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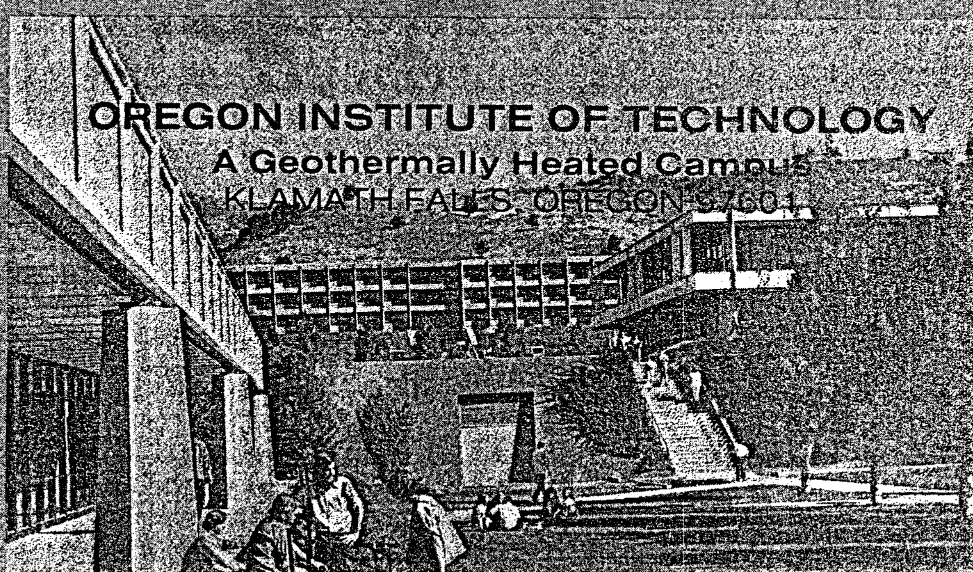

GEO-HEAT CENTER

DISCLAIMER

HEAT PUMP SYSTEM

A.C. DAVIS HIGH SCHOOL

July 1980

DISCLAIMER

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A. C. DAVIS HIGH SCHOOL

The following study is the result of a request to the Geo-Heat Utilization Center for Technical Assistance.

Introduction

A. C. Davis High School is operated by the Yakima Public Schools. Located between Sixth and Seventh Avenue South, in Yakima, Washington, the campus consists of 7 buildings with a total floor plan of approximately 179,100 square feet. For purposes of this study, the buildings were designated 1 through 7 per Figure #1 in the appendix. The three phases of construction dated 1966, 1970 and 1975 are of standard institutional masonry design, typical of modern public school construction. Three gas fired boilers located in building number 2 currently supply steam for space and potable hot water heating for the entire campus. Due to rising fuel costs, the school district has asked if the high school can be heated geothermally.

Summary of Conclusion

It is now economically feasible to heat Davis High School using water-to-water heat pumps. The heat pumps are necessary to boost the relatively low temperature resource (80°F) to a more usable range (140°F). This higher temperature would then be sufficient to supply both space and potable hot water heating requirements. The existing boilers, some condensate piping, and terminal units would be removed.

Four water-to-water heat pumps, an underground water distribution system, and several new terminal units would be installed under the proposed design. The estimated capital cost of the new system is $830,000. Annual energy savings due to reduced natural gas purchases are expected to be approximately 200,000 therms/yr with a first year value of about $101,000. This savings, less operating costs when applied with escalation considerations over a period of twenty years results in a present worth of $104,836 when discounted at 8%. This is the amount of surplus generated after the payment of all obligation, when the project is financed with 8% bonds.

Availability of Geothermal Water

There is evidence of a geothermal resource in the area of Davis High School. Calculations for this report were based on data obtained from the Creamery well owned by Yakima City Creamery. The well was temperature logged by Geo-Heat Center personnel on June 6, 1980. A maximum temperature of 93°F was obtained at a depth of approximately 1680 feet. As a result of this, a conservative figure of 80°F was used to determine equipment requirements for the high school. It should be pointed out that heat pump performance and energy use improve as resource temperature increases. If a higher temperature than 80°F is encountered at the high school, energy savings greater than those set forth in this report may be expected.

Heating Load Calculations

Due to the type of construction involved an outside design temperature of 5°F (ASHRAE 97.5%.) was used in heat loss calculations. The result of this was to somewhat reduce the required heating load as compared to the original design based on -10°F outside temperature. In conjunction with this, an inside design temperature of 65°F was chosen. The total building heat loss calculations were performed by closely examining sample sections of each building and extrapolating these findings to the total building based on floor area. This method resulted in an overall heating load at the above design temperatures of about 35 $BTUH/FT^2$. The space heating load (based on the 35 $BTUH/FT^2$ figure) was then used to determine air delivery temperatures and equipment requirements. Equipment load or load imposed by ventilation air was first calculated based on present design flows (as far as could be determined from drawings). In many cases design flows were found to be far in excess of ASHRAE requirements. A second calculation was then performed based on ASHRAE minimum requirements as set forth in 1977 Fundamentals Chapter 21, Table 6. Allowable reductions for filtration and temperature control were then applied. Classroom rates were based on an average class size of 30 students. The results of this reduction are shown in Table 4 of the appendix. The reduced ventilation rates were used for equipment duties in the proposed design. Energy use figures for both proposed and existing systems were then generated and are available in Tables 4, 5 and 6 in the appendix. It is strongly recommended that existing ventilation rates be closely scrutinized and reduced to absolute minimum whenever possible. For a minimum of capital investment this can result in significant reductions in energy cost.

Potable hot water use was based on an expected 1980-81 enrollment of 1100 students.

Annual energy use figures were based on figures provided by R. S. Cameron and Co., and were the result of a recent energy audit of Davis High School.

The Geothermal System

Figures 3, 4 and 5 show the basic plan for the proposed system. Included are flows, heating duties and key temperatures and pressures.

For purposes of this study the production well was placed at the extreme southeast corner of the campus. Further analysis may yield a different location, however, this position provided the means for a conservative estimate of the distribution system. A well depth of 1000 feet is anticipated, to be composed of: 300 ft. of 16" bore - 14" casing; 200 feet of 14" bore - 12" casing; and 500 feet of 10" bore - 8" casing. This design should produce the required peak flow of 935 gpm at 80°F water. A deep well turbine pump with variable speed drive will require a 100 hp electric motor to deliver the geothermal water through the 6" discharge piping to four heat pumps. This piping will be uninsulated PVC, buried as per Figure 4 in the appendix. Insulation is not required due to the low temperature of the geothermal water. The water is considered safe for use as make up to the domestic hot water system and for direct use in the heat pump evaporators. Should this prove not to be the case, a heat exchanger would be required for each of the four heat pumps. This would result in minor increases in both the capital and operating costs of the system, but would not significantly affect the overall economic analysis.

For purposes of this study four Westinghouse Model TPE-063 heat pumps were selected. These will be placed, one each, in buildings 2, 5, 6 and 7. Geothermal water will circulate from the supply piping through the evaporator of each unit in a parallel configuration. The cooled geothermal water will then be disposed of at the injection well. In addition, a small amount of water will be split off from the main stream at each unit before entering the evaporator. This will serve as make up to the potable water heating system for each unit.

The compressors of the heat pumps require a total of 708 kw at peak conditions to compress the vaporized refrigerant to the higher temperature. This electricity contributes to the overall heating requirements. The heating system water, flowing through the condenser, extracts this heat to provide the necessary space and potable hot water heating. A water storage tank accepts the return water and make-up water needed to offset the potable hot water consumed. Typical flow diagrams are shown in Figures 4 and 5 of the appendix. Total heating capacity, at peak is approximately 9,000,000 BTU/HR of which 712,000 BTU/HR is for potable hot water heating.

The geothermal system has been designed to generate both space and potable hot water heating. During the winter months when heating demand is high, the system will work at near optimum conditions. However, when space heating demand is low or non-existent, in the spring and summer months it may prove impractical to run the heat pumps to generate only small amounts of potable hot water. At some point it will become more economical to heat potable hot water by direct electric resistance, or natural gas means. Time did not permit a detailed analysis of this situation. The energy use figures in Tables 4 and 5 reflect usage that would result from 100% potable hot water generation from the heat pumps. It is recommended that some means of backup be provided.

Modifications

Building #1.

This building, housing primarily Band and Chorus facilities, is currently heated by AH-1 (air handler), 11 fan coil units and 3 unit ventilators. The preheat and reheat coils currently in AH-1 are served by steam. As the heat transfer characteristics are not compatible with 140° water they will have to be replaced. Some plumbing changes will also be required to accommodate the use of pump #3 for supplying heating water to AH#1 during the heating season. The existing fan coil units should operate on the 140° heating water with no major modification other than an increase in fan speed. All unit ventilators and AH-1 should be closely examined for proper ventilation rates. Potable hot water and space heating water will be supplied by heat pump #2 in the basement of building #5.

Modifications - Cont'd

Building #2

Building #2 serves as the administration center and mechanical room in in the present design. Currently it is heated by 4 unit ventilators, 16 fan coil units, 2 convectors, 2 steam unit heaters and the commons area is handled by AH-3 located in building #3.

The major modification to this building will be the removal of the existing boilers and the installation of heat pump #1 in the boiler room. The heat pump will be tied into the existing potable hot water and space heating systems. The two steam unit heaters in the basement office and shop will be replaced with suitable hot water models. In the main administration office area only the two convectors on the south wall will have to be replaced with fan coils as they will be ineffective at 140° temperature. The four unit ventilators should be examined for excessive outside air and fan speeds should be increased on all fan coils and unit ventilators. The lack of modifications on these units rests on the assumption that the existing coil is of multirow design. Pumps 2, 3 and 4 will have to be connected to the new storage tank for the heating system as in Figure 6 in the appendix. It is recommended that a backup electric heater or small recirculation pump be installed in the present potable hot water storage tank to compensate for standby heat losses.

Building #3

This building currently houses the cafeteria, kitchen, library, and some classroom space. It is heated primarily by 2 air handling units (AH-3 and AH-2) and a few fan coil type units.

Heat for this building will be supplied by heat pump #1 in building #2. The same consideration for the fan coil units apply as in the above buildings. The 3 coils in units AH-3 and AH-2 will have to be replaced as they currently use steam as a heating medium. In order to circulate water to these units during the heating season, plumbing modifications will have to be made to chilled water pump #2 in building #2. The two 96 MBH steam unit heaters in the penthouse will also have to be replaced with hot water models. Domestic hot water will be supplied from the existing system located in building #2. Again, ventilation rates for units AH-2 and 3 should be checked for excess .

Modifications - Cont'd

Building #4

This building houses primarily classroom areas and is presently heated by reheat boxes exclusively. These reheat coils are currently operating on 130 to 160°F water and should be capable of supplying the required amount of heat under the proposed design. In some uses the situation is only marginal. Every effort should be made to increase the mix air temperature to these coils by reducing ventilation rates to minimum, especially at or close to design conditions.

Water for space heating and potable use will be supplied by heat pump #2 in building #5. Again, some electric backup should be provided to compensate for standby losses from storage.

Building #5

The stage and auditorium are located in building #5. It is currently heated by a large air handling unit, the details of which were not available on the plans. In addition, several small fan coils and convectors supply heat to the landing and balcony areas.

In the basement the 2 steam cabinet unit heaters and one steam duct coil will require replacement with hot water coils. Also, condensate line sizes will have to be enlarged to accommodate higher flow rates. The four unit ventilators located on the first floor and lower balcony will have hot water circulated to the chilled water coils during the heating season. This will be accomplished by tying pump #1 into the heating circuit. The remaining steam equipment (2 coils in the lower balcony area, 2 small convectors and 2 cabinet unit heaters) will all require replacement. These units, in addition to the coil in the main air handler, will be included in the new hot water circuit. Flow will be generated by a new pump in parallel with existing pump #1. Potable hot water will be distributed from the existing storage tank to which some electrical backup should be provided to compensate for standby losses.

Building #6

This building contains two floors of vocational training rooms and a third floor consisting primarily of classroom areas. It is presently heated by 52 unit ventilators, 10 fan coil units, 9 convectors and 2 make-up air handling units 6-1 and 6-3. In many cases it was found that the existing heating coils in the fan coils and unit ventilators were not able to supply the necessary amount of heat at 140°F water supply temperature. This situation could change however, if ventilation rates are reduced to minimums. The proposed design was based on the use of the chilled water coils for heating purposes. Since they are of multirow design, sufficient heat transfer capability is available for 140°F temperatures. The use of the chilled water coils for heating service will be facilitated by connecting circulating pump #4 to the heating circuit. In addition, 9 convectors (located primarily in lavatories) will have to be replaced with small fan coil units and tied into the chilled water/heating water circuit. Air handling units 6-1 and 6-3 also require heating coil replacement and each will have to be tied into the new plumbing arrangement. Potable hot water will be distributed from the existing storage tank with new electric backup heat. Heat pump unit #3 will be installed in the mechanical room.

Building #7

This building currently houses the gymnasium, shop areas, locker rooms and some vocational training facilities. It is heated by 7 air handling units, 11 unit air ventilators, 5 fan coils, 10 convectors and two duct heat coils.

The same approach will be employed here as in building #6. The chilled water pump (#4) will be used to distribute hot water to all units. Some valving and plumbing modification will be required at the pump to accomplish this.

The 10 convectors will have to be replaced with small fan coil units and tied into the present chilled water circuit (now serving as heating circuit also).

Of the 7 air handling units, 3 are able to use the cooling coil for heating and will require only minor plumbing and control modifications. The remaining 4 units must have new heating coils installed and connected to the chilled water piping.

Potable hot water will be distributed from the existing storage facilities with new electrical backup added.

Heat pump unit #4 will be installed in the mechanical room.

A. C. DAVIS HIGH SCHOOL
SPACE HEATING ECONOMIC ANALYSIS

The current annual cost of natural gas was established as $101,803. This annual cost was projected through the year 2000 at the following inflation rates:

1981-1984	7.6%
1985-1989	8.4%
1990-1994	10.3%
1995-2000	10.6%

Heat pump operation and pumping costs were estimated to be $29,554 per year. These costs were projected through the year 2000 at the following inflation rates:

1981-1988	8.9%
1989-2000	8.6%

Maintenance costs for the system were estimated to be $31,925 per year. These costs were projected at an inflation rate of 7% per annum through the year 2000, which is also the assumed economic inflation rate.

Insurance costs were estimated to be $3,693 per year and were projected to increase at 2% per annum over the 20-year project life.

Using these figures, Table I was compiled to indicate the projected cash flows.

It was assumed that the high school would finance the project with an 8% tax-free bond, maturing in 20 years. Based on these calculations, the high school could afford to spend approximately $935,000 for the project. Although the system appears to be marginally feasible, it should be understood that all inflation rates used were ultra-conservative and any actual increase in the cost of natural gas beyond our projections would make the project much more feasible. It is also likely that the system will last much longer than 20 years and the annual savings during this extended life will be in excess of $330,000 per year.

SUMMARY OF CAPITAL AND OPPERATING COSTS
TABLE 2

CAPITAL COSTS

PRODUCTION AND INJECTION WELL	$ 70 000
TURBINE PUMP	70 000
UNDERGROUND PIPING	35 000
HEAT PUMPS	320 000
WELL HEAD BUILDING	10 000
CONVECTOR REPLACEMENTS	10 000
AIR HANDLER COIL REPLACEMENTS	45 000
CIRC PUMPS AND SPARES	25 000
INTERNAL PIPING ALLOWANCE	50 000
MISC. MECHANICAL AND ELECTRICAL	50 000
ENGINEERING @ 10%	70 000
SUB TOTAL	755 000
CONTINGINCY	75 000
TOTAL	$ 830 000

OPPERATING COST

MANTAINANCE	31,925
INSURANCE	3693
ELECTRIC POWER FOR SYSTEM @ .02150 $/KW	29 554
TOTAL ANNUAL OPPERATING COST FOR FIRST YEAR	$ 65 172

NATURAL GAS SAVINGS

201,312 THERMS/YR @ .5057 $/THERM

TABLE # 3

HEAT PUMP DUTY

BUILDING	NO. OF UNITS	MODEL NO.	PEAK LOAD BTU/HR × 10⁶			EVAPORATOR WATER			CONDENSER WATER			COMP. INPUT KW
			SPACE HEAT	HOT WATER	TOTAL	°F IN	°F OUT	FLOW GPM	°F IN	°F OUT	FLOW GPM	
#2 AND #3	1	TPE 063	2.03	.164	2.2	80	65	223	120	140	223	173
#1, 4 AND 5	1	↓	2.54	.144	2.69	↓	↓	272	↓	↓	272	212
#6	1	↓	1.67	.100	1.77	↓	↓	179	↓	↓	179	140
#7	1	↓	2.02	.304	2.33	↓	↓	236	↓	↓	236	183
			8.26	.712	8.99			910	—	—	910	708

TABLE 4

SPACE AND DOMESTIC HOT WATER HEATING LOADS
PEAK AND ANNUAL

BUILDING NO.	SPACE HEATING PRESENT (1) ×10^6 BTUH	SPACE HEATING PRESENT (1) ×10^9 BTU/YR	SPACE HEATING PROPOSED (2) ×10^6 BTUH	SPACE HEATING PROPOSED (2) ×10^9 BTU/YR	DOMESTIC HOT WATER (3) PRESENT ×10^6 BTUH	DOMESTIC HOT WATER (3) PRESENT ×10^9 BTU/YR	DOMESTIC HOT WATER (3) PROPOSED (3) ×10^6 BTUH	DOMESTIC HOT WATER (3) PROPOSED (3) ×10^9 BTUH	TOTAL ANNUAL HEATING LOAD PRESENT	TOTAL ANNUAL HEATING LOAD PROPOSED
1	.312	.535	.312	.535	.0208	.00749	.0208	.00749	.556	.556
2	2.19	3.76	1.72	2.95	.0416	.0149	.0287	.005	3.77	2.95
3	.509	.874	.346	.594	.197	.0706	.135	.0473	.945	.641
4	1.86	3.19	1.42	2.44	.0832	.0299	.0832	.0299	3.22	2.47
5	.806	1.38	.778	1.33	.0323	.0119	.0323	.0119	1.39	1.34
6	1.87	3.21	1.67	2.86	.100	.0359	.100	.0359	3.25	2.89
7	3.01	5.17	2.02	3.47	.366	.132	.304	.130	5.30	3.6
TOTALS	10.56	18.12	8.27	14.18	.841	.303	.704	.267	18.43	14.45

(1) FIGURES BASED ON 35.2 BTU/FT² HEATING LOSS AND ASHRAE AVERAGE OCCUPANCY AND VENTILATION RATES. 5°F DESIGN TEMP. 1715 OPERATING HRS. 65° INSIDE DESIGN

(2) FIGURES BASED ON 35.2 BTU/FT² @ 5°F ODT. AND 1715 HRS. ASHRAE MINIMUM VENTILATION (F 37.12) AND AVG. CLASS SIZE OF 30 STUDENTS.

(3) BASED ON ASHRAE USAGE FIGURES FOR HIGH SCHOOLS (37.12 5) REDUCTION IN "PROPOSED" FIGURES RESULTS FROM USE OF 80°F MAKE UP WATER.

TABLE #5

ESTIMATED ENERGY USE FIGURES FOR PROPOSED SYSTEM

(GAS FIGURES IN THERMS/YR ELECTRICITY IN KW/YR)

BLDG	FT²	GAS		ELECTRICITY			TOTAL GAS	TOTAL ELEC.
		SPACE HEATING	HOT WATER	LIGHTING	COOLING	OTHER (1)		
1	12,320	0	0	51,004	3618	69819	0	124441
2	12,057	0	0	49916	3541	371550	0	425007
3	29,160	0	0	120 722	8564	165,254	0	294 540
4	33,370	0	0	138,152	9800	189113	0	337065
5	19,524	0	0	80,829	2867	482,223	0	565919
6	30,660	0	0	126932	9004	419137	0	555073
7	42,004	0	0	173,896	6168	558792	0	738856
TOTAL	179,095	0	0	741006	43563	2394947 (2)	0	3179543

(1) INCLUDES TURBINE PUMP ELECTRICITY CONSUMPTION

(2) INCLUDES CONSUMPTION OF COMPRESSORS AND 22% OF COMPRESSOR CONSUMPTION FOR NEW PUMPS.

TABLE #6

ENERGY USE FIGURES FOR EXISTING SYSTEMS (1)

(GAS FIGURES IN THERMS/YR ELECTRICITY IN KW/HR)

BLDG.	FT²	GAS		ELECTRICITY			TOTAL GAS	TOTAL ELEC
		(2) SPACE HEATING	D.H.W. (4)	LIGHTING	COOLING	OTHER (3)		
1	12,320	8735	93.6	51 004	3618	69,819	8829	124441
2	12,057	5831	186	49916	3541	68,328	6017	121785
3	29,160	37,573	882	120722	8564	165254	38455	294540
4	33,370	31,923	374	138,152	9800	189113	32,297	337065
5	19,524	13,816	149	80829	2867	110,645	13,830	194,341
6	30,660	32,094	449	126932	9004	173755	32,543	309691
7	42,004	51,694	1650	173896	6168	238043	53,344	418107
TOTAL	179,095	197,525	3787	741006	43,563	1014957	201312	1799526

(1) BASED ON GROSS USAGE FIGURES IDENTIFIED BY R.S. CAMERON AND CO. FOR 7/78 → 7/79

(2) ALLOWS FOR 12.6% CONTRIBUTION TO ANNUAL HEATING LOAD BY LIGHTING AND 80% BOILER EFF.

(3) DISTRIBUTION OF REMAINING (AFTER LIGHTING AND COOLING) ELECTRICITY DISTRIBUTED ACCORDING TO FLOOR AREA.

(4) FIGURES FOR DOMESTIC HOT WATER ARE BASED ON ASHRAE FIGURES FOR HIGH SCHOOLS AND 80% EFF.

FIGURE # 1
A.C. DAVIS HIGH SCHOOL
BLDG. REFERENCE NUMBERS.

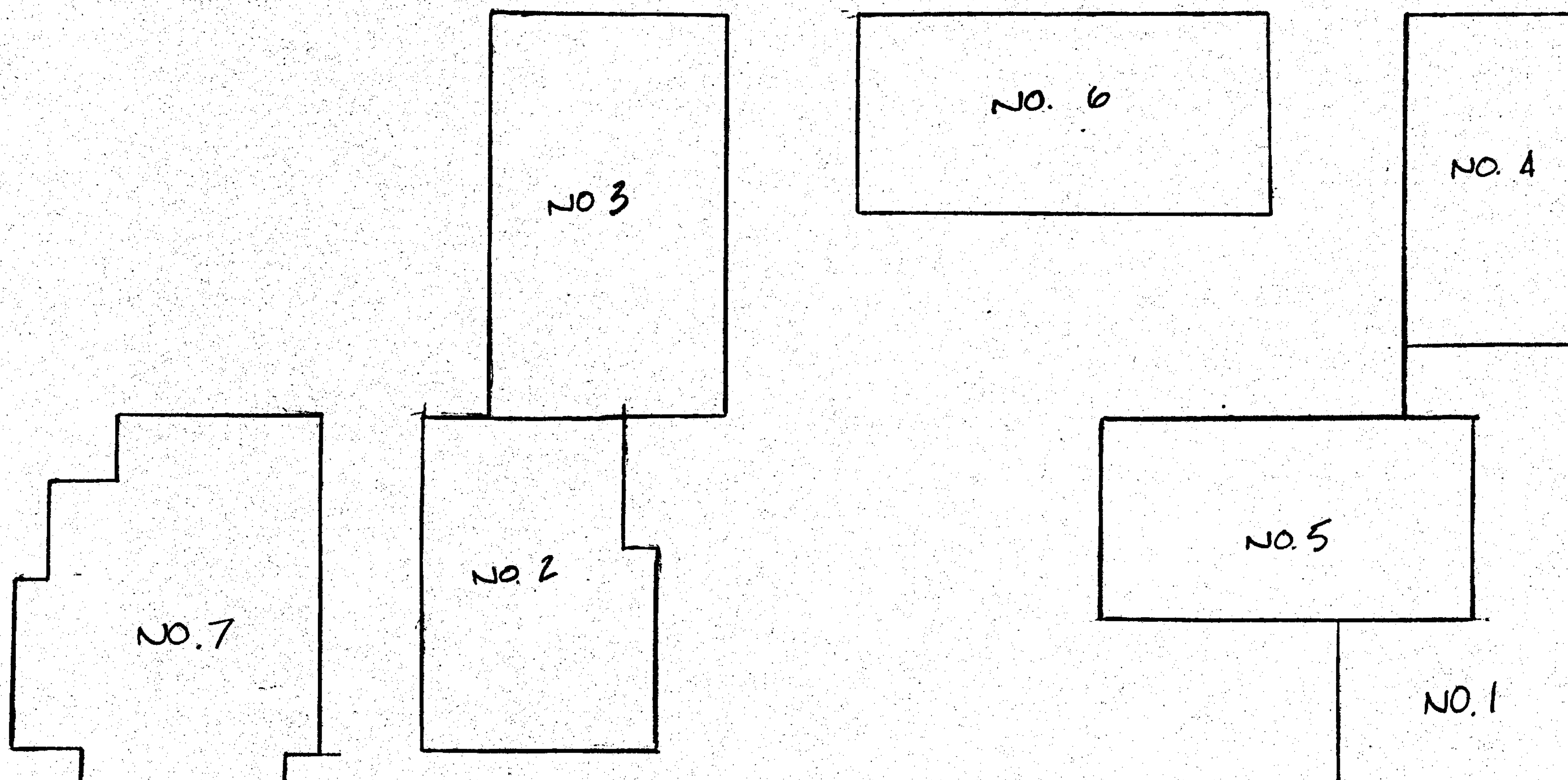


FIGURE #2

GEOTHERMAL WATER DISTRIBUTION SYSTEM

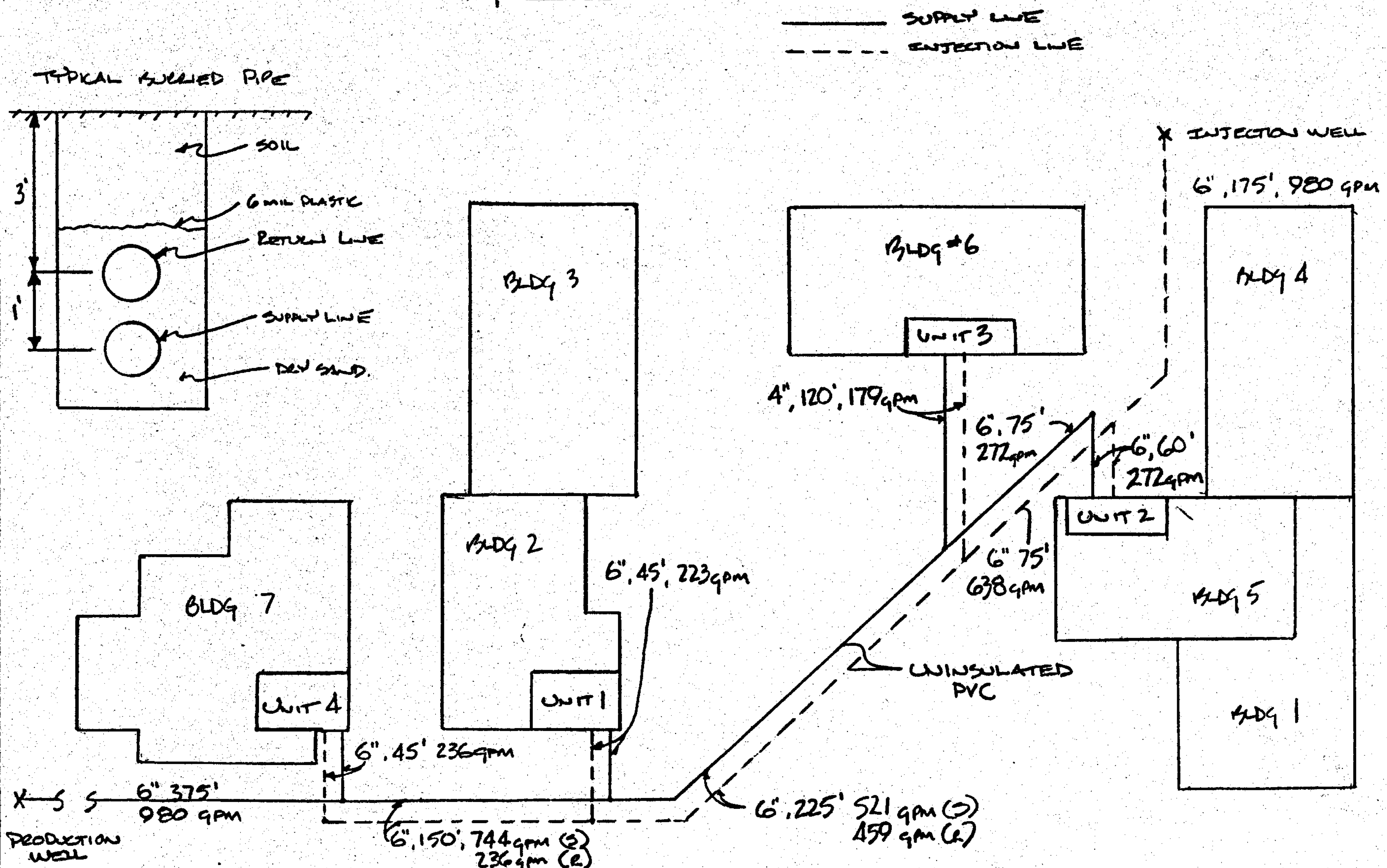


FIGURE #3

GEOTHERMAL WATER FLOW DIAGRAM

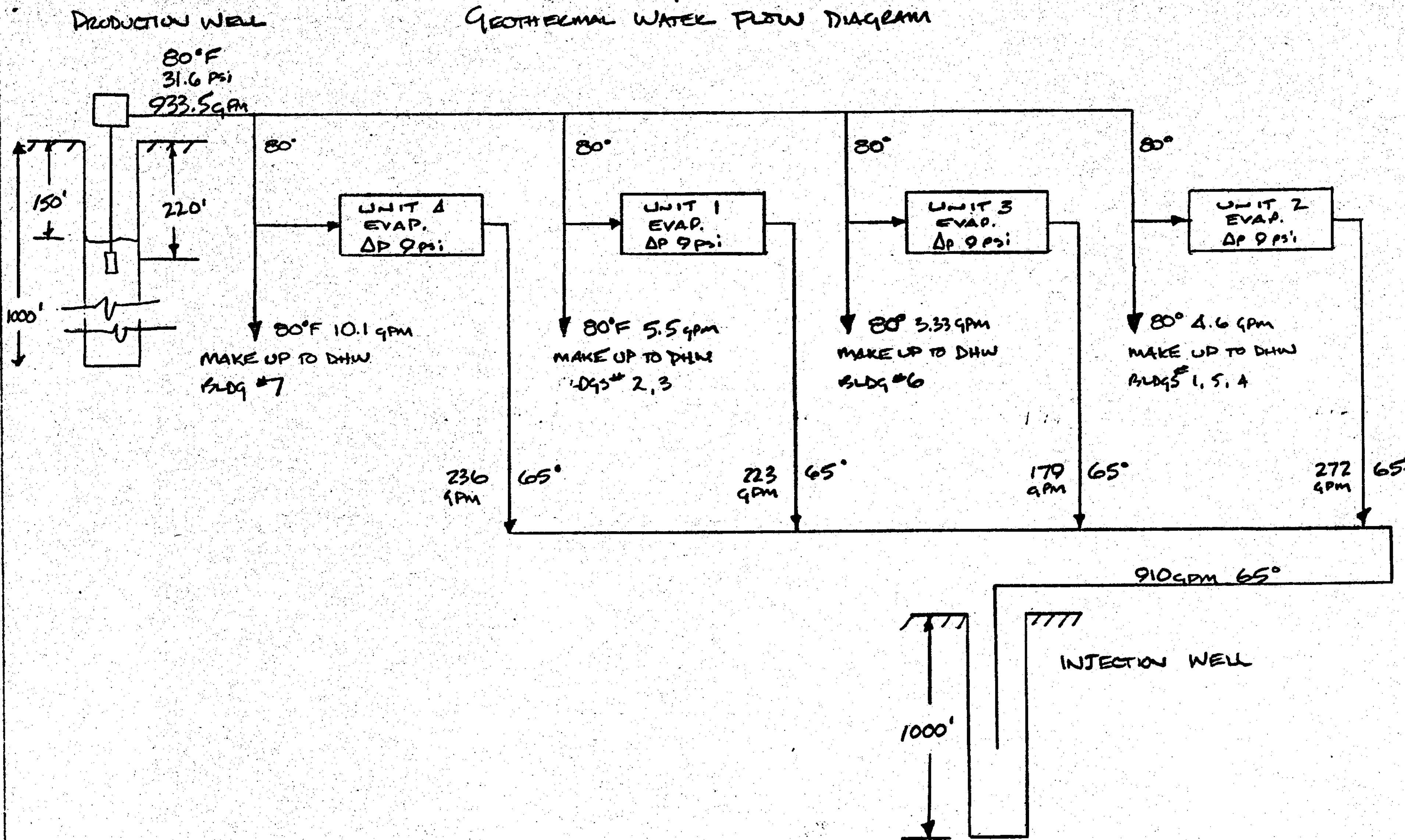


FIGURE #4

FLOW DIAGRAM FOR SYSTEM #1 (BLDGS 2 AND 3)
SYSTEM #2 (BLDGS 1,4,5) SIMILAR

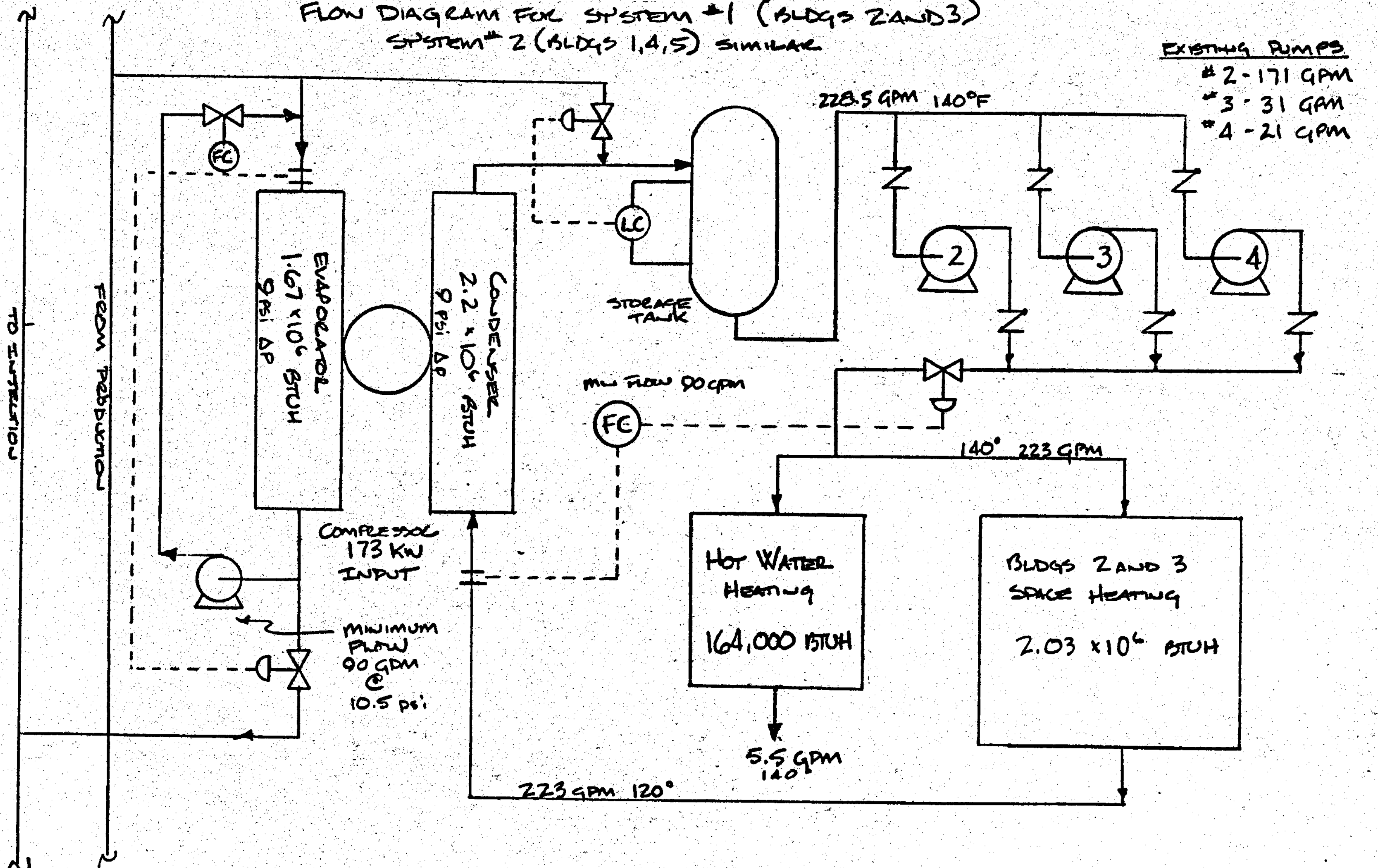
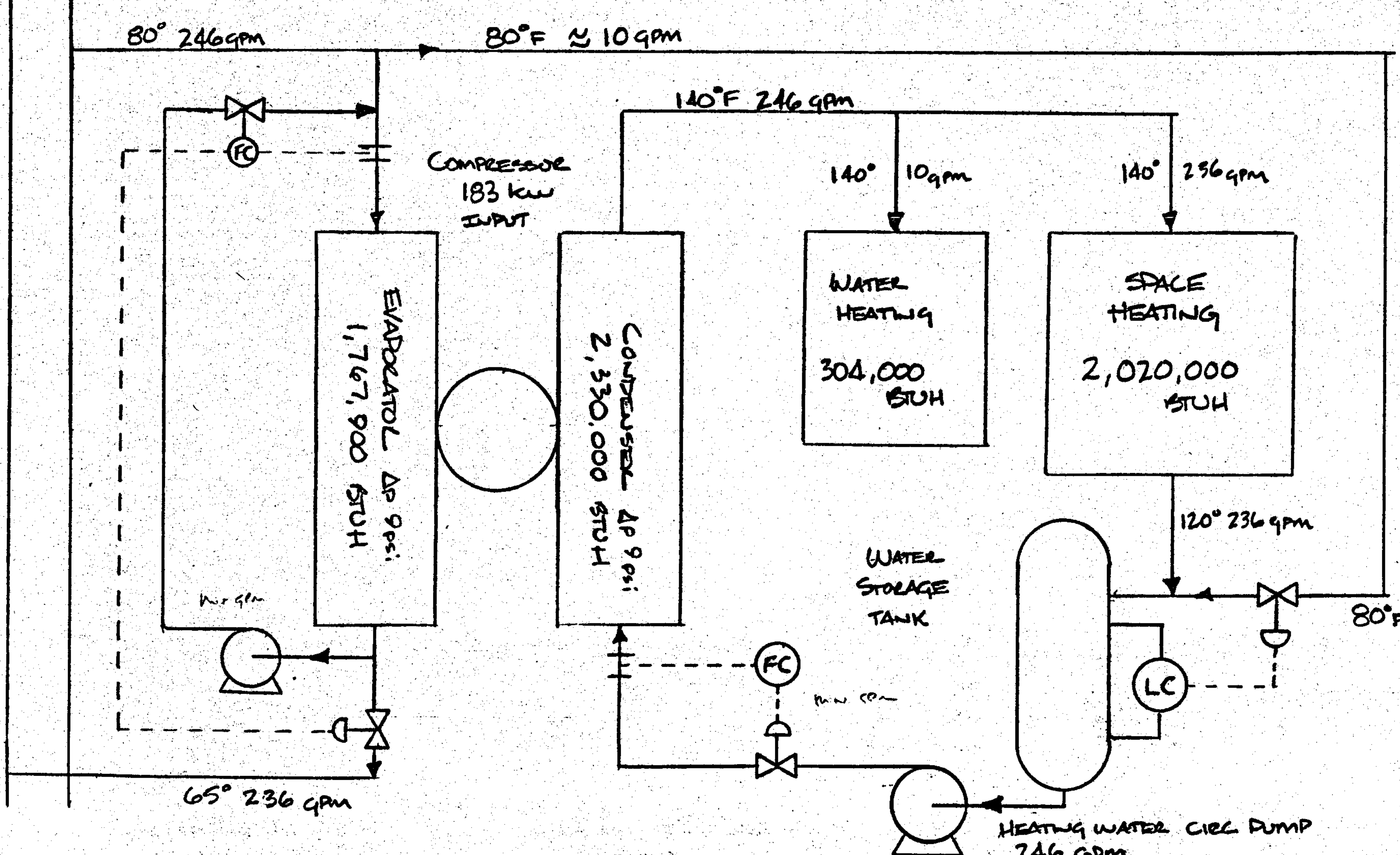


FIGURE #5

FLOW DIAGRAM FOR BLDG # 7

(BUILDING 6 SIMILAR)



ADDENDUM

A. C. DAVIS HIGH SCHOOL

Yakima, WA

The following is a reply to the questions raised by the R. S. Cameron Company in its August 15, 1980 "Report on Geothermal Report".

Item 1, Page 1. Proposed capacity. Given the present conditions at the high school we would have to agree that the originally proposed capacity would not meet requirements. However, that design was based on significantly reduced ventilation rates. The present ventilation rates at Davis High School are far in excess of current practice, ASHRAE minimum, State Building Code, State Health Dept., Superintendent of Public Instruction and Uniform Building Code requirements. As evidenced by the attached figures(Appendix A) for building #6, maintaining these rates (currently at 2.8 times minimum requirements) results in substantially higher energy use than would otherwise be necessary. Specifically 17,428 therms/yr or $9411 dollars at .54 $/therm for building #6 only. this building was part of the most recent phase of construction, it is not unreasonable to expect that this condition exists in the other buildings as well. Regardless of the school's plans for geothermal, this problem should be examined in greater detail.

In addition, we have examined the gas use figures generated by R.S. Cameron and Company for the 78-79 winter. With these figures and data from the National Weather Service in Yakima, we have calculated (Appendix B) peak monthly heating loads using the ASHRAE degree day method. We have found this procedure valid in other studies and in analysis of the campus here at Oregon Institute of Technology. The attached data indicates a peak load in the month of February of about 12,000,000 BTU/HR. This is based on present conditions at the high school and is considerably less than the 18,000,000 BTU/HR felt to be necessary by the R. S. Cameron Co.

Given this present peak load of 12,000,000 BTU/HR, we feel that with reduction in ventilation rates, a peak load of 9,000,000 BTU/HR is a reasonable figure.

Item 2, Page 1. Electrical Costs. Pacific Power and Light, the electrical power supplier for the Yakima area, has in fact had rate increases since June, 1979, the latest being May 12, 1980. Calculations for the original study were based on May billing figures as obtained from the school business office. PPL has had recent rate increases in all of its service areas of between 6-9% and these have been incorporated into the current economic calculations. It is expected that any near-term increases will not exceed the 6-9% rate, however attempts to verify rates of increases have met with no success at the time of this report.

Natural gas in Yakima has an already approved rate increase of 18% over the next 18 months (the 4¢ already in effect has been incorporated into the latest cost figures).

Natural gas is expected to inflate at much higher rates than electricity due to deregulation. Some sources estimate this escalation at as much as 30% per year for the next few years then tapering off to match fuel oil. The escalation rates used in the study are available in the Economic Analysis section. We feel these are in fact somewhat conservative for natural gas in light of the already approved increases.

Item 3, Page 2. Cost Estimate. A revised cost estimate (Appendix C) has been compiled for a system to satisfy current conditions. After visiting the school it was apparent that some costs required adjustment. A revised capital cost for the design would be $1,120,000. This cost increase is primarily due to higher well drilling costs and more extensive piping modification requirements.

Item 4, Page 2. Distribution System. After visiting the campus, it was obvious that the originally proposed piping system was not a workable design. The attached diagram (Appendix D) indicates the new routing of geothermal delivery mains. The lines could be installed under the sidewalks and grass areas between the buildings and the street. Conversations with the Yakima City Engineer have indicated that Schedule 40 PVC pipe is permissible in this type of installation.

Item 1, Page 2. Part Load Efficiency. Appendix E shows curves provided by Westinghouse indicating part load performance of Templifier centrifugal heat pumps specifically for this application. From these curves we have determined that an overall (system) COP of 3.28 will be most accurate for energy costs. This would result in approximately a 6% decrease in the projected electrical use for space and domestic hot water heating that appears in the original study. Thus, the figures used in that study are actually in excess of the amount of energy that would be used.

Item 2, Page 3. Water Fouling. The creamery well has, and any projected well in the area probably will have, potable water of about 100 parts per million total dissolved solids. This water quality is much better than many municipal systems. Calculation of the Langlier Saturation Index indicates that the creamery well water is not expected to cause either corrosion or scaling. Isolating heat exchangers, exotic or even nonstandard materials, will not be required.

Attached is a copy of the water analysis performed by University of Utah Research Institute for Roger Howe Associates, Inc. in conjunction with another proposed project in Yakima.

Item 3, Page 3. Domestic Hot Water System. As stated above the well water is of sufficient quality for use as make-up to the domestic hot water system. This will result in a reduction of present energy requirements due to the higher make-up water temperatures.

The placement of heat exchangers between the heating system water and individual storage facilities should eliminate the sanitation problems existing in the original design. In addition, the existing steam heat exchangers could serve as stand-by.

Item 4, Page 3. Inquiries were made to Bonneville Power Administration, Washington Public Power Supply, and Pacific Power and Light. In all three cases we found that no policy covering water source heat pumps is currently in force. (although they did not recommend any future resistance heating or air source heat pumps requiring resistance heat supplementation). The general feeling is that the reliability of the electric power is at least as good as natural gas. The natural gas supply for the Yakima area comes from Canada and there are no long-term assurances that it will continue. The cost of the gas is almost certain to increase faster than electrical energy which will always be supplied to some degree by hydroelectric means. All agree that in the event of an extreme drought there will be some power shortages, but we have already seen natural gas curtailments and can probably expect to see more in the future.

As for electrical power failures or serious curtailments, the effect would be the same with the present system or a heat pump system since neither can operate without electricity.

Item 5, Page 3. Contrary to the original report, the existing boilers can remain in place. Space is available just outside the mechanical room for installation of heat pump number 1. With the boilers remaining, the current cooling system can be retained. Allowances have been made in the utility use figures for this situation.

The following economic analysis indicates that a heat pump system based on present conditions at Davis High School is not economically feasible. We believe this is the result of an unrealistically high heating load imposed by excessive ventilation rates. So far as can be determined there are no Code stipulations or unusual mechanical problems that would prevent reduction of these rates by substantial amounts. The result of this would not only cause the heat pump system to appear more economically attractive, but would result in immediate energy use reductions and related cost saving to the school. Given the present heating load for Davis (12,000,000 BTU/HR), with reasonable reduction in ventilation, the peak load figure used in the original study appears to be valid. Using that figure (9,000,000 BTU/HR) and the cost increases outlined in this report, a heat pump system would still be less than economically feasible. However, it would be more attractive than one based on the present 12,000,000 BTU/HR figure. Should natural gas rates inflate at a rate above those forecast in this report, the situation would be subject to review. For instance if natural gas inflates at 15-18% the next 5 years then reverts to the inflation rates we used, the project will be very economically feasible.

A. C. DAVIS HIGH SCHOOL

SPACE HEATING ECONOMIC ANALYSIS

The current annual cost of natural gas was established as $103,389. This annual cost was projected through the year 2000 at the following inflation rates:

1981-1984	7.6%
1985-1989	8.4%
1990-1994	10.3%
1995-2000	10.6%

Heat pump operation and pumping costs were estimated to be $37,788 per year. These costs were projected through the year 2000 at the following inflation rates:

1981-1988	8.9%
1989-2000	8.6%

Maintenance costs for the system were estimated to be $38,099 per year. These costs were projected at an inflation rate of 7% per annum through the year 2000, which is also the assumed economic inflation rate.

Insurance costs were estimated to be $7,866 per year and were projected to increase at 2% per annum over the 20-year project life.

Using these figures, the following table of projected cash flows was compiled.

Assuming that the high school would finance the project with 8% tax-free bonds maturing in 20 years, a net present value of the 20-year cash flows was calculated at 8% annually. The results of these calculations indicate that the high school could afford to spend $630,686 for this project. The estimated capital investment is $1,270,000; therefore, the project is not feasible.

Further calculations were done to find some interest rate for borrowed money that would make the project feasible. The rate found was 2-1/2%, indicating that the capital investment will have to be decreased or the annual operating costs would have to be decreased in order to make the project worthwhile.

A second economic analysis was run to determine the feasibility of this project with higher inflation rates for natural gas. A 10% increase for the year 1981 has already been announced by the supplier of natural gas; and based on experience over the past three years, it was assumed that natural gas prices would inflate at 20% per year from 1982 through 1985. All other inflation rates remain the same as in the first year analysis.

The results of the second run were that the school could afford to spend $1,754,947 on the project if they can finance it with an 8% tax-free bond issue. Thus, the project is feasible. A word of caution. It may be erroneous to assume that inflation rates for natural gas in the next five years will follow the pattern established in the past three years.

A. C. DAVIS HIGH SCHOOL
20-YEAR PROJECTION OF COSTS AND BENEFITS

20-Year Projected Cost Natural Gas	Geothermal System Electrical Cost	Geothermal System Maintenance Cost	Geothermal System Insurance Cost	20-Year Projected Cash Flow	Net Present Value at 8%	Net Present Value at 2.5%
111245.	41151.	40765.	8023.	21306.	19727.	20788.
119701.	44813.	43615.	8183.	23084.	19791.	21976.
128796.	48801.	46672.	8347.	24976.	19826.	23193.
138587.	53145.	49940.	8514.	26987.	19836.	24453.
150228.	57875.	53435.	8684.	30232.	20575.	26734.
162847.	63026.	57176.	8858.	33786.	21291.	29151.
176526.	68635.	61178.	9035.	37677.	21984.	31718.
191355.	74744.	65461.	9216.	41933.	22655.	34444.
207426.	81172.	70043.	9400.	46812.	23418.	37518.
228794.	88152.	74946.	9588.	56106.	25987.	43873.
252359.	95734.	80192.	9780.	66652.	28586.	50855.
278352.	103967.	85806.	9975.	78603.	31214.	58516.
307023.	112908.	91812.	10175.	92126.	33874.	66917.
338646.	122618.	98239.	10379.	107409.	36568.	76123.
374543.	133163.	105116.	10586.	125676.	39618.	86905.
414244.	144615.	112474.	10798.	146356.	42720.	98747.
458154.	157052.	120347.	11014.	169740.	45875.	111742.
506719.	170559.	128772.	11234.	196153.	49087.	125993.
560431.	185227.	137786.	11459.	225958.	52357.	141612.
619837.	201156.	147431.	11688.	259560.	55686.	158720.
				TOTAL 1811140.	TOTAL 630686.	TOTAL 1270000.

A. C. DAVIS HIGH SCHOOL
20-YEAR PROJECTION OF COSTS AND BENEFITS

(INCREASED INFLATION RATES THROUGH 1985)

20-Year Projected Cost Natural Gas	Geothermal System Electrical Cost	Geothermal System Maintenance Cost	Geothermal System Insurance Cost	20-Year Projected Cash Flow	Net Present Value at 8%
113727.	41151.	40765.	8023.	23787.	22025.
136473.	44813.	43619.	8183.	39856.	34170.
163769.	48801.	46672.	8347.	59945.	47586.
196521.	53145.	49940.	8514.	84922.	62420.
235826.	57875.	53435.	8684.	115830.	78832.
255635.	63026.	57176.	8858.	126574.	79763.
277108.	68635.	61178.	9035.	138259.	80672.
300386.	74744.	65461.	9216.	150964.	81561.
325618.	81172.	70043.	9400.	165002.	82542.
359157.	88152.	74946.	9588.	186469.	86371.
396150.	95734.	80192.	9780.	210443.	90255.
436953.	103967.	85805.	9975.	237204.	94197.
481960.	112908.	91812.	10175.	267063.	98193.
531602.	122618.	98239.	10379.	300365.	102262.
587951.	133163.	105116.	10586.	339085.	106893.
650274.	144615.	112474.	10798.	382386.	111614.
719203.	157052.	120347.	11014.	430789.	116423.
795439.	170559.	128772.	11234.	484873.	121339.
879756.	185227.	137786.	11459.	545282.	126343.
973010.	201156.	147431.	11688.	612733.	131460.
				TOTAL 4901840.	TOTAL 1754947.

APPENDIX 'A'
VENTILATION FIGURES FOR BLDG #6

CURRENT VENTILATION RATE(6)

UNIT VENTILATORS AND FAN COIL UNITS(2)

24 @	262.5 cfm	- 6300
12 @	350 "	- 4200
2	150	- 300
5	100	- 500
5	525	- 2625
6	437.5	- 2625
2	50	- 100
1	60	- 60
		16,710 cfm

REQUIREMENTS AT ASHRAE MINIMUMS(6)

AREA	cfm/ft²	ft²	cfm
STORAGE	.015	2436	36.5
LAVATORY	.5	1344	672
CORRIDOR	.25	3240	810
CLASSROOM	.25	10364	2591
CRAFT	.15	9280	1392
LABORATORY	.15	2888	433
			5935

EXCESS VENTILATION

16,710 − 5935 = 10,775 cfm

HEATING REQUIREMENT IMPOSED BY EXCESS VENT. @ PEAK

10,775 · 1.08 · (65 − 0) = 756,405 BTUH

ANNUAL ENERGY USE DUE TO EXCESS VENTILATION

(756,405 · 6592 · 24 / 65 · .75 · 100,000)(.71) =

17,428 THERMS @ .54 $/THERM = $9411

A.C. DAVIS HIGH SCHOOL

GAS USAGE WINTER '78 '79 - 196,014 THERMS

$$E = \left(\frac{H_L \cdot DD \cdot 24}{\Delta t \cdot \eta \cdot V}\right)(C_D)^{(5)(6)}$$

- E - FUEL CONSUMPTION FOR ESTIMATE PERIOD
- H_L - DESIGN HEAT LOSS BTUH
- DD - NUMBER OF DEGREE DAYS FOR ESTIMATE PERIOD
- Δt - DESIGN TEMPERATURE DIFFERENCE
- η - FULL LOAD EFFICIENCY
- V - HEATING VALUE OF FUEL
- C_D - INTERIM CORR FACTOR FOR HEATING EFFECT VS DEGREE DAYS

$$196,014 = \left(\frac{H_L \cdot 6992^{(1)} \cdot 24}{65 \cdot .75 \cdot 100000}\right)(.71)$$

H_L = 8,506,970 BTUH - AVERAGE PEAK LOSS '78-'79

MONTH	DD[2]	MIN TEMP	C_D	Δt	USAGE[3] (THERMS)	CALCULATED[6] DESIGN LOAD
JAN.	1549	-10	.64	75	48,595	11 488 716 BTUH
FEB.	901	-10	.64	75	29 404	* 11 951 239
MAR.	641	24	1.0	41	15 314	3 061 008
AP.	456	26	1.0	39	10 693	2 857 915
OCT.	470	20	.89	45	10 123	3 403 172
NOV.	975	6	.758	59	33.231	8 290 326
DEC.	1155	-9	.647	74	30 671	9 491 250

PEAK LOAD 11,951,239 - FEB '79
≈ 12,000,000 BTUH

(1) FIGURES FOR OCT 78 TO AP '79 YAKIMA WEATHER SERVICE. FIGURES FOR MAY - SEPT FROM NOAA FIGURES AUG. '41-'70
(2) FIGURES FROM YAKIMA WEATHER SERVICE FOR '78-'79 WINTER
(3) FIGURES FROM R.S. CAMERON FOR '78-'79 WINTER.
(4) ALL GAS ASSUMED TO BE USED FOR SPACE HEATING PURPOSES. SHOULD YIELD SOMEWHAT HIGH HEAT LOSS FIGURES.
(5) CORRECTION FACTOR FOR OVERSIZING NOT CONSIDERED. SHOULD YIELD A HIGH PEAK LOAD FIGURE
(6) ASHRAE DEGREE DAY EQUATION WITH OVERSIZING CORRECTION OMITTED FROM 1976 SYSTEMS VOL 43.8.

SUMMARY OF CAPITAL AND OPERATING COSTS
(BASED ON PRESENT VENTILATION RATES)

CAPITAL COSTS

PRODUCTION AND INJECTION WELLS	155000
TURBINE PUMP	70 000
UNDER GROUND PIPING	60 000
SIDEWALK REPAIR	15 000
HEAT PUMPS	430 000
WELL HEAD BUILDING	10 000
CONVECTOR REPLACEMENTS	10 000
AIR HANDLER COIL REPLACEMENTS	45 000
CIRC. PUMPS AND SPARES	25 000
INTERNAL PIPING ALLOWANCE	80 000
MISC MECHANICAL AND ELECTRICAL	100 000
ENGINEERING @ 10%	100 000
DOMESTIC HOT WATER RETROFIT	11 000
SUB TOTAL	1,100,000
CONTINGENCY	170 000
TOTAL	$ 1 270 000

OPERATING COSTS

MAINTANANCE	38 099
INSURANCE	7866
ELECTRICAL POWER FOR SYSTEM @ .0234 $/KW	37 788
	$ 83,753

NATURAL GAS SAVINGS

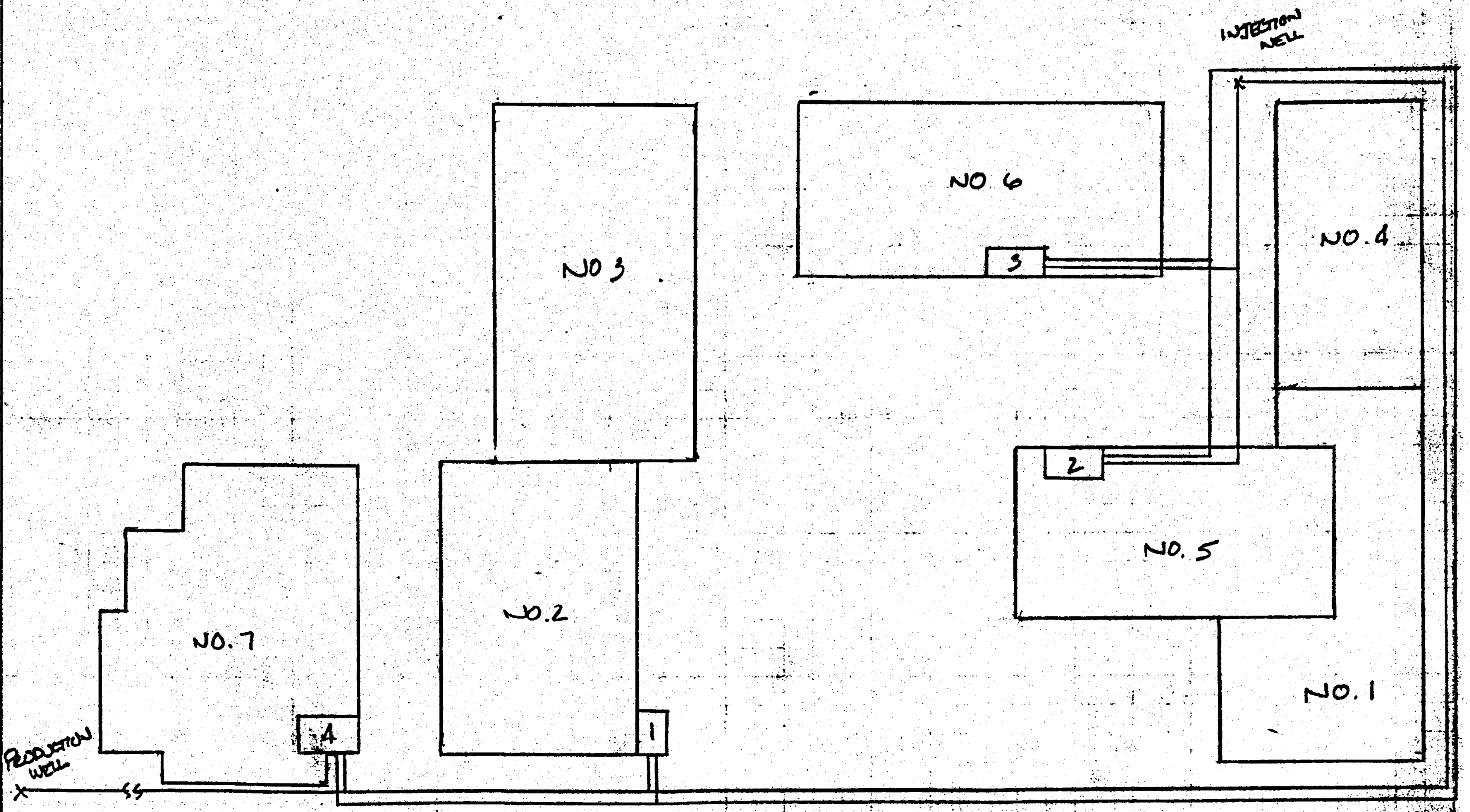
189 461 THERMS/YR @ .5457 $/THERM

= 103 389

APPENDIX D

A.C. DAVIS HIGH SCHOOL

GEOTHERMAL PIPING SYSTEM LAYOUT



APPENDIX E

UNIT #1 - CAPACITY OF 3.057×10^6 BTUH
300 GPM SOURCE WATER

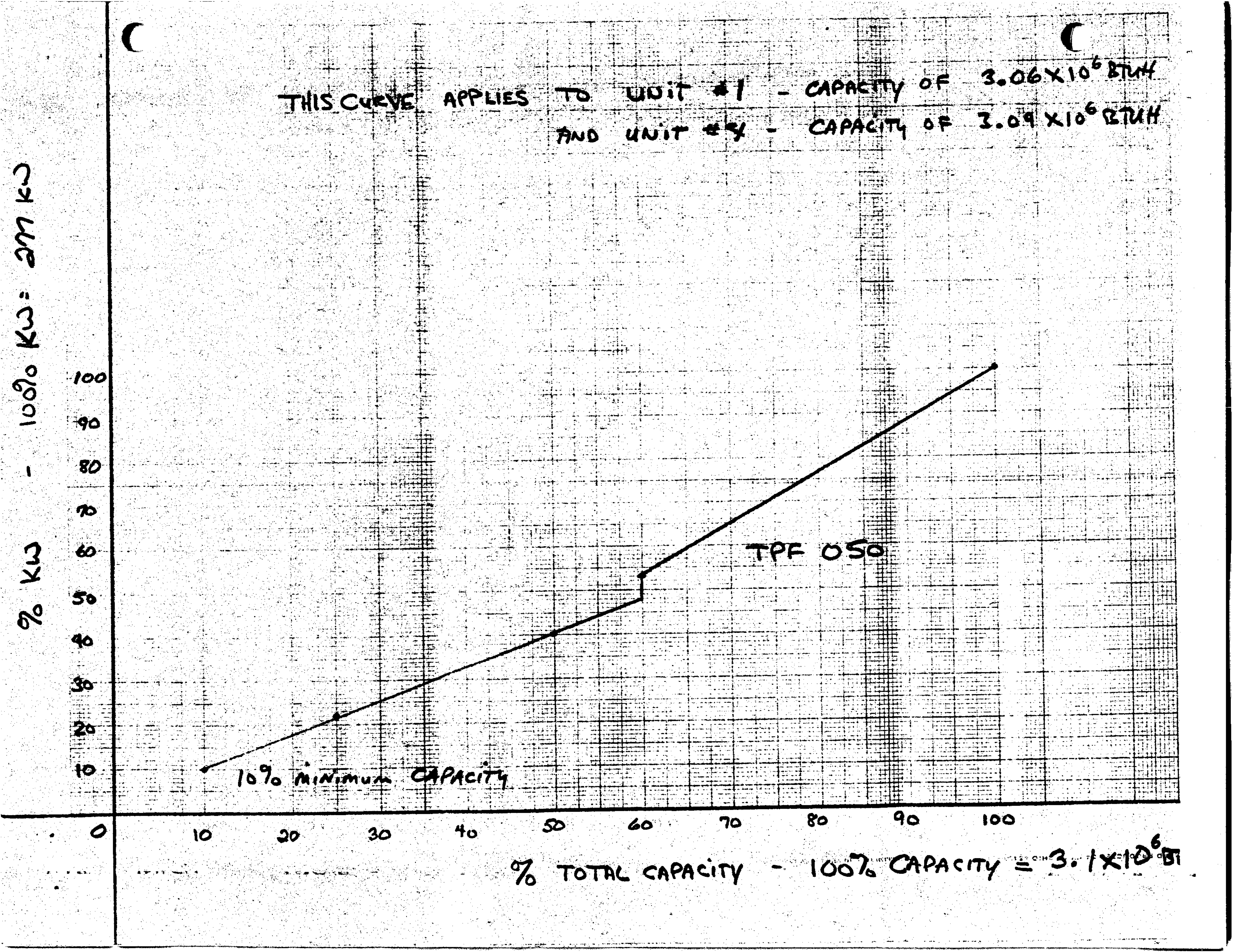
% CAPACITY	CAPACITY	KW INPUT	COP
100	3.057×10^6	277	3.94
75	1.84×10^6	147	3.65
50	1.52×10^6	110	4.06
25	$.77 \times 10^6$	62	3.64
10	$.30 \times 10^6$	28	3.11

UNIT #2 - CAPACITY OF 3.742×10^6 BTUH
390 GPM SOURCE WATER

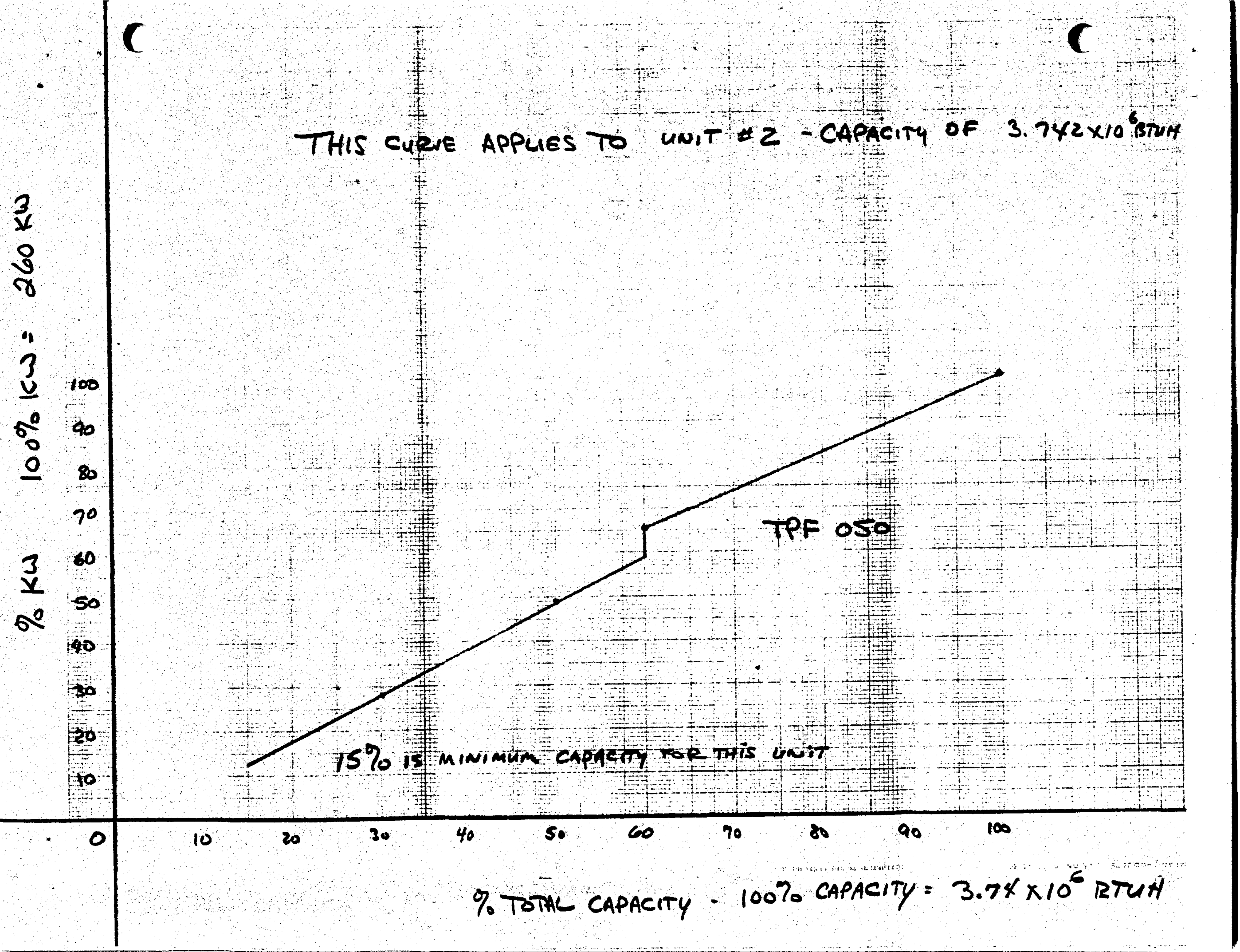
100	3.742×10^6	260	4.19
75	2.84×10^6	170	3.86
50	1.87×10^6	128	4.29
25	1.06×10^6	79	3.90
15 (MIN.)	$.56 \times 10^6$	-	-

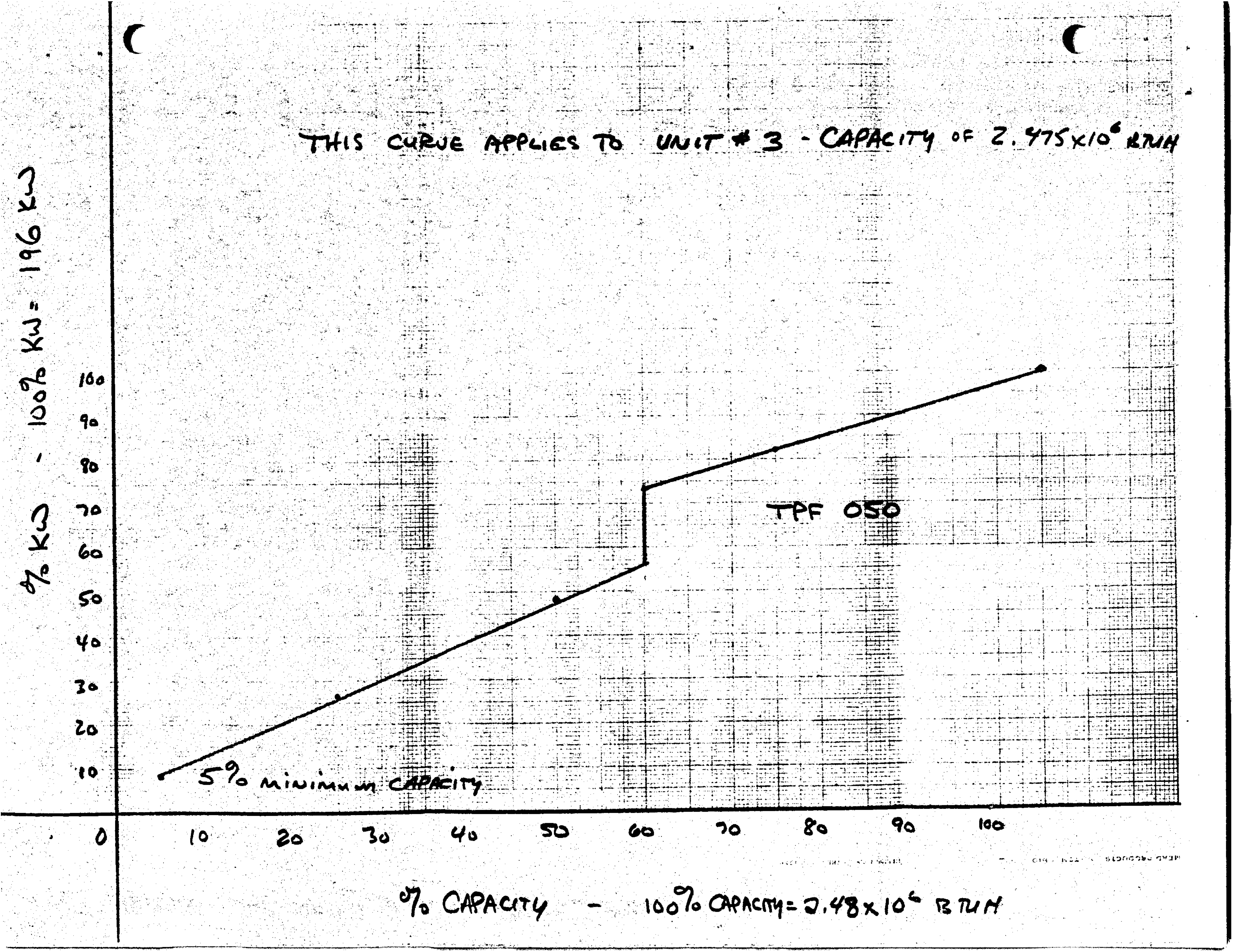
UNIT #3 - CAPACITY OF 2.475×10^6 BTUH
244 GPM SOURCE WATER

100	2.47×10^6	196	3.69
75	1.85×10^6	160	3.39
50	1.24×10^6	95	3.79
25	$.61 \times 10^6$	52	3.41
5	$.13 \times 10^6$	16	2.41



THIS CURVE APPLIES TO UNIT #1 - CAPACITY OF 3.06X10^6 BTUH
AND UNIT #4 - CAPACITY OF 3.09 X10^6 BTUH
% KW - 100% KW = 2M KW
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
TPF 050
10% MINIMUM CAPACITY
% TOTAL CAPACITY - 100% CAPACITY = 3.1X10^6 BT

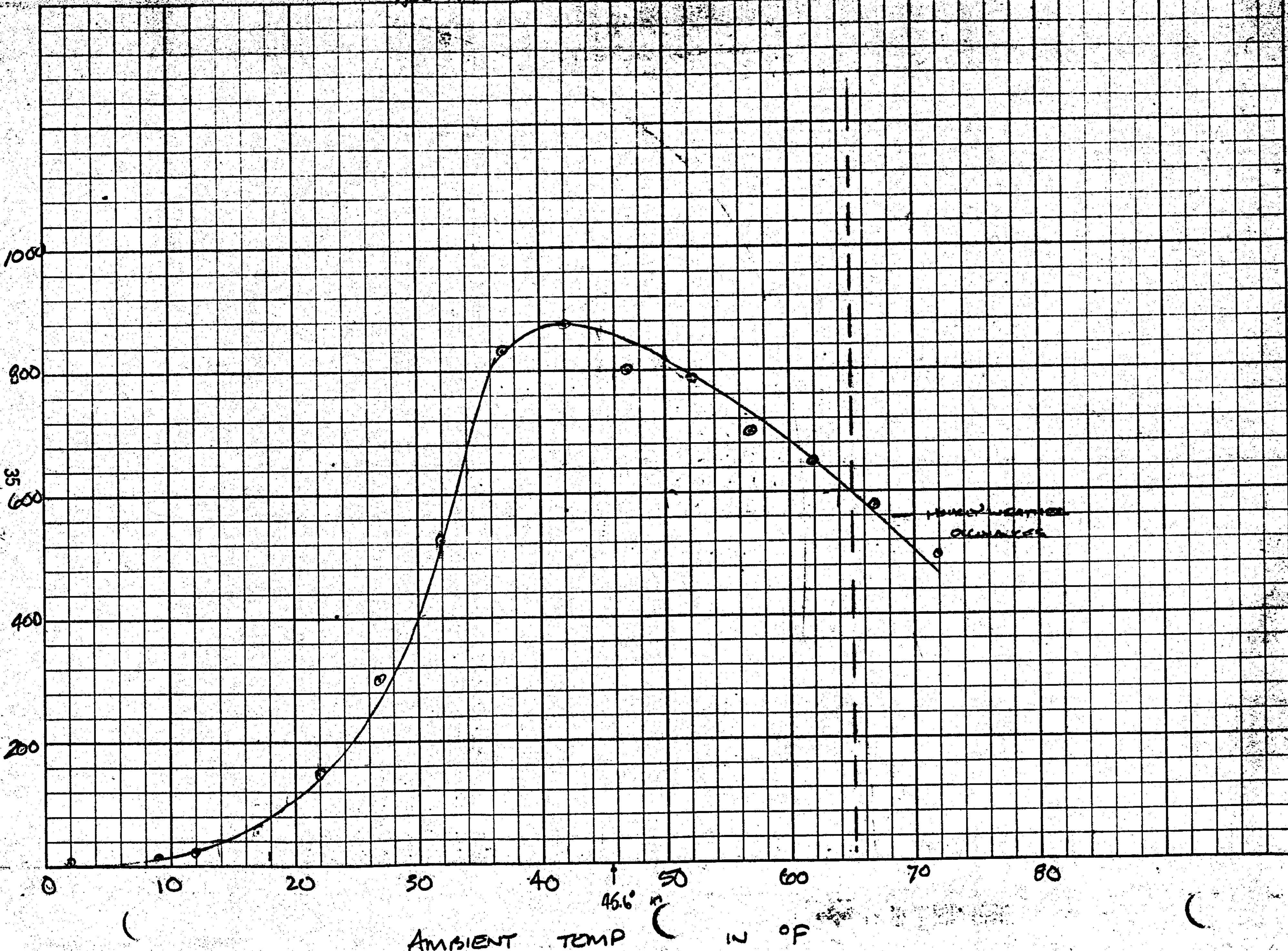

THIS CURVE APPLIES TO UNIT #2 - CAPACITY OF 3.742 X 10^6 BTUH
% KW 100% KW = 260 KW
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
TPF 050
15% IS MINIMUM CAPACITY FOR THIS UNIT
% TOTAL CAPACITY - 100% CAPACITY = 3.74 X 10^6 BTUH



THIS CURVE APPLIES TO UNIT # 3 - CAPACITY OF 2.475x10⁶ BTUH
% KW - 100% KW = 196 KW
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
TPF 050
5% MINIMUM CAPACITY
% CAPACITY - 100% CAPACITY = 2.48x10⁶ BTUH

APPENDIX E

HOURLY WEATHER OCCURANCES



ROGER LOWE ASSOCIATES INC.
EARTH SCIENCES

July 2, 1980

John Graham and Company
Energy Management Department
1110 Third Avenue
Seattle, Washington 98101

Attention: Mr. Arun Jhaveri

Report Addendum
Geotechnical Well Feasibility Study
St. Elizabeth Hospital
Yakima, Washington
RLAI Project No. 604-01

Gentlemen:

This letter provides the results of water quality testing by the University of Utah Research Institute (UURI) on samples collected from the Creamery Well. This addendum to our June 20, 1980 report completes the scope of services for our geothermal well feasibility study for the St. Elizabeth Hospital.

FIELD PROCEDURES

A representative from UURI collected water samples from the Creamery Well on June 3, 1980. The samples were filtered, fixed with nitric acid, and stored in glass containers for shipment to the UURI laboratory. The pH of the well water was measured at 7.2 at the site.

CHEMICAL ANALYSES

Testing at the UURI lab resulted in the following results:

Parameter	Concentration (ppm)
Total Dissolved Solids	120
Na	51
K	$\leq$0.5
Ca	1.4
Mg	none detected
Si	7
F	1.2
Cl	14
SO_4	none detected

JOHN GRAHAM AND COMPANY
JUL - 3 1980
JG RRK FDH ATS HRT Des Ar PRD Struct Civil Mech Elect Specs Const Acctg Traffic Est Job Proj. Eng.
Ur Pln Env Ser St Pln Sp Pln Bus Dev Spec Pro Lib WPC M File J File E File Anch Houston Client

MAIL: P.O. BOX 3885, BELLEVUE, WA. 98009 - TELEPHONE (206) 453-8383
LOCATION: BENAROYA BUSINESS PARK, BLDG. 4, SUITE 219 - 300 120th AVE. N.E., BELLEVUE, WA.

GEOTHERMOMETRY

In the subsurface certain ions are in chemical equilibrium with the surrounding soil and rock materials. The concentration of the ions increases as temperature increases. By determining the chemical concentration of certain critical ions and applying mathematical procedures to the concentrations, the warmest past temperature of the sampled water can be estimated. Several sets of ions (geothermometers) can be used for estimating temperature. When two or more of the geothermometry calculations are in close agreement, confidence in the calculated temperature is increased.

UURI estimated the warmest past temperature of water collected from the Creamery Well using the Na-K-Ca geothermometer and the quartz-silica geothermometer. The results of their calculations are as follows:

Geothermometer	Estimated warmest past temperature	
Na-K-Ca	54°C	(129°F)
SiO_2	53°C	(127°F)

The calculated values are in close agreement and indicate the possibility that water from the Creamery Well may have been as warm as 125 - 130° F and cooled by upward flow before reaching the well location.

CONCLUSIONS

Water from the Creamery Well is relatively low in dissolved solids and is of good quality. The parameters tested are within drinking water standards. Based on the available data, the well water is not expected to cause corrosion or scaling problems in the heat pump coils, the wells, or the geologic materials surrounding the injection well.

The results of the geothermometry indicate that the potential for producing water up to 125°F is very good. The values do not affect the estimate of the local geothermal gradient, as presented in our report of June 20.

Please call us if you have any questions regarding this addendum.

Yours very truly,
ROGER LOWE ASSOCIATES INC.

James A. Miller, Senior Geologist

Jon W. Koloski, Associate

JAM/JWK/cp
8 copies submitted

R. S. CAMERON & COMPANY, P. S.
ARCHITECTS ENGINEERS
MEMBER AMERICAN INSTITUTE OF ARCHITECTS
1014 SOUTH THIRD AVENUE YAKIMA, WASHINGTON 98902 PHONE (509) 453-5501

REPORT ON GEO-THERMAL REPORT

August 15, 1980

After examining this report, it is our recommendation that this report not be accepted or released for publication until it has been revised to rectify the following deficiencies:

1. The proposed installed capacity is insufficient to handle the Winter time load and we feel it should be doubled. This will be discussed in greater detail below.

2. The analysis of electrical operating costs fail to recognize that there is a substantial upcoming power cost increase this Fall and that the Power Company has not had an increase in rates since June, 1979, but during this time the gas rates have nearly doubled, so that now it is the Power Company's turn to play catch-up. Comparison should be made on basis of revised power rates.

3. The cost estimate that has been prepared for the proposed job appears to be insufficient in respect to well costs, electrical costs, water distribution main and mechanical system modification cost. We feel that a minimum budget of $1,155,000 be set up for the construction of the project based on the capacities used in the report. If our recommendations for system capacity are followed, the budget would be approximately $1,900,000.

4. The proposed distribution system does not appear to be feasible in that some of it cuts across the existing court and it is necessary to cut up the existing concrete retaining walls, steps, fountain and court yard. We believe that this line will be routed around the outside of the property and must meet requirements for construction imposed by the City Engineering Department, thus rendering the use of plastic pipe questionable.

In addition to the foregoing, there are a number of relevant concerns which we believe have been ignored or inadequately addressed. These are:

1. Part load efficiencies of equipment and its effect on annual power consumption and operating cost.

2. Well water fouling at heat exchange surfaces and loss of efficiency due to having isolating heat exchangers in system.

3. Sanitation aspects of proposed domestic hot water layout.

4. Reliability of power source. Present utility and governmental projections are that our Pacific Northwest Region will have insufficient electrical energy during the next decade. Conversions such as this only serve to aggravate this problem. Consideration of backup provisions in event of curtailment have not been addressed.

5. Data should be revised to take into account the cooling systems both existing and proposed.

Now to return to Item 1 in our list of difficiencies, we find that the projected annual load of 14.45 billion BTU's/yr. agrees pretty well with the annual gas consumption when using an average annual boiler efficiency of 75%, which is a reasonable overall figure. If this annual usage be divided by the 1,715 annual operating hours in the school year, the hourly capacity required would be 8.43 million BTU's/hr. The installed capacity is projected at 9 million BTU's/hr. giving only about 7% extra capacity available for carrying peak loads in the Winter months.

REPORT ON
GEO-THERMAL REPORT

8/15/80

Our study of gas consumption rates indicates that the January consumption goes as high as 2.3 times the average consumption. The number of degree days in January is 1.87 times the average number of degree days per month in the school season. So it appears to us that the installed capacity to meet peak loads should be about 18 million BTU's/hr. or about twice the contemplated capacity. The present installed boiler capacity consists of two(2) 14 million BTU's/hr output boilers and one(1) 9 million BTU's/hr. output boiler, making a total capacity of 37 million BTU's/hr. In the Winter it is necessary to fire both large boilers to carry the load in the daytime. Although the present system has a certain number of inefficiencies and a comfortable safety factory, we believe it is totally inconceivable that an installation having 25% of present installed output capacity will be adequate, therefore we have made the recommendations that the proposed capacity of heat pumps be doubled.

The revision of electrical operating costs and investment costs will have a substantial effect on the payoff conclusions reached and the report should be revised taking these changes into account.

G. FORREST SAINSBURY
Professional Engineer