The Integration Of PEPSE Into The Performance Testing Program At The Bruce Mansfield Power Plant

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ABSTRACT

The PEPSE[1] program has been a useful tool in analyzing the performance of power plant equipment. Initially, emphasis was placed on developing a model to obtain the design heat balance conditions. The model produced results that were within 0.05% of design heat balance load and within 1 Btu/KWHR of the design heat rate. Then a model was developed to simulate the actual turbine cycle. This involved a more detailed model of the low pressure turbines, condenser, and feedwater heater system. The results of this model were used as a basis for the actual turbine cycle.

Once the basis was developed, the program was used to determine the effects actual operating procedures had on plant efficiency. Sensitivity studies involving the feedwater heater system were conducted and the results indicated the importances of proper cycle operation.

The program was also used in analyzing actual performance test data. The effect of cycle isolation and changes in individual component efficiency were quantified so that actual turbine performance could be monitored.

Individual component modeling was also accomplished. A condenser model was developed and sensitivity studies were conducted to determine the affect of circulating water flow, condenser duty, and fouling on condenser performance. The results were used in an economic study to determine if new circulating water pump impellers could be justified.

The feedwater heaters have also been successfully modeled. Presently, the condenser and feedwater heater design mode models are being incorporated into the turbine model and actual performance test data will be analyzed through the use of PEPSE.

INTRODUCTION

The PEPSE program has been used to model the three units at the Bruce Mansfield electric power generating station, located at Shippingport, Pennsylvania. The units are all similar in their heat source and turbine cycles. They are supercritical, coal fired boilers and single reheat, condensing turbines. Each unit is rated at 868 megawatts with a throttle flow of 6,040,699 pounds per hour at 3515 psia and 1000°F. At full capacity, the plant burns approximately 24,000 tons of coal daily. Therefore, it is essential to operate the plant in the most efficient manner possible.

The Performance Group has made many changes over the past three years to improve the monitoring of the units. This was the first step toward developing a functional performance testing program. Most of the changes were along the lines of improving the accuracy and repeatability of the existing instrumentation. Currently, turbine and boiler cycles are tested semiannually. A very useful data base has been developed on the turbines by trending corrected test data. However, repeatable cycle conditions are required for an accurate analysis. Repeatability was difficult to achieve with these complex systems, but through the use of PEPSE, the differences in cycle operation could be accounted for and proper corrections made.

Turbine Design Cycle

Before PEPSE could be utilized a model had to be developed.

Using the vendor's heat balance[2] at rated load, a model of the turbine cycle was constructed. After several consultations with the PEPSE representatives[3], all the required information was obtained and the model produced results that were within 0.05% of vendor's design load and 1 Btu/KWHR of the design heat rate.

The model was then expanded to represent the actual turbine cycle. This involved detailing the low pressure turbines, condenser, and feedwater heating systems. These modifications increased the number of streams from 93 to 167 and the number of components from 62 to 106.

The output of this model was used as a basis for the actual design case. This model enabled variations in cycle conditions to be analyzed individually.

Sensitivity Studies

Sensitivity studies were conducted involving the feedwater heating system. These studies produced valuable information on the affects that feedwater heaters have on unit load and heat rate.

In the first case, one of the two parallel banks of high pressure feedwater heater was taken out of service. Half the feedwater was routed through the other bank and the remainder was sent through a bypass line. These flows are mixed downstream of the final feedwater heater enroute to the boiler. PEPSE indicated increases of 54.4 megawatts in unit capacity and 269 Btu/KWHR in turbine gross heat rate.

In the second sensitivity example, the affects of isolating the #3 low pressure (L.P.) heater were investigated. In order for

PEPSE to do an accurate analysis, the #4 low pressure heater had to be modeled in the design mode. It's performance changed when the #3 L.P. heater was removed from service. The model of the #4 L.P. heater operating in the design mode with vendor design input values[4] indicated output values of the shell and tube sides which practically matched the vendor design output specifications[5]. This model was then integrated into the turbine model and the isolation of the #3 L.P. heater could be analyzed. The results from PEPSE indicated a decrease in unit load of 4.2 megawatts and an increase of 37 Btu/KWHR in heat rate.

These two examples alone indicate the justification of PEPSE as a tool in performance testing. It can predict the actual effect a single action will have on the entire cycle. This type of information is vital in developing an accurate economic analysis of operational and maintenance procedures. Many times the sensitivity of the instrumentation is not acceptable to conduct an enconomic analysis. An example of this is the feedwater flow measurements at the Bruce Mansfield Plant. The sensitivity of the heat rate calculation is $\pm$ 50 Btu/KWHR because the feedwater flows are not totally repeatable. This error range is usually unacceptable in an economic analysis. Therefore, PEPSE is a useful tool in aiding the Performance Group in economic studies.

Actual Data

The PEPSE model of the turbine cycle has been the most beneficial in aiding in analyzing actual turbine performance. The turbines are tested at valves wide open and as close to design inlet pressure and temperatures as possible. Corrections are made to the measured pressures throughout the turbine cycle and to the load when there are deviations from design conditions. This data, along with the temperatures throughout the cycle, are trended versus time. This data is used to detect changes in the cycle. This procedure required repeatable cycle operating conditions. All heaters are to be in service and auxiliary steam systems are to be isolated. However, these conditions are difficult to obtain entirely and this is where PEPSE has aided the Performance Group. PEPSE was used to analyze the data shown on figures 1-5 to determine the affect that the repairs made to the high pressure turbine, during a unit turbine outage, had on the unit's capacity. The table on the following page summarizes the conclusions drawn.

The outage occurred between the 7-29-82 and 11-4-82 tests. It is evident that the gain in the unit's capacity was approximately 20 megawatts. PEPSE was used to determine the effects of partially bypassing the high pressure feedwater heaters and deaerator. The bypass flows were calculated, using data obtained from the station thermocouples, by comparing the actual outlet temperatures with the expected outlet temperature. This data is illustrated on figure 6.

PEPSE was then used to determine the affect these bypass flows had on unit capacity and the proper corrections were made to the corrected loads.

Test Date	3-23-82	7-29-82	11-4-82	3-10-83	7-6-83
Actual Gross MW	868.0	855.8	897.0	878.0	881.0
Correct. To Design Conditions	-5.0	+14.2	-14.0	-3.7	+8.6
	863.0	870.0	883.0	874.3	889.6
Minus Gain Due to Bypass. H.P. Feed-water Heaters	-0.0	-5.7	-5.7	-0.0	-4.6
	863.0	864.3	877.3	874.3	885.0
Plus Loss Due to Bypass. Deaerator	+0.8	+0.8	+0.8	+0.0	+0.0
	863.8	865.1	878.1	874.3	885.0
Plus Loss Due to Partially Closed #2 Contr. Valve	+0.0	+0.0	+6.5	+0.0	+0.0
	863.8	865.1	884.6	874.3	885.0
Plus Loss Due to Decreased Boiler Feed Pmp. Perf.	+0.0	+0.0	+0.0	+9.0	+0.0
	863.8	865.1	884.6	883.3	885.0

Through the use of PEPSE, known differences in cycle conditions can be quantified. This enables the Performance Section to obtain repeatable cycle testing and therefore achieve an accurate analysis.

Condenser Model

The Performance Group has also done individual component testing. At the present time, much emphasis has been placed on the condenser performance, because two of the three units operate with losses attributed to higher than expected back pressure. This is evident when back pressures are plotted versus circulating water inlet temperatures for all three units. (Figure 7) A great deal of data has been collected on all three units to determine the differences in the circulating water flow, heat load, and/or heat transfer coefficients. PEPSE has been used in analyzing this data.

In developing the model, the vendor's design specifications[6] were again used as the criteria for an acceptable model. Not all of the required information was obtainable, (examples: internal and external tube fouling factors) so estimations were made and an acceptable model was developed. This model was initially used to develop design performance curves. These curves are shown on figures 8 and 9. The first curve, temperature rise versus heat load at various circulating water flows, was used to determine the differences noticed in temperature rise. It was estimated that Unit #1 had 4.77% less circulating water flow than Unit #3 because of differences found in pumps and system resistance. PEPSE was again used to calculate curves for back pressure versus heat load at the reduced circulating water flow. Actual back pressure were then compared to the PEPSE calculated values. Unit #3's back pressure was very close to the expected value based on the PEPSE calculation at design conditions (282,000 GPM and 97% heat load). Unit #1's actual data was 0.2 "Hg higher than the expected back pressure at its condition of 4.7% decreased flow and 108.0% heat load. Therefore, it was believed that Unit #1 had additional resistance to heat transfer. Actual tube fouling could be eliminated because of the similarities in cycles and operations between the units. Air in-leakage was believed to be the difference and actual vacuum pump air flows support this conclusion.

Initially, when the differences in pumps and system resistance were discovered, the difference in performance was believed curable by installing a bigger impeller. But, when it was determined that these pumps would deliver approximately 4.7% more flow, economically they could not be justified. PEPSE aided in this analysis by determining the change in back pressure for this increase in flow.

Future Uses

The uses of PEPSE are widely varied in the power plant. The Performance Group of the Bruce Mansfield Power Plant plans to further expand its uses in the turbine and condenser areas and to develop a heat source model.

The turbine model will be used in the performance mode to analyze actual performance test data. This will enable the group to investigate smaller sections of turbine performance with the purpose of locating specific areas of degradation and to quantify them. Using PEPSE in this manner will improve the overall turbine testing results.

PEPSE will be utilized for the ongoing investigation to find and quantify the reasons for the decreased condenser performance.

A heat source model will be developed when it becomes available to evaluate the following areas. First, we would hope to be able to determine the effects of off-design flows on expected temperature rises across various sections of the boiler, and secondly to evaluate the extent of slagging on reheater and other surfaces due to a change in coal. This would be useful if an alternate coal was to be used in the future. Thirdly, to determine the cause of the high exit gas temperature leaving the economizer and its effect on air heater performance. Ultimately, to quantify in a economic sense the various losses and make this information available to the operators so that corrective action can be taken.

Conclusion

In conclusion, PEPSE has aided the Performance Group in many ways. Sensitivity studies were conducted on the turbine cycle and individual components, which quantified the importance of proper cycle operation. Actual data was analyzed to determine the effects maintenance had on the performance of the turbine cycle and individual components. PEPSE has demonstrated the ability to function as a performance analyzing tool and, therefore, the integration of PEPSE into the performance testing program at the Bruce Mansfield Power Plant has been justified.

Footnotes

[1]W.C. Kettenacker et. al., PEPSE Manual, Rev. 8, Energy Incorporated, May 1982.

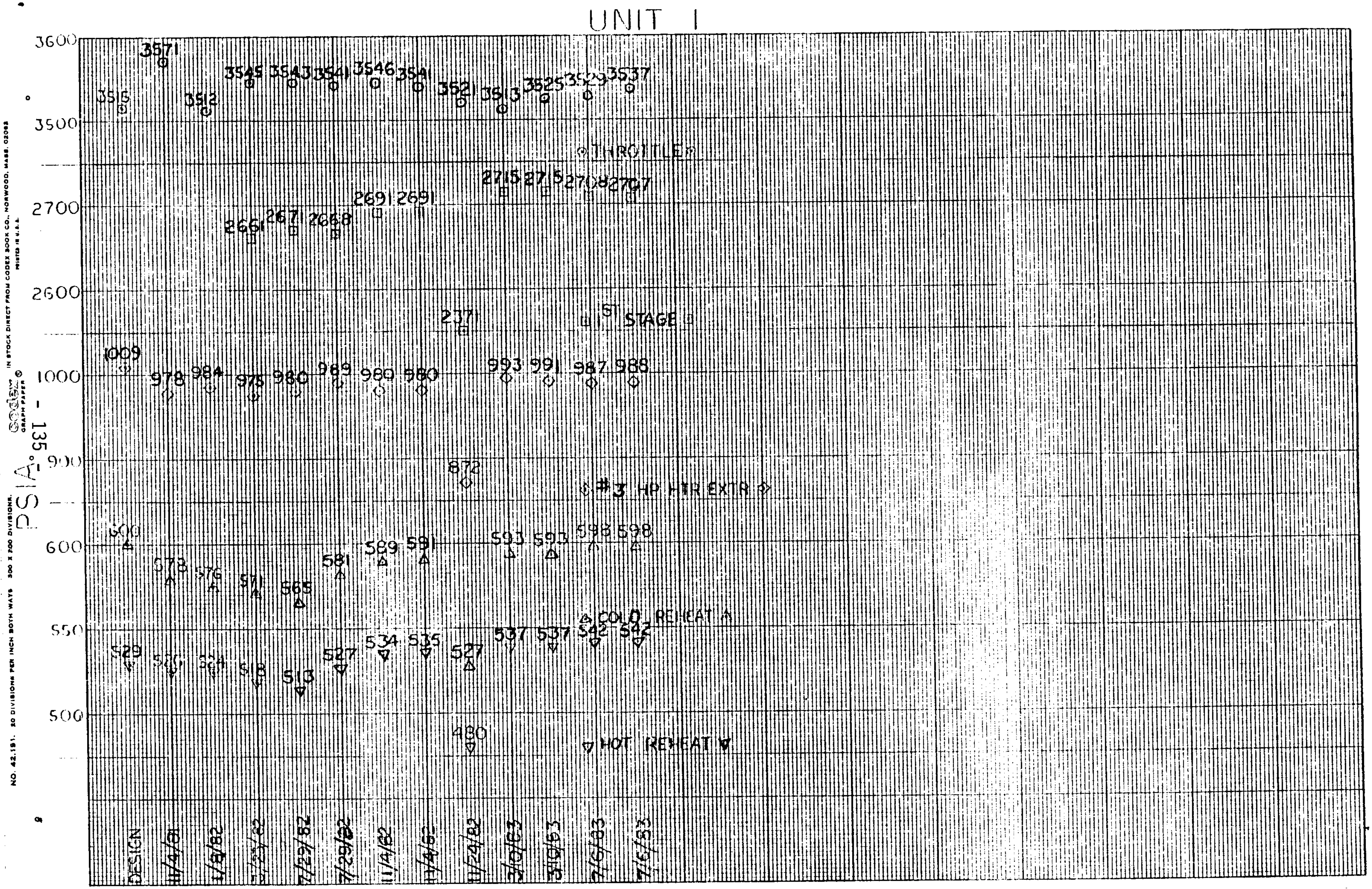
[2]Turbine Cycle Heat Balance, General Electric Company, Schenectady, New York, June 7, 1974. Sheet 562-441-HB-891.

[3]W.C. Kettenacker, PEPSE Representative, Energy Incorporated.

[4]Feedwater Heater Specification Sheet, Yuba Heat Transfer Corporation, Tulsa, Oklahoma. February, 1971. Sheet 75-H-944-4.

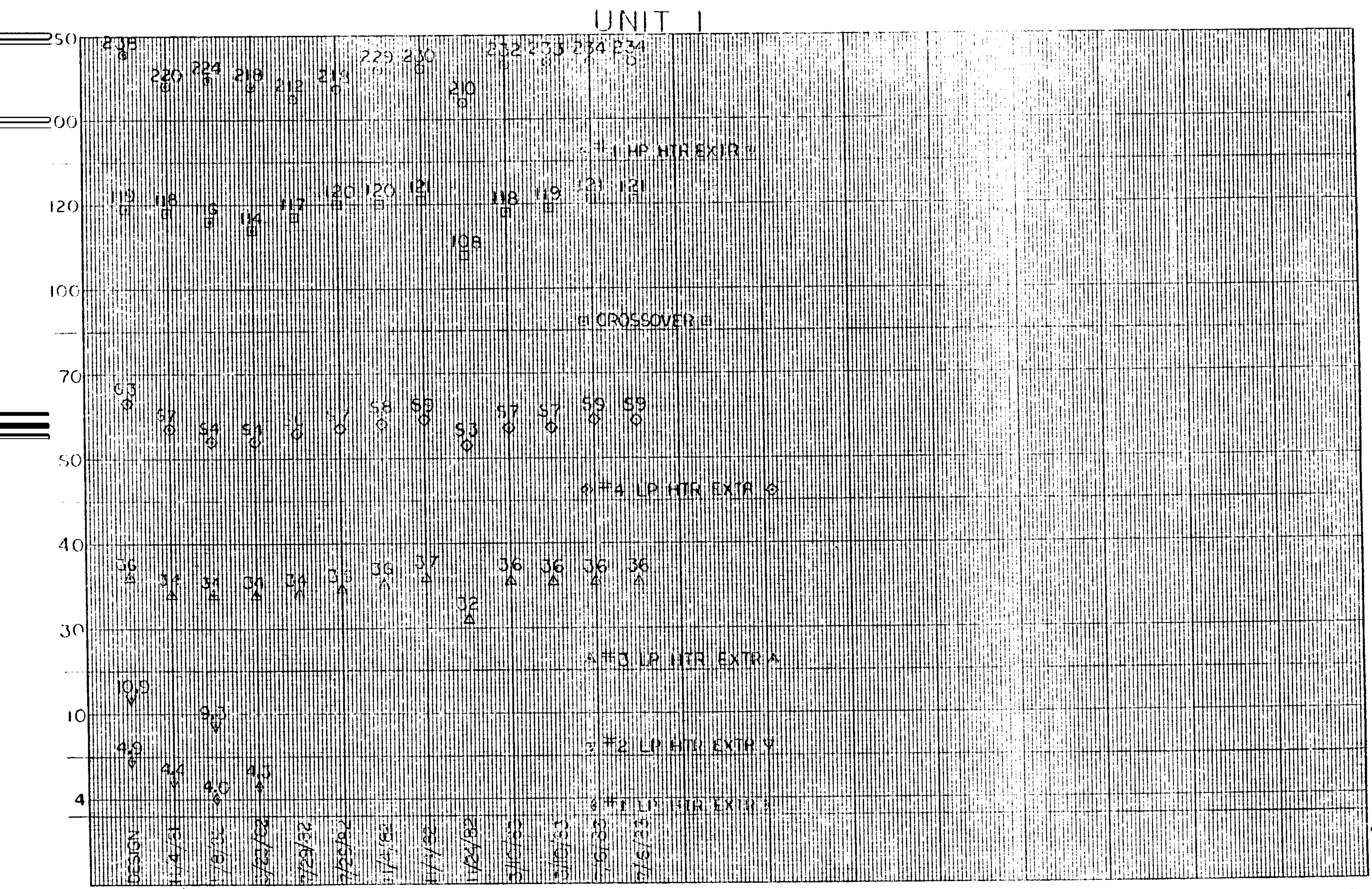
[5]IBID.

[6]Instructions for Maintenance and Operation of Surface Condenser and Auxiliary Equipment, Ingersoll-Rand Company, Phillipsburg, New Jersey, Bulletin No. 7.1.



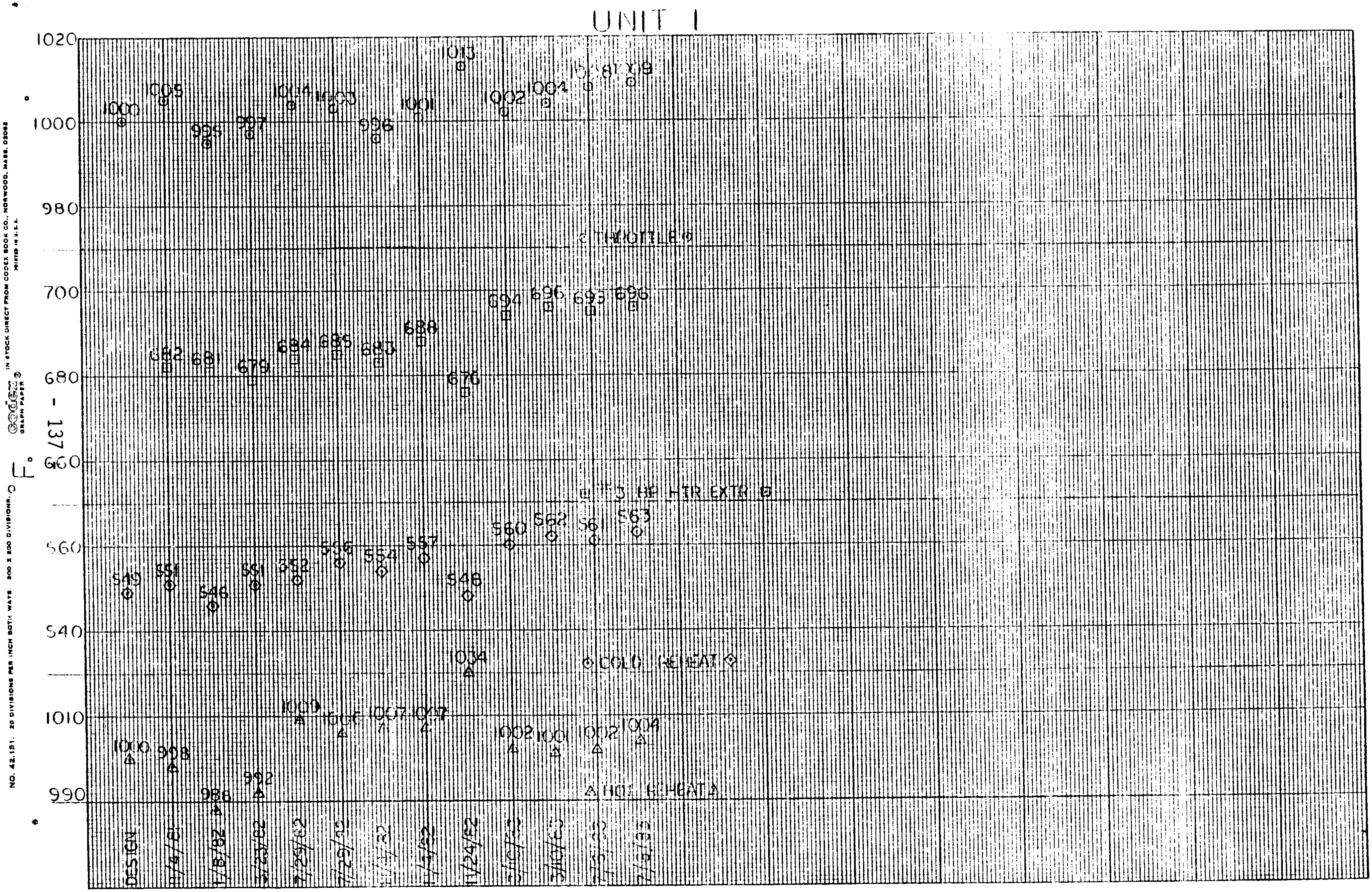
Corrected Pressure Plot

Figure 1



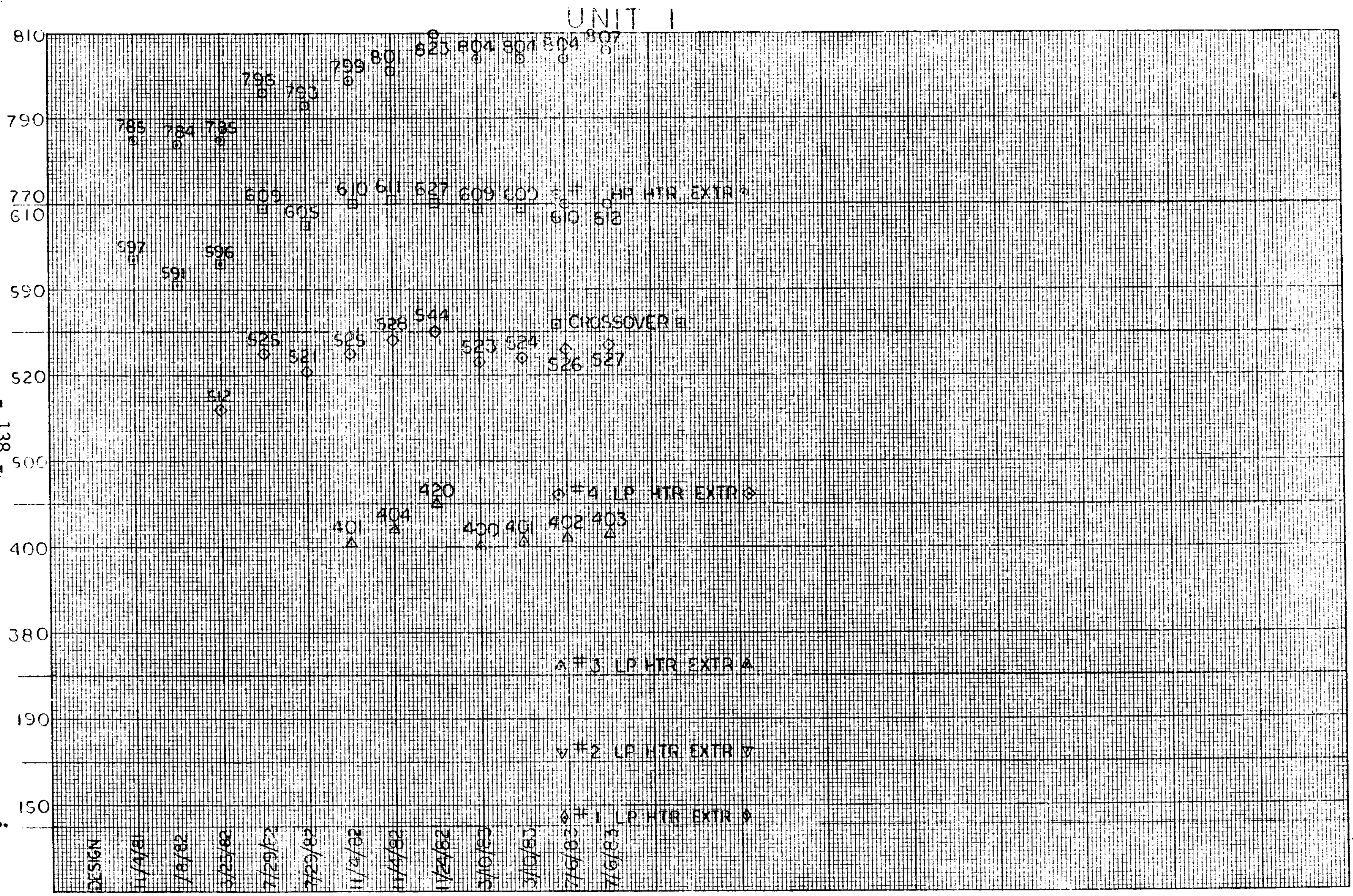
Corrected Pressure Plot

Figure 2



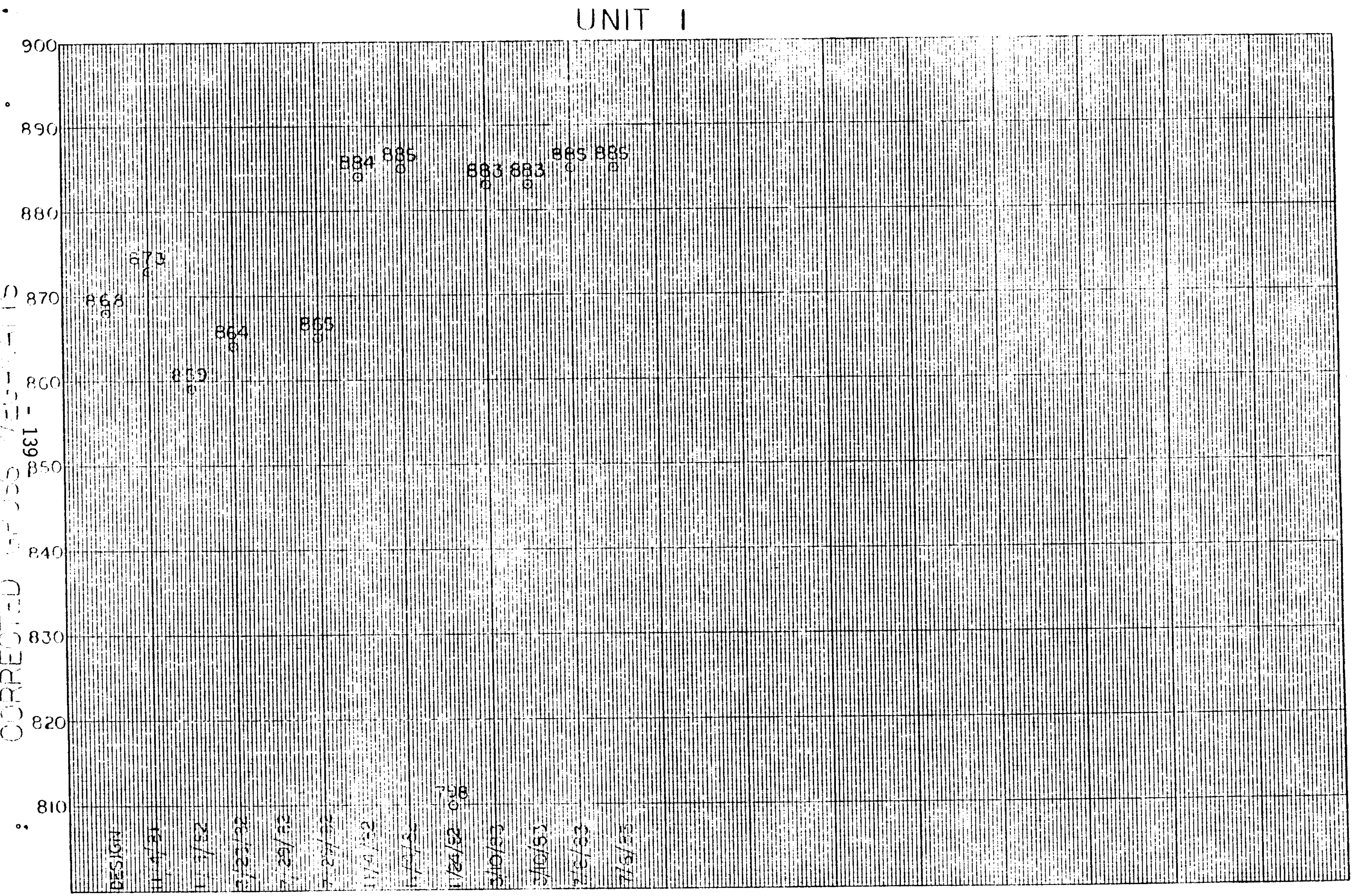
Temperature Plot

Figure 3



Temperature Plot

Figure 4



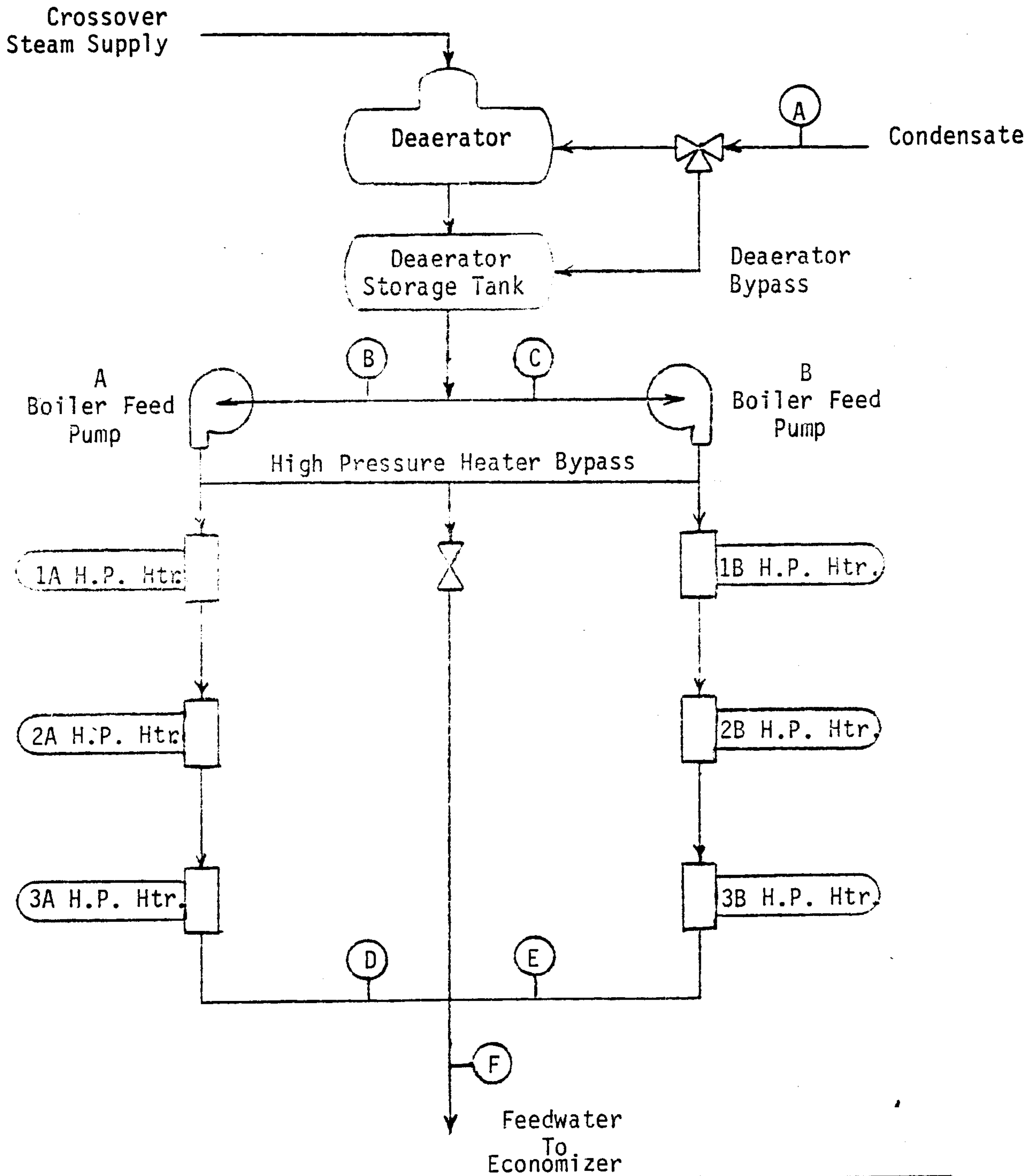
Corrected Megawatt Plot

Figure 5

SUBJECT: Schematic of Deaerator and H.P. Heater Bypass

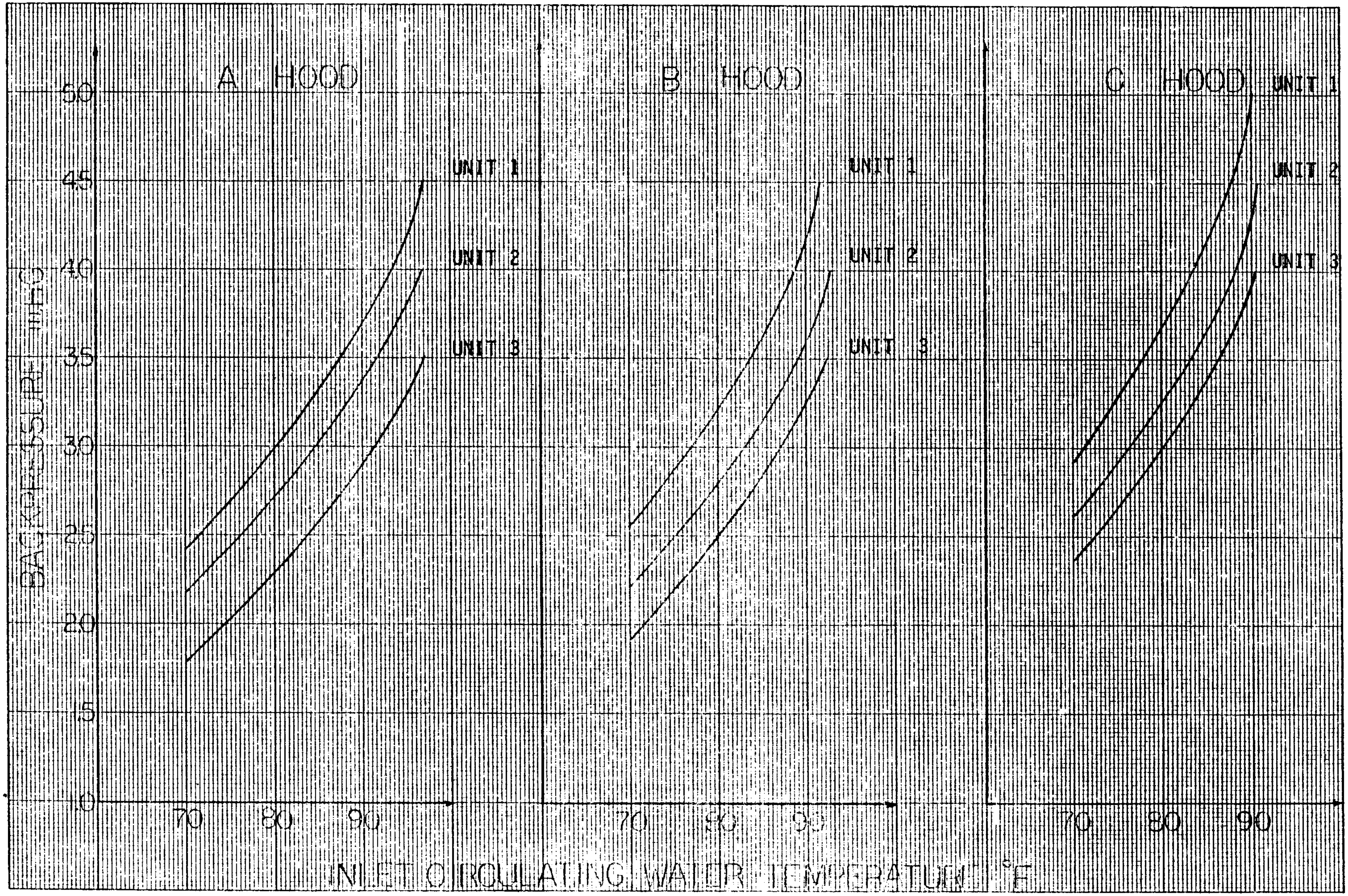
DRAWN/PREPARED BY: M.J. Woodward DATE 9-22-83

SHEET NO. ____ OF ____



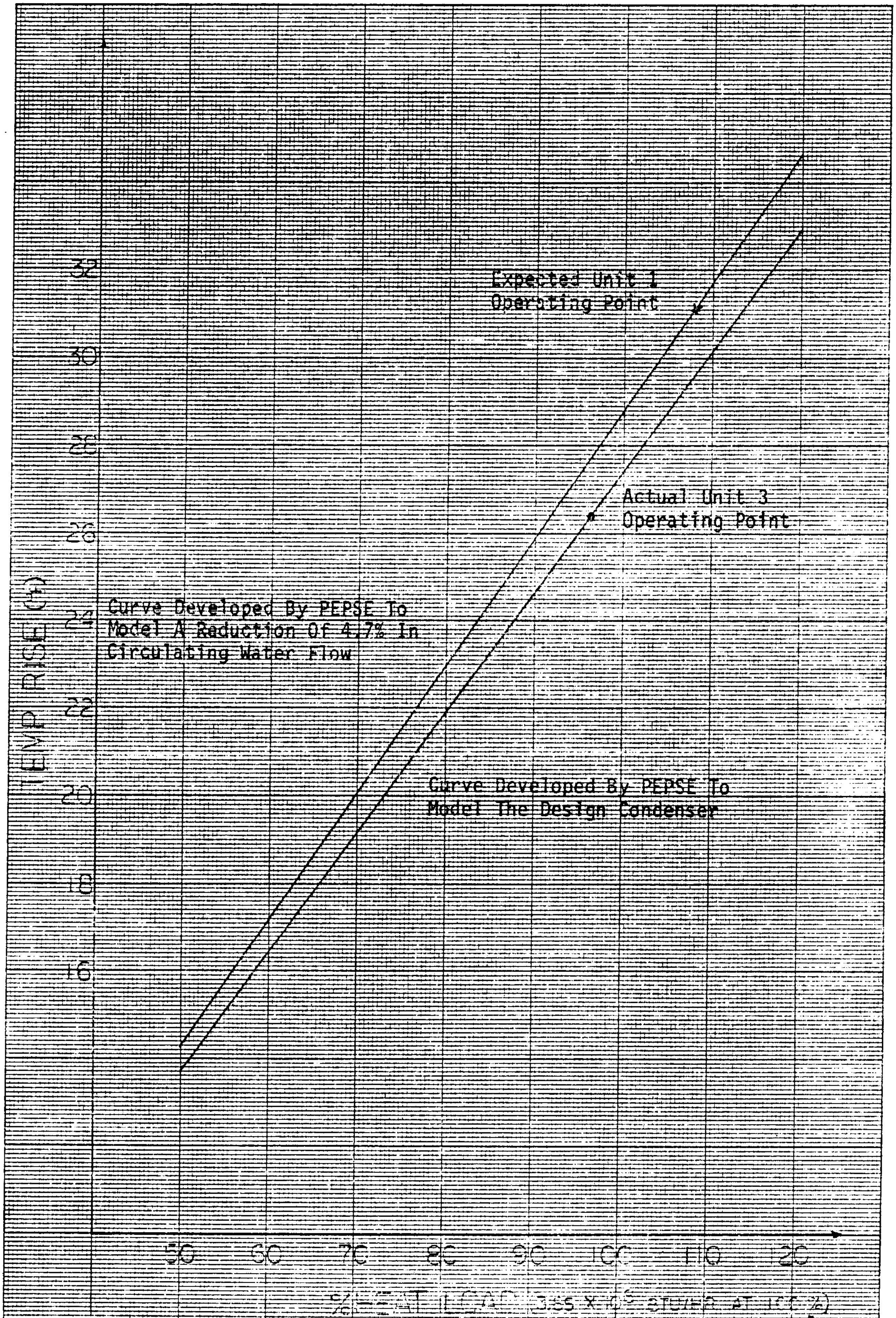
Test Date	A	B	C	Deaerator Bypass Flow	D	E	F	H.P. Htr. Bypass Flow
3-23-82	287.0	326.0	326.0	1,250,000	538.8	540.1	539.8	-
7-29-82	287.0	326.0	326.0	1,250,000	538.7	541.3	529.3	235,000
11-4-82	287.0	326.0	326.0	1,250,000	537.7	539.7	529.0	235,000
3-10-83	287.0	333.0	333.0	-	541.0	541.7	535.5	190,000
7-6-83	287.3	333.0	333.0	-	540.3	540.3	540.3	-

Figure 6



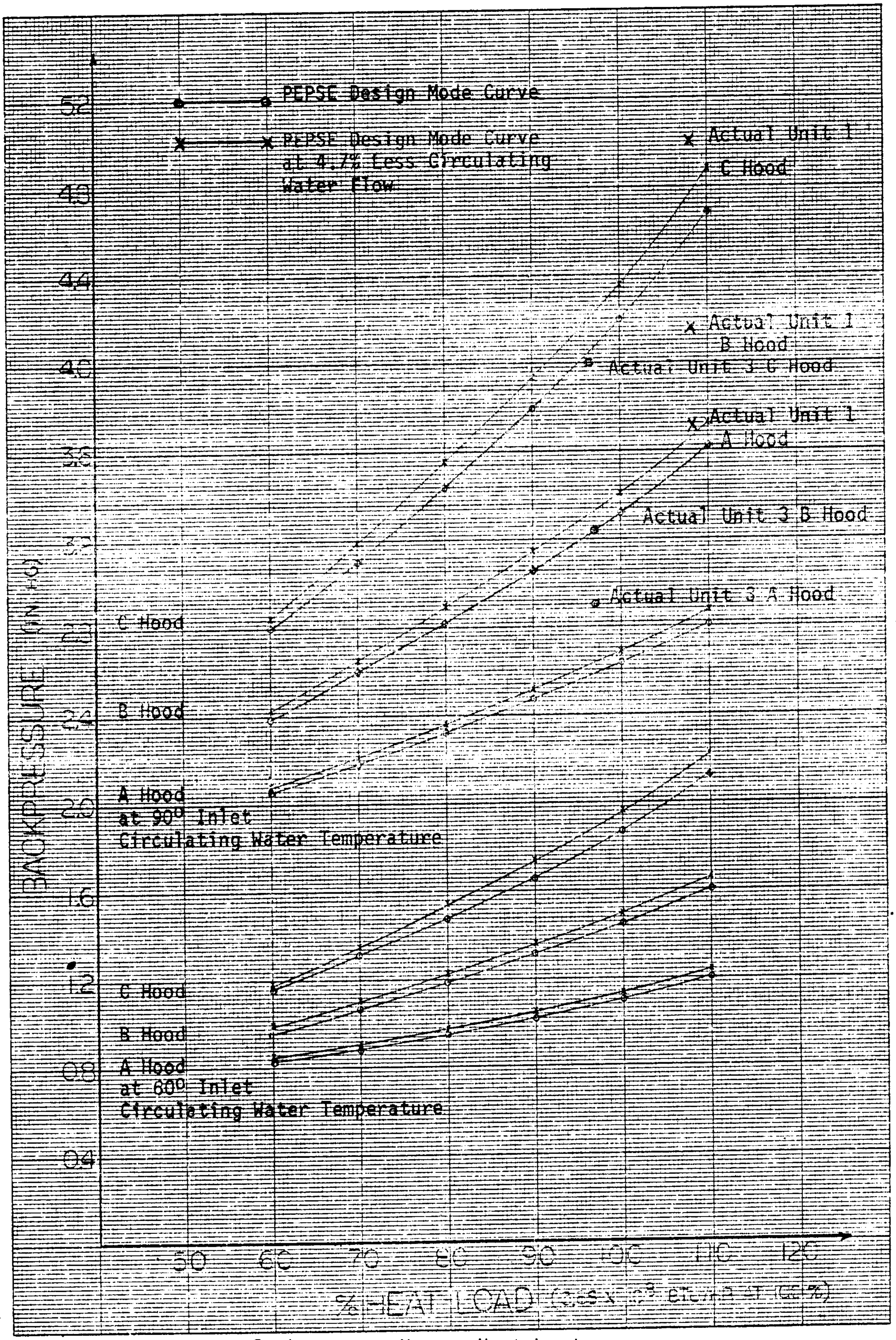
Backpressure Versus Inlet Circulating Water Temperature

•Figure 7



Temperature Rise Versus Heat Load

Figure 8



Backpressure Versus Heat Load
Figure 9