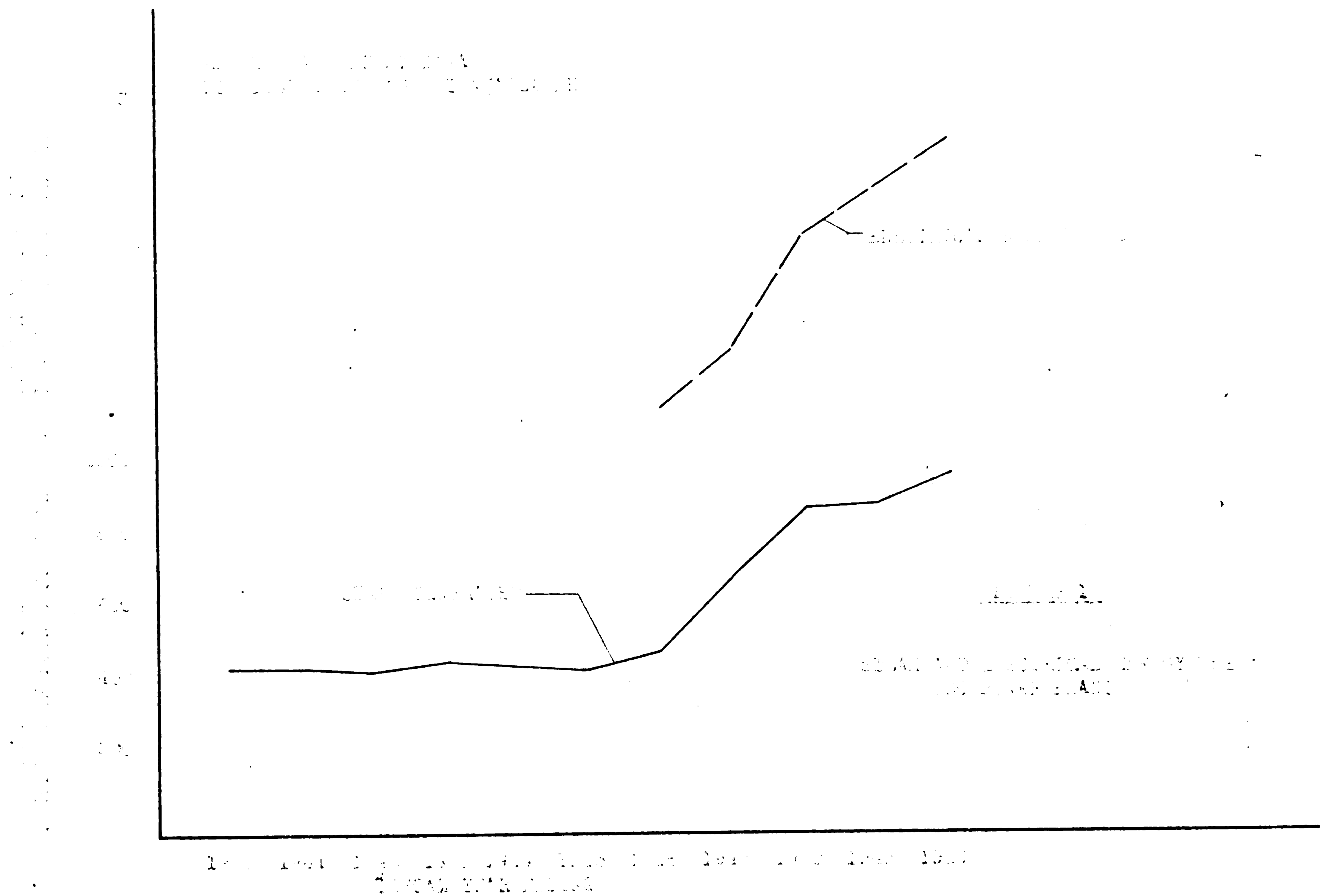
The Diesel installation could be used to handle such a situation. Inasmuch as fixed costs, etc., have already been charged to the summer account, the cost for this additional service would involve cost of fuel required, lube oil charge, and cost of repairs. That is, the unit cost of operation would be determined as follows:

(30760 plus 1640 plus 8350) over 5,580,000 or 7.3 mills per kwhr. Thus the Diesel installation would reduce the cost by (.025 minus .0073) (181,000) or $3200 per summer period.

ELECTRICAL ENERGY BOUGHT AND SOLD TO LANSING BY THE MICHIGAN STATE COLLEGE POWER PLANT

Period June 10th - September 15th

Year	KWHR Bought	KWHR Sold	Liability	Asset	Overall Cost
1945	49,000	269,000	$1231	$538	$693
1946	41,000	297,000	1031	594	437
1947	149,000	293,000	3731	586	3145
1948	175,000	398,000	4381	796	3585
1949	161,000	392,000	4031	784	3247
1950	181,000	388,000	4531	776	3755



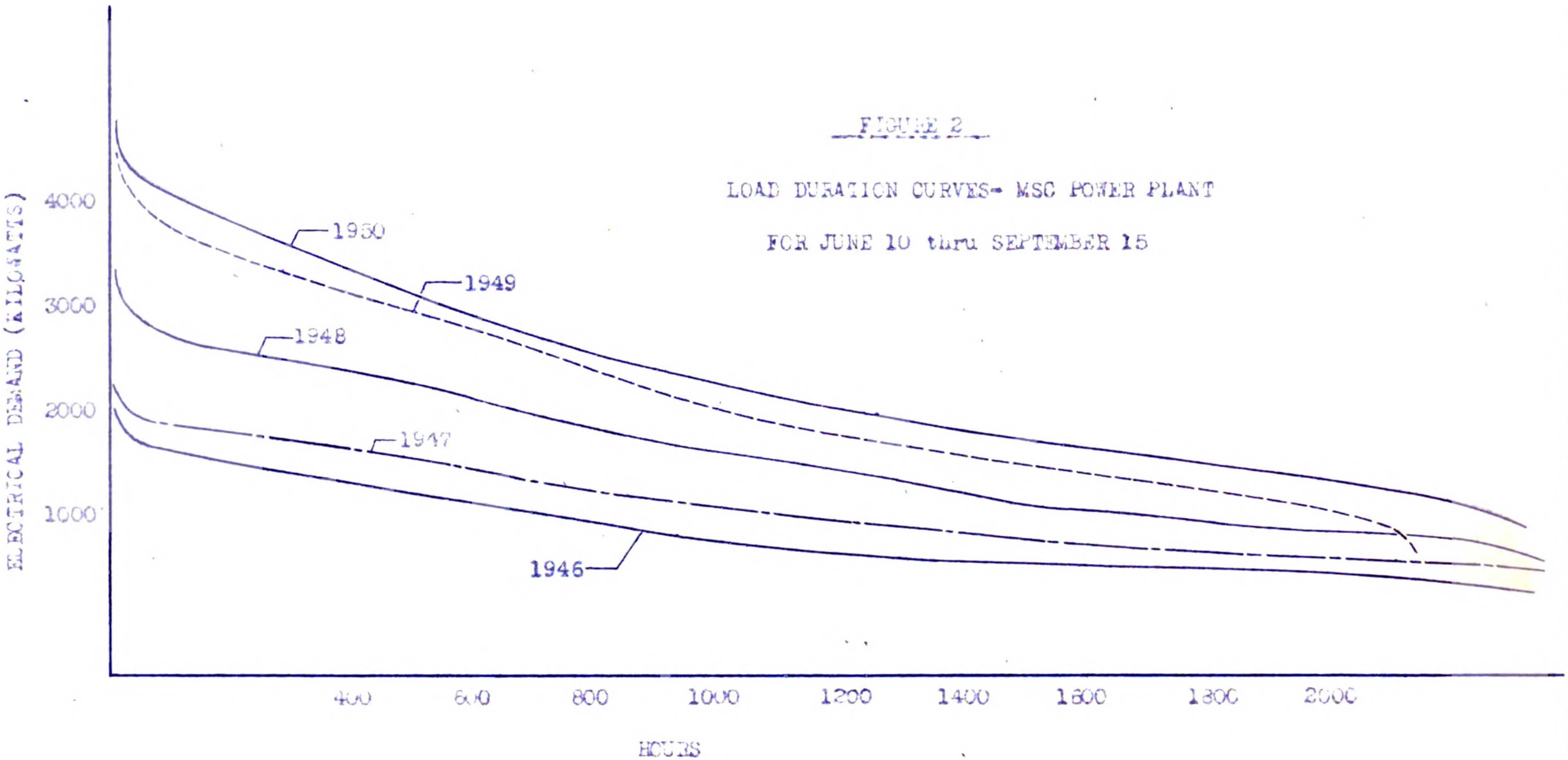


FIGURE 2

LOAD DURATION CURVES- MSC POWER PLANT

FOR JUNE 10 thru SEPTEMBER 15

M.DELICH 12-[illegible]-50

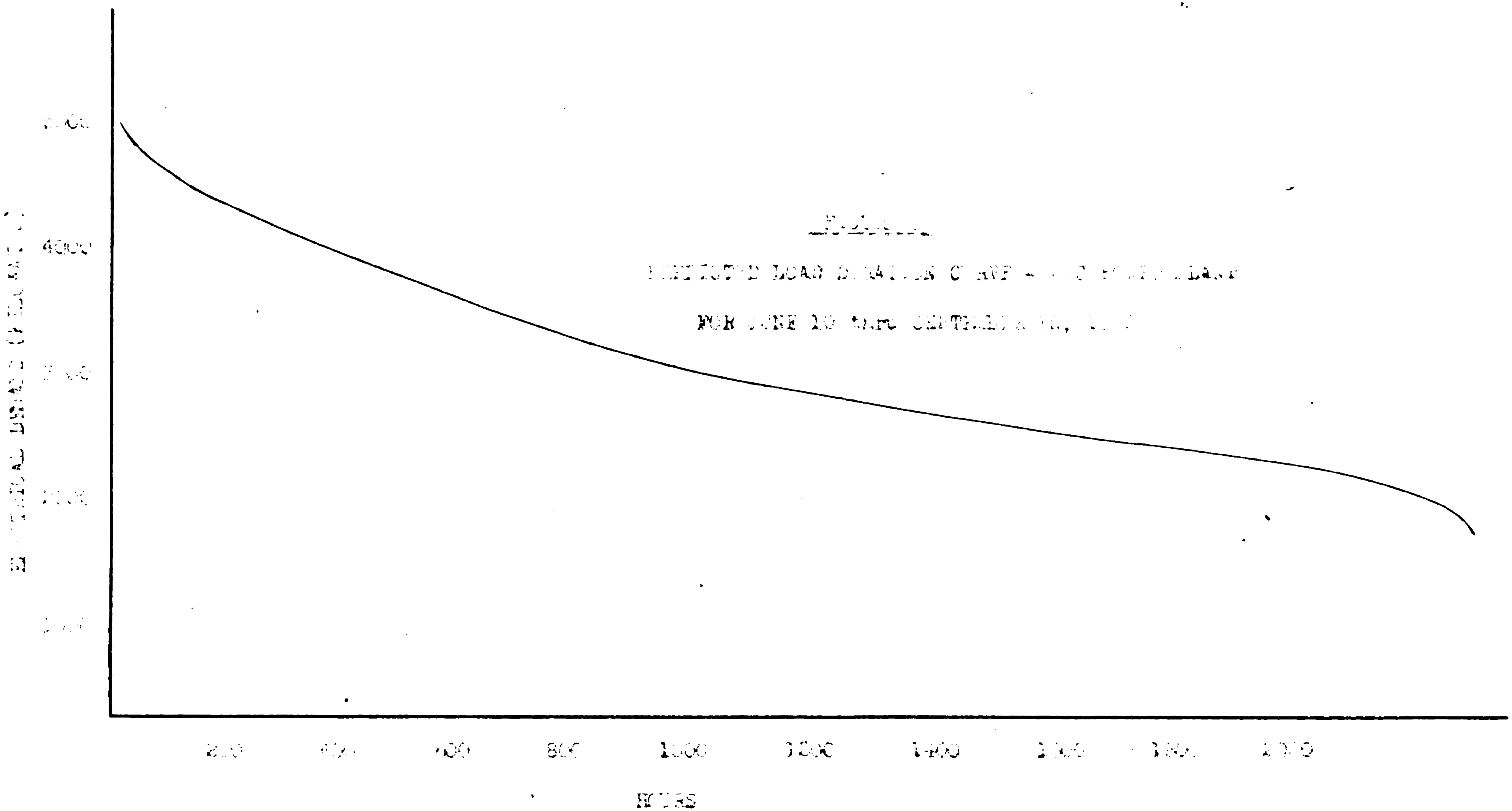
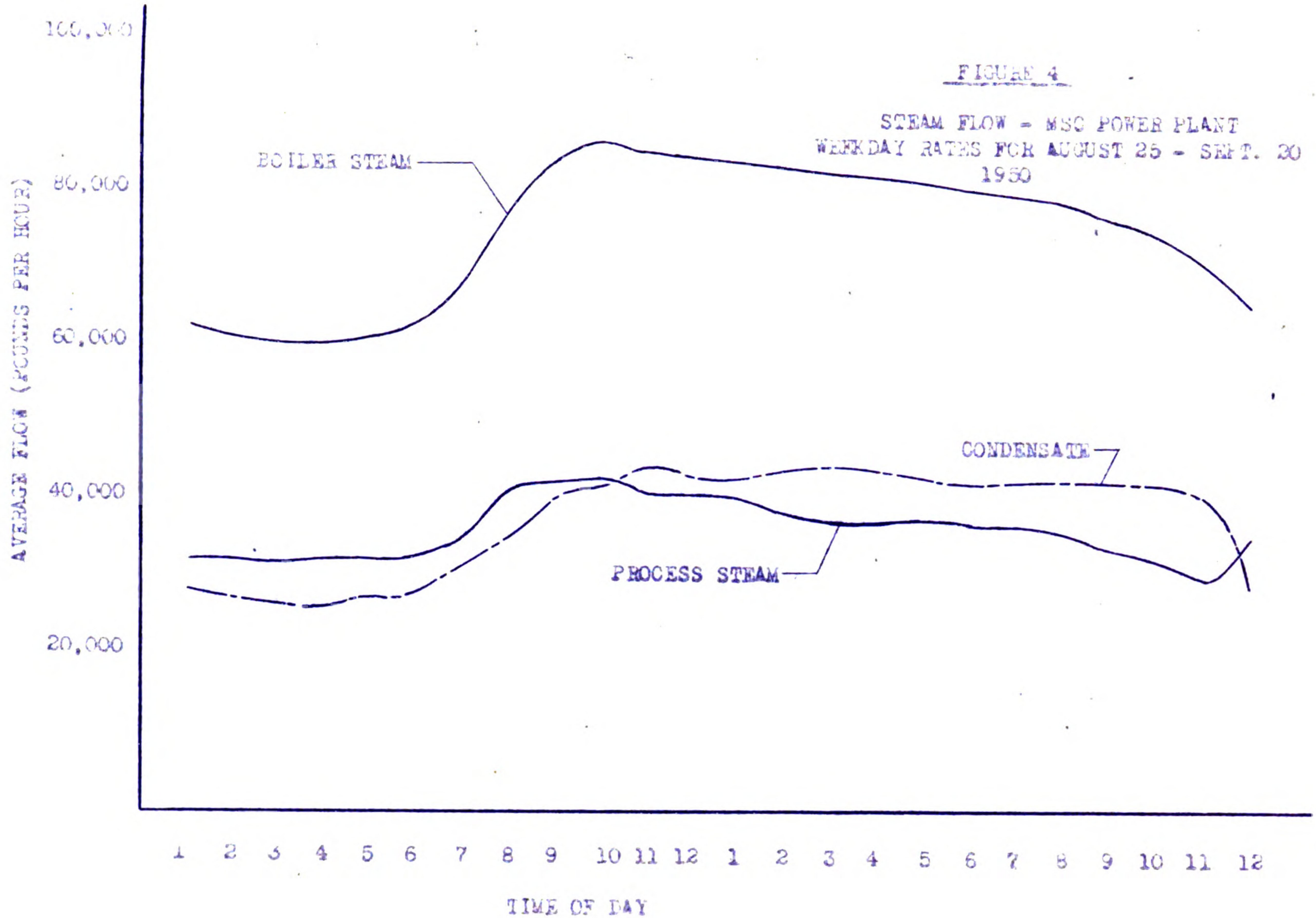
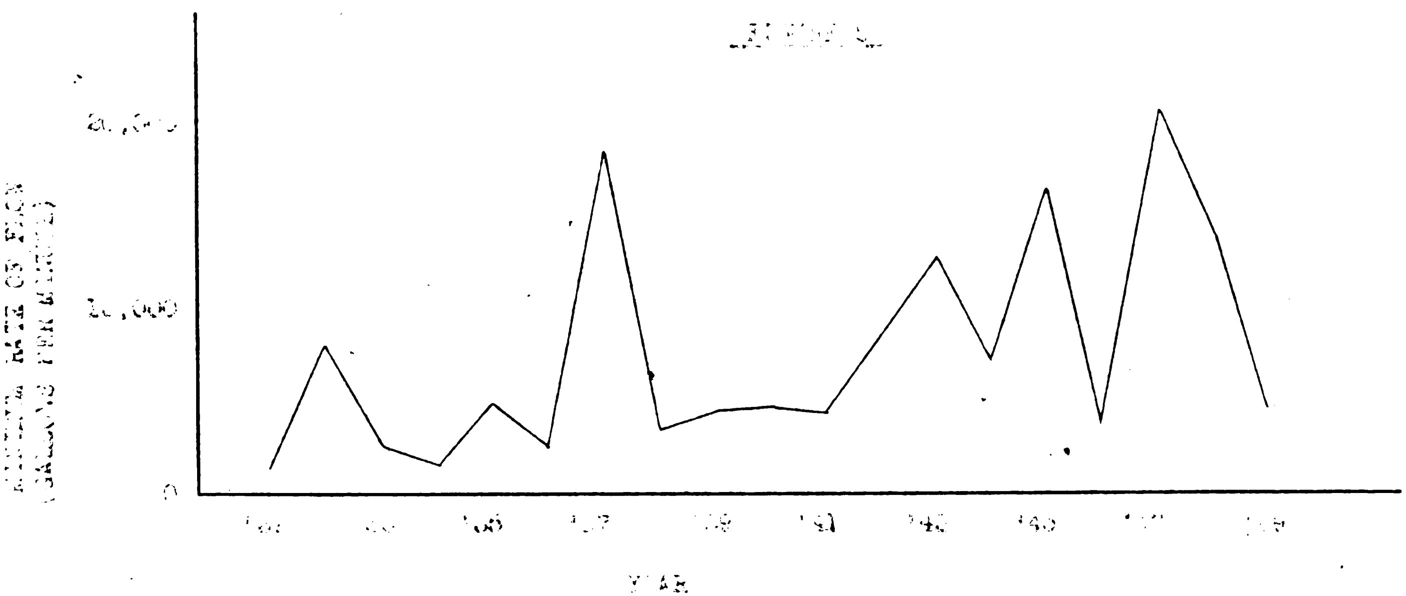

4000
800
1400
HOURS

FIGURE 4

STEAM FLOW - MSC POWER PLANT
WEEKDAY RATES FOR AUGUST 25 - SEPT. 30
1950



M.DELICH 12-21-50


10,000
0
YEAR

[illegible]
[illegible]

FIGURE 6

VACUUM CORRECTION CURVES
NO.3 - 3000KW - CONDENSING AUTOMATIC EXTRACTION UNIT
MSC POWER PLANT

BASIC STEAM CONDITIONS:
230 PSIG - 550 deg.F - 28 in. Hg. Vac.
EXTRACTION AT 5 PSI GAGE

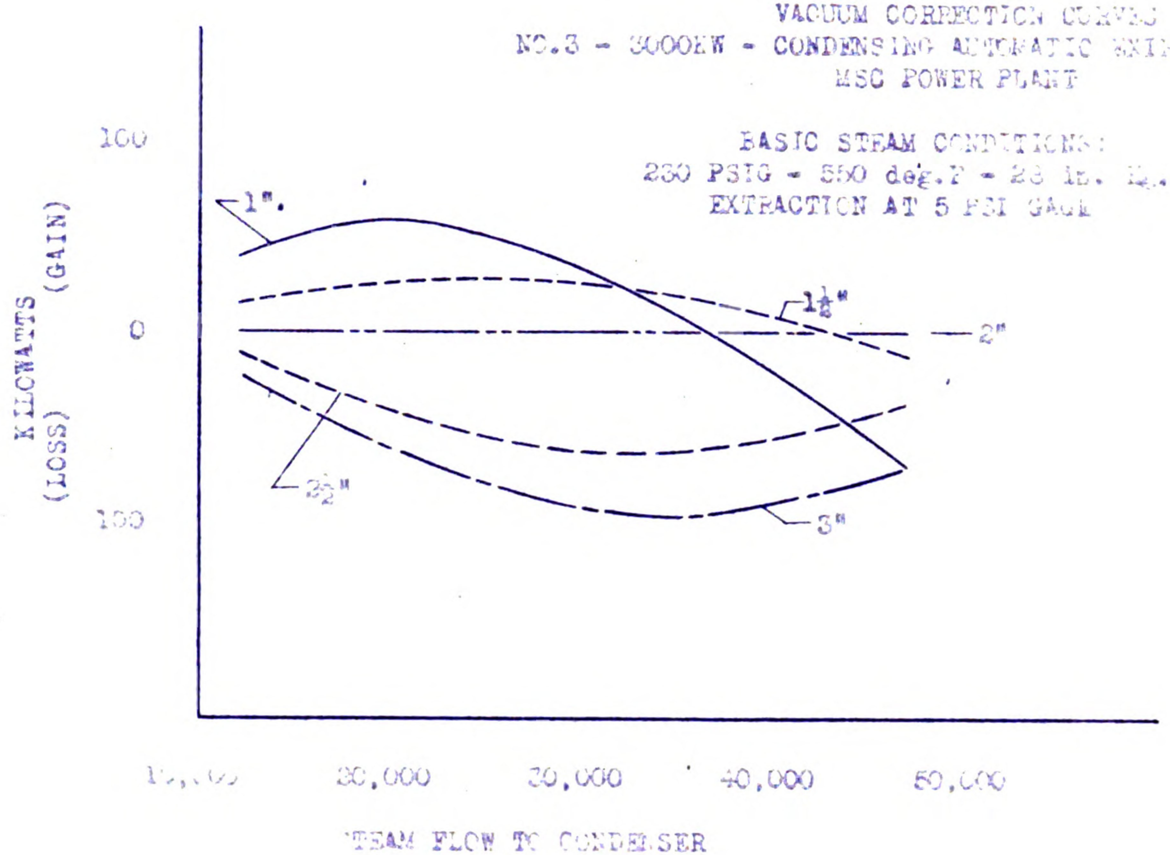
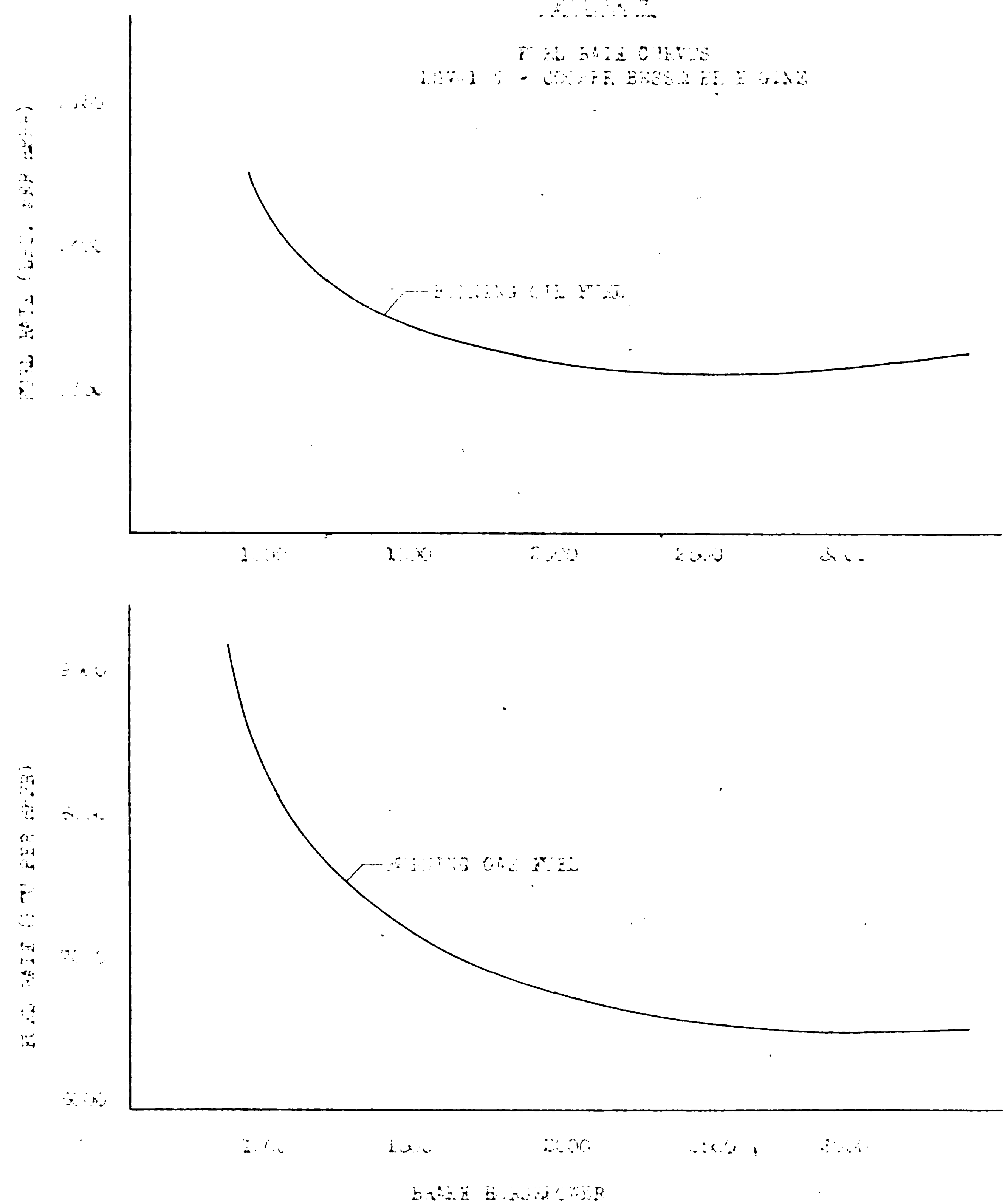
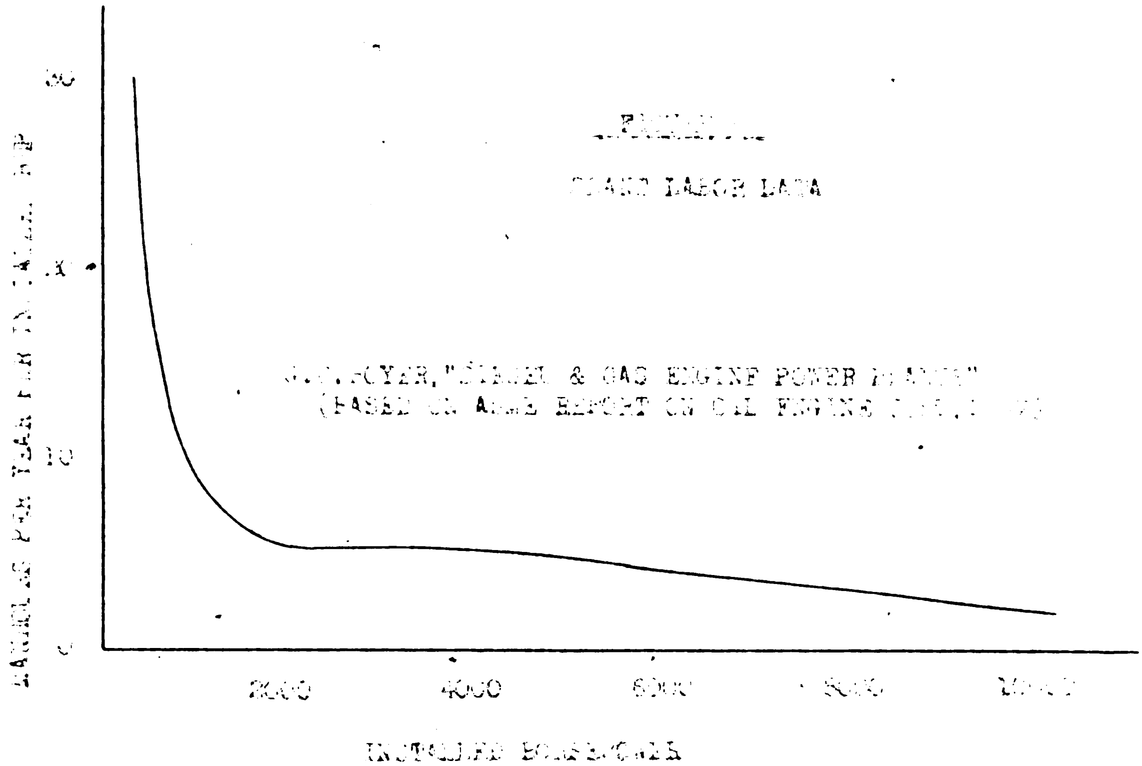
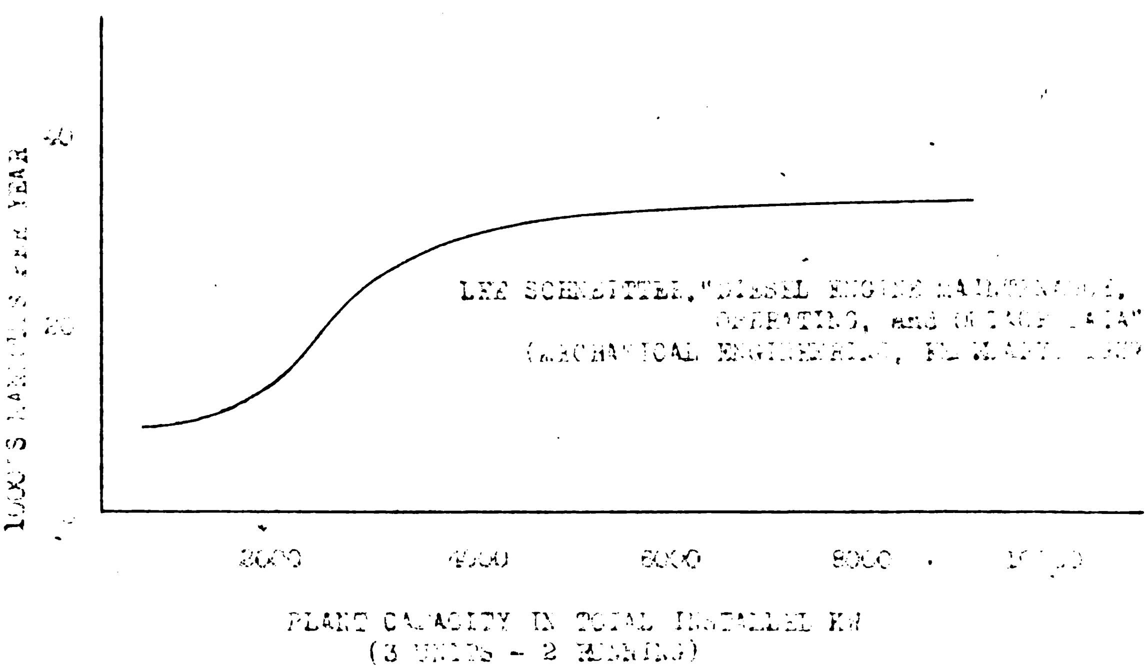


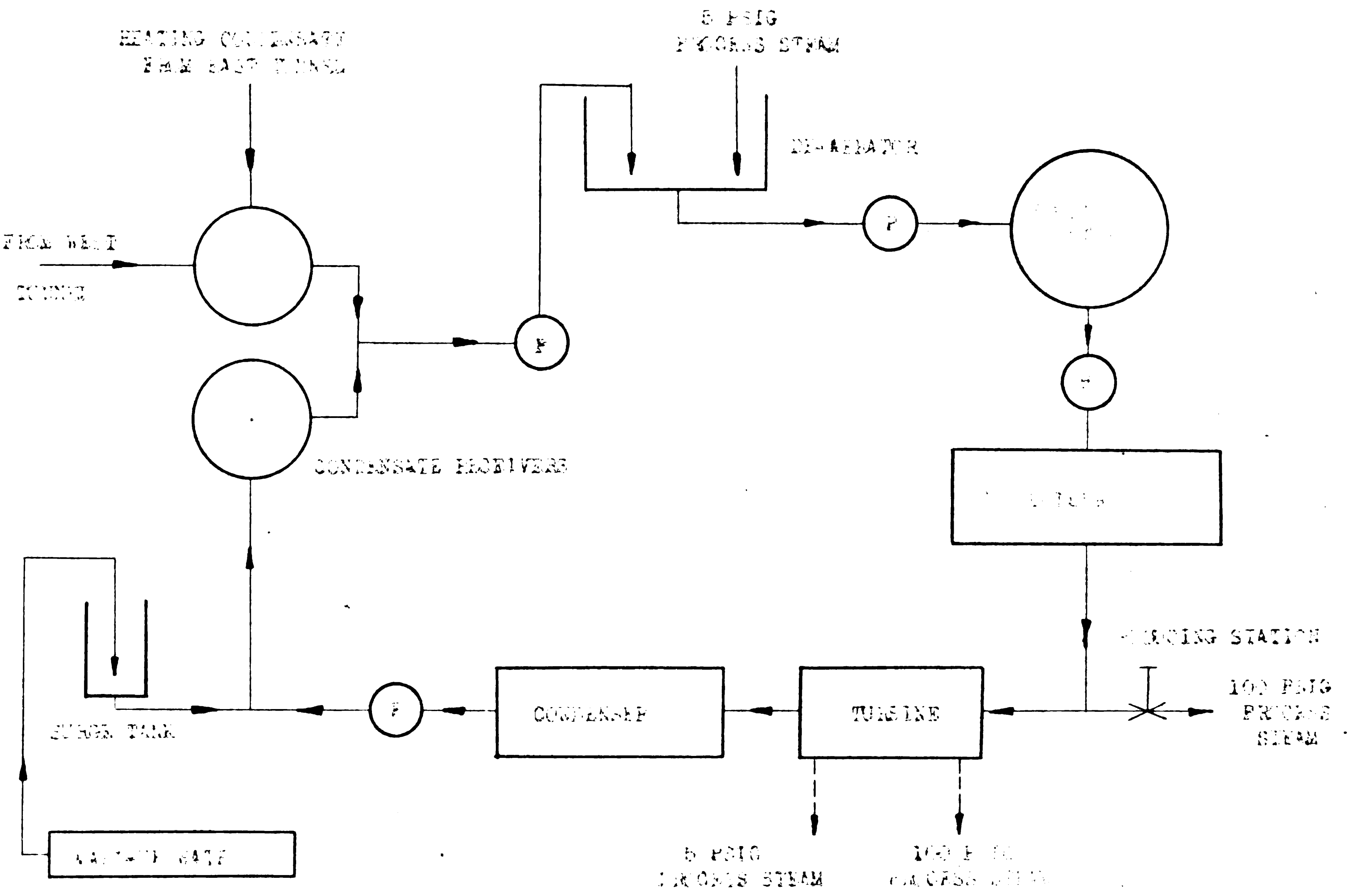
FIGURE 2

FUEL RATE CURVES
LEVEL [illegible] - COOPER BESSEMER ENGINE




PLANT LABOR DATA
& GAS ENGINE POWER
10
0
2000
4000


40
20
1000'S
YEAR
LEE SCHNEITTER, "DIESEL ENGINE
OPERATING, AND
MECHANICAL ENGINEERING,
2000
4000
6000
8000
PLANT CAPACITY IN TOTAL INSTALLED KW
(3 UNITS - 2 RUNNING)


HEATING CONDENSATE
FROM EAST TUNNEL
FROM WEST
TUNNEL
5 PSIG
PROCESS STEAM
DE-AERATOR
P
CONDENSATE RECEIVERS
SURGE TANK
CONDENSER
TURBINE
100 PSIG
PROCESS
STEAM
5 PSIG
PROCESS STEAM

TIME of DAY	TEMPERATURE (deg. F), [illegible]																							
6-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7-8	100	103	104	-	-	100	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8-9	103	104	104	-	100	102	100	-	104	100	-	-	-	100	-	-	101	100	104	[illegible]	101	[illegible]	104	102	104
9-10	104	105	104	-	100	102	102	-	105	102	100	-	-	100	-	-	102	100	[illegible]	[illegible]	107	107	105	108	106
10-11	105	105	104	-	100	102	102	-	105	102	102	-	106	104	-	100	102	101	102	108	[illegible]	[illegible]	106	[illegible]	108
11-N	105	108	104	-	101	102	102	-	103	100	100	-	-	104	-	100	105	-	105	[illegible]	107	[illegible]	107	106	106
N-1	105	105	104	-	[illegible]	107	103	-	102	-	-	-	-	100	-	102	103	-	[illegible]	[illegible]	[illegible]	-	108	106	106
1-2	106	106	104	-	[illegible]	[illegible]	[illegible]	-	106	-	-	-	-	100	100	102	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	108	105	[illegible]
2-3	107	108	103	-	[illegible]	107	101	-	105	100	-	100	100	100	100	102	103	102	[illegible]	[illegible]	[illegible]	-	104	106	[illegible]
3-4	107	106	104	-	[illegible]	[illegible]	[illegible]	-	104	100	-	-	104	100	104	102	100	102	[illegible]	[illegible]	[illegible]	[illegible]	108	108	104
4-5	107	106	104	-	[illegible]	[illegible]	[illegible]	-	104	-	-	-	104	-	-	104	105	-	[illegible]	[illegible]	[illegible]	[illegible]	106	104	104
5-6	106	108	104	-	-	[illegible]	[illegible]	-	-	-	-	-	-	-	-	102	105	-	[illegible]	-	-	-	-	-	[illegible]
6-7	106	106	[illegible]	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	104	-	[illegible]	[illegible]	-	-	102	-	-
7-8	100	105	[illegible]	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	104	-	[illegible]	-	-	-	-	-	-
8-9	100	106	-	-	-	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	105	-	[illegible]	-	-	-	-	-	-
9-10	-	100	100	-	-	[illegible]	[illegible]	-	-	100	100	-	-	-	-	-	108	-	[illegible]	-	-	-	-	-	-
10-11	-	-	-	-	-	[illegible]	[illegible]	-	-	-	-	[illegible]	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-
11-[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE [illegible]

CONDENSER COOLING WATER DATA - [illegible] POWER PLANT
FOR JUNE 20 thru SEPTEMBER 15, 1952

MLIT-232

Sheet No. 1 of 2 sheets

MECHANICAL ENGINEERING LABORATORY
MICHIGAN STATE COLLEGE

Running Log of LOAD DURATION DATA - JUNE 10 thru SEPT. 15
MICHIGAN STATE COLLEGE POWER PLANT

Observers: Lee, Douglas; Delich, Michael

Date Nov. 22, 19 50

No.	Load (KW)	1946 No. Hours	1946 Total Hours	1947 No. Hours	1947 Total Hours	1948 No. Hours	1948 Total Hours	1949 No. Hours	1949 Total Hours	1950 No. Hours	1950 Total Hours
1	2600	- -	- -	1	1	129	337	53	744	94	839
2	2500	- -	- -	2	3	140	477	71	815	70	909
3	2400	1	1	0	3	90	567	70	885	117	1026
4	2300	0	1	5	8	50	617	68	953	84	1110
5	2200	3	4	38	46	61	678	91	1044	120	1230
6	2100	5	9	55	101	90	768	91	1135	114	1344
7	2000	17	26	167	268	80	848	118	1253	143	1487
8	1900	45	71	159	427	103	951	87	1340	105	1592
9	1800	119	190	122	549	176	1127	184	1524	161	1753
10	1700	147	337	105	654	124	1251	107	1631	133	1886
11	1600	113	450	100	754	96	1347	198	1829	131	2017
12	1500	130	580	175	929	116	1463	58	1887	93	2110
13	1400	106	686	154	1083	171	1634	167	2054	107	2217
14	1300	104	790	173	1256	214	1848	42	2096	90	2307
15	1200	148	938	215	1471	399	2247	57	2153	4	2311
16	1100	204	1142	198	1669	80	2327	1	2154	- -	- -
17	1000	397	1539	467	2133	24	2351	- -	- -	- -	- -
18	900	550	2089	203	2336	0	2351	- -	- -	- -	- -
19	800	216	2305	8	2344	1	2352	- -	- -	- -	- -
20	700	24	2329	- -	- -	- -	- -	- -	- -	- -	- -
21	600	1	2330	- -	- -	- -	- -	- -	- -	- -	- -
22											
23											
24											
25											

Remarks:

MLIT-232

MECHANICAL ENGINEERING LABORATORY
MICHIGAN STATE COLLEGE

Running Log of LOAD DURATION DATA - JUNE 10 thru SEPT. 15
MICHIGAN STATE COLLEGE POWER PLANT

Observers: Lee, Douglas; Delich, Michael

Date Nov. 22, 1950

		1946		1947		1948		1949		1950	
No.	Load (KW)	No. Hours	Total Hours	No. Hours	Total Hours	No. Hours	Total Hours	No. Hours	Total Hours	No. Hours	Total Hours
1	4600	-	-	-	-	-	-	-	-	1	1
2	4500	-	-	-	-	-	-	1	1	2	3
3	4400	-	-	-	-	-	-	1	2	5	8
4	4300	-	-	-	-	-	-	2	4	5	13
5	4200	-	-	-	-	-	-	5	9	10	23
6	4100	-	-	-	-	-	-	6	15	22	45
7	4000	-	-	-	-	-	-	9	24	35	80
8	3900	-	-	-	-	-	-	20	44	37	117
9	3800	-	-	-	-	-	-	35	79	50	167
10	3700	-	-	-	-	-	-	33	112	55	222
11	36000	-	-	-	-	-	-	69	181	42	264
12	3500	-	-	-	-	1	1	44	225	33	297
13	3400	-	-	-	-	1	2	48	273	46	343
14	3300	-	-	-	-	1	3	48	321	51	394
15	3200	-	-	-	-	4	7	64	385	43	437
16	3100	-	-	-	-	6	13	74	459	52	489
17	3000	-	-	-	-	14	27	83	542	63	552
18	2900	-	-	-	-	21	48	50	592	42	594
19	2800	-	-	-	-	50	98	64	656	79	673
20	2700	-	-	-	-	110	208	35	691	72	745
21											
22											
23											
24											
25											

Remarks:

MLIT-232

Sheet No. 1 of 3 sheets

MECHANICAL ENGINEERING LABORATORY
MICHIGAN STATE COLLEGE

Running Log of CALCULATED PROCESS STEAM FLOW

MICHIGAN STATE COLLEGE POWER PLANT

Observers: Lee, Douglas; Delich, Michael

Date Oct. 6, 1950

(Pounds per Hour)

No.	Hour	F Sept. 1	S Sept. 2	S Sept. 3	M Sept. 4	T Sept. 5	W Sept. 6	Th Sept. 7	F Sept. 8	S Sept. 9	S Sept. 10
1	12-1	28000	31500	29100	31300	31300	40400	38500	28700	30200	29800
2	1-2	32300	30200	31100	30000	11500	41700	36300	30900	30700	27600
3	2-3	31100	31400	30900	30600	43700	40200	36300	28100	31300	29200
4	3-4	31500	30100	29700	31400	33600	43100	38100	29200	30000	29100
5	4-5	31100	31000	29800	31300	37800	42200	33800	25500	30000	28100
6	5-6	30000	32100	31500	26400	33300	38300	36000	29900	28900	21800
7	6-7	22000	27800	30600	33500	30100	43300	39300	24500	31000	24300
8	7-8	42300	33300	28300	30500	29100	41600	42600	23500	31400	42000
9	8-9	39500	30700	31800	31500	37600	49900	42100	26300	33400	30000
10	9-10	29000	32500	29600	35100	41500	48700	44100	30800	34100	32300
11	10-11	30600	33000	29300	30700	42700	48200	38100	20300	30100	30300
12	11-12	31300	36000	30400	36100	46200	46800	39700	33800	37100	29800
13	12-1	42500	33800	32700	31800	47200	46700	32400	27800	37500	30300
14	1-2	31500	28700	33200	32200	42800	37700	31200	24200	28100	27700
15	2-3	34200	32400	31000	33400	39700	41900	35900	24800	32200	31700
16	3-4	34700	31800	30900	32700	38500	42800	38300	27000	29700	30200
17	4-5	35900	30800	29800	32200	37500	41900	37800	27400	31400	29300
18	5-6	32900	30900	30900	31500	38500	40900	32700	31700	30400	29500
19	6-7	31800	32800	30600	31500	38300	40600	32300	37800	31000	29700
20	7-8	32100	31200	31100	30600	38000	39100	31300	36400	30600	29200
21	8-9	31200	31700	29800	30800	37500	37700	32100	30900	31400	29500
22	9-10	44600	33600	35100	28500	43000	39600	28800	33800	30400	29500
23	10-11	36000	31300	28500	35900	41700	43900	35300	32800	31600	29500
24	11-12	32800	32400	29700	34300	52500	41200	32800	32400	30800	30500
25											

Remarks:

MECHANICAL ENGINEERING LABORATORY
MICHIGAN STATE COLLEGE

Running Log of CALCULATED PROCESS STEAM FLOW

MICHIGAN STATE COLLEGE POWER PLANT

Observers: Lee, Douglas; Delich, Michael

Date Oct. 6, 1950

(Pounds per Hour)

No.	Hour	M Sept. 11	T Sept. 12	W Sept. 13	Th Sept. 14	F Sept. 15	S Sept. 16	S Sept. 17	M Sept. 18	T Sept. 19	W Sept. 20
1	12-1	28800	29500	31800	32600	39100	43700	46300	48200	42700	35200
2	1-2	29900	29500	29600	32100	36900	33900	47000	45200	44500	31900
3	2-3	28900	28400	29400	31500	36200	33700	45100	46100	40900	28200
4	3-4	29400	27700	29200	30100	35200	33200	46100	44800	40800	31500
5	4-5	27300	28700	28800	31500	35900	34000	46200	44300	43000	30900
6	5-6	30600	28700	28500	31400	37300	35400	46800	44600	41500	33500
7	6-7	24900	28500	28800	27200	33300	30700	49700	46800	40200	28000
8	7-8	31200	27500	36000	34100	41200	40700	43800	54600	46500	40200
9	8-9	33200	39300	36600	49000	47500	36800	33100	60100	54500	55300
10	9-10	33700	37100	48600	47100	48100	36800	48400	57400	58300	54300
11	10-11	35000	35900	37400	46300	55200	31000	50400	59600	57700	57000
12	11-12	42100	34100	36400	48600	49900	54900	48100	56900	59900	55700
13	12-1	39800	29000	30100	46400	52300	- - -	47400	54600	59500	51500
14	1-2	34600	39600	38300	48600	54700	- - -	51500	53700	55700	47800
15	2-3	37300	34300	37200	43300	50100	51300	49000	53700	48300	40500
16	3-4	35300	35800	39500	41500	50800	51300	46000	37500	60500	38600
17	4-5	34300	35600	36500	48800	45200	51600	46000	53900	56400	36900
18	5-6	27100	36600	36100	44300	45500	45500	48000	55700	54000	38900
19	6-7	33300	35200	35100	41800	48300	46500	30000	56100	51600	40700
20	7-8	34500	34900	35000	46800	40300	50500	56100	52600	50600	41600
21	8-9	30000	32000	37000	43300	48300	46500	56100	50800	47600	34300
22	9-10	28500	35200	34500	38300	46300	50300	46400	47400	40000	33200
23	10-11	30800	32700	35300	38800	46100	49100	47900	56200	44500	36900
24	11-12	21100	32100	35100	41600	44300	48900	50100	56100	45000	- - -
25											

Remarks:

MLIT-232

MECHANICAL ENGINEERING LABORATORY
MICHIGAN STATE COLLEGE

Running Log of CALCULATED PROCESS STEAM FLOW
MICHIGAN STATE COLLEGE POWER PLANT

Observers: Lee, Douglas; Delich, Michael

Date Oct. 6, 1950

(Pounds per Hour)

No.	Hour	F Aug. 25	S Aug. 26	S Aug. 27	M Aug. 28	T Aug. 29	W Aug. 30	Th Aug. 31
1	12-1	- - -	27800	20300	17600	- - -	31200	29900
2	1-2	- - -	5000	20400	18700	- - -	31200	31600
3	2-3	- - -	25000	300	20500	- - -	31100	30700
4	3-4	- - -	21300	42000	20300	- - -	33100	29900
5	4-5	213	21300	19600	18200	- - -	31100	31500
6	5-6	- - -	24500	27200	13200	- - -	34300	35700
7	6-7	- - -	21900	18800	23200	- - -	36000	34000
8	7-8	- - -	22700	18400	30000	- - -	27000	32300
9	8-9	- - -	24500	17400	28500	- - -	44800	35800
10	9-10	- - -	23200	24100	35200	- - -	27100	37100
11	10-11	- - -	20400	21700	30300	- - -	36500	37600
12	11-12	- - -	20000	22700	36300	- - -	36900	38100
13	12-1	- - -	29500	22800	35100	- - -	38600	33100
14	1-2	- - -	15400	19700	28000	- - -	32500	33400
15	2-3	- - -	30100	22600	32900	- - -	33500	35100
16	3-4	- - -	14700	20300	34600	- - -	36100	35800
17	4-5	43600	23200	20600	333000	- - -	35100	36300
18	5-6	24700	14100	18900	33600	- - -	33800	34300
19	6-7	24300	27400	22000	29700	- - -	32900	33400
20	7-8	19700	23700	19600	21800	- - -	35800	36800
21	8-9	26800	19000	22300	37400	- - -	33300	33400
22	9-10	28900	21800	19200	29700	- - -	33400	31100
23	10-11	18800	19900	22900	34100	- - -	36600	36800
24	11-12	23900	21100	20300	21900	- - -	34300	35700
25								

Remarks:

MLIT-232

MECHANICAL ENGINEERING LABORATORY
MICHIGAN STATE COLLEGE

Running Log of HEATING CONDENSATE DATA - APPROXIMATE CHECK ON PROCESS STEAM DATA - MICHIGAN STATE COLLEGE POWER PLANT

Observers: Lee, Douglas; Delich, Michael

Date Dec. 28, 1950

No.	Hour			W Sept. 6	Th Sept. 7	F Sept. 8	S Sept. 9	S Sept. 10				
				(Pounds per Hour)								
1	12-1			- - -	- - -	- - -	- - -	- - -				
2	1-2			- - -	- - -	- - -	- - -	- - -				
3	2-3			- - -	- - -	- - -	- - -	- - -				
4	3-4			- - -	- - -	- - -	- - -	- - -				
5	4-5			- - -	- - -	- - -	- - -	- - -				
6	5-6			- - -	- - -	- - -	- - -	- - -				
7	6-7			- - -	- - -	- - -	- - -	- - -				
8	7-8			- - -	- - -	- - -	- - -	- - -				
9	8-9			- - -	- - -	- - -	- - -	- - -				
10	9-10			- - -	37600	- - -	- - -	19800				
11	10-11			- - -	33500	- - -	18000	16300				
12	11-12			- - -	31300	28800	18800	19200				
13	12-1			- - -	- - -	24000	19800	19800				
14	1-2			32500	29500	26300	- - -	20500				
15	2-3			33000	31300	24400	17200	20100				
16	3-4			30400	30300	24800	15600	- - -				
17	4-5			31300	33500	26900	20600	- - -				
18	5-6			30400	27400	24000	- - -	- - -				
19	6-7			- - -	- - -	- - -	- - -	- - -				
20	7~~0~~8			- - -	- - -	- - -	- - -	- - -				
21	8-9			29900	- - -	- - -	- - -	- - -				
22	9-10			31500	- - -	- - -	- - -	- - -				
23	10-11			21500	- - -	- - -	- - -	- - -				
24	11-12			20900	- - -	- - -	- - -	- - -				
25												

Remarks: