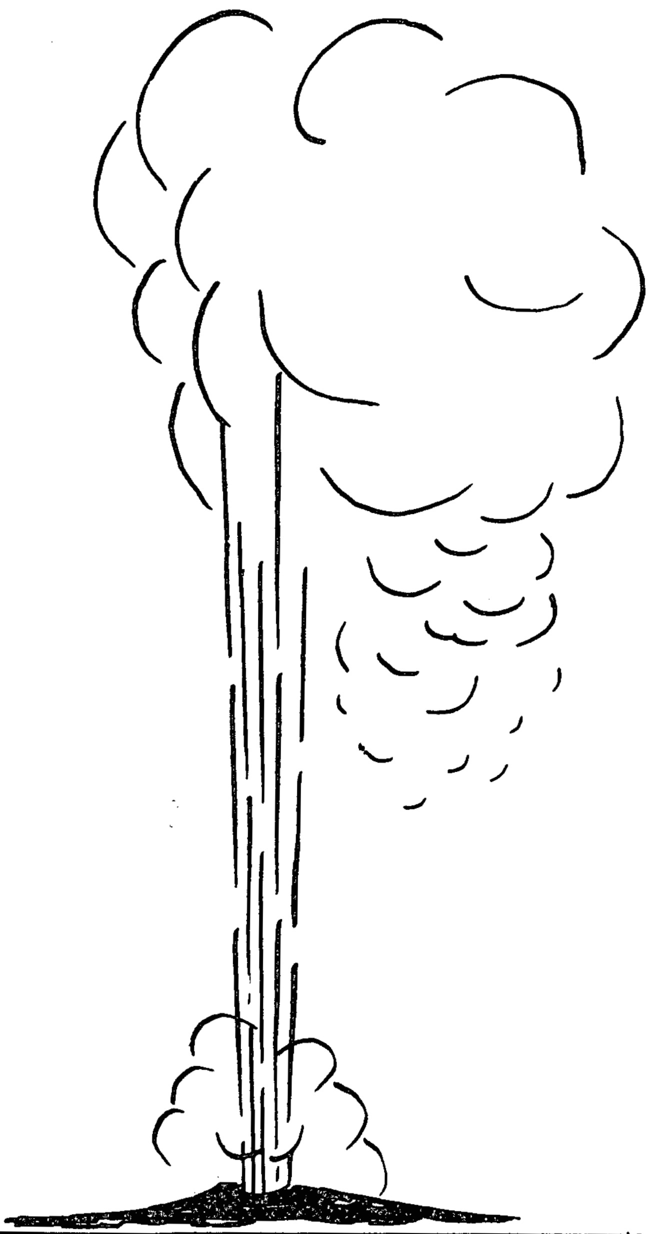

SAN-1740-2

MULTI-USE GEOTHERMAL ENERGY SYSTEM WITH AUGMENTATION FOR ENHANCED UTILIZATION

A Non-Electric Application of Geothermal Energy in Susanville, California

Second Quarterly Technical Report for April 1—June 30, 1978

MASTER

By
G. R. Cunnington
G. K. Olson

Work Performed Under Contract No. ET-78-C-03-1740

Aerojet Energy Conversion Company
Sacramento, California

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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SECOND QUARTERLY TECHNICAL REPORT

PERIOD COVERED:
1 APRIL 1978 - 30 JUNE 1978

CONTRACT NO. ET-78-C-03-1740

PREPARED FOR:

U. S. DEPARTMENT OF ENERGY
GEOTHERMAL ENERGY DIVISION
SAN FRANCISCO OPERATIONS OFFICE

PREPARED BY:
G. R. CUNNINGTON
G. K. OLSON

AEROJET ENERGY CONVERSION COMPANY
SACRAMENTO, CALIFORNIA

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SECTION I

A. ABSTRACT

The objectives of this study are to determine the economic and technical feasibility of using the low to moderate temperature geothermal resource in the Susanville anomaly in a district heating/cooling system for public or private users and in a Park of Commerce developed in conjunction with the resources development. The Susanville resource temperature is known to be a minimum of 150°F and is projected to be a maximum of 239°F.

The drilling of a production well is scheduled for this fall. For any geothermal project where the reservoir has been identified but not completely defined, there are three major uncertainties which affect the engineering and economic analysis: (1) the reservoir production temperature, (2) the production well flow rate, and (3) the cost per production and re-injection well. The reservoir temperature affects the size of geothermal system components and the type of system used. The flow rate per production and re-injection well affects the number of wells required and therefore, the cost of the reservoir development. The cost per production and re-injection well depends on drilling cost per foot, success rate in drilling, and the depth of the well. Because these factors all contribute to major capital outlays, design approaches have been studied which will permit economical utilization of the resource regardless of the outcome of the drilling. The system selected will depend on the result of the drilling program. This study presents a data base on systems for the temperature range from 150-239°F.

The results of the engineering and economic study currently indicate the region and conditions for economic feasibility summarized in Figure 1. Based on a predicted fuel inflation rate of 7% and a municipal bond interest rate of 10%, the development of the Susanville Geo-Heating District is economically feasible over the entire range of anticipated reservoir conditions. Under conditions of high well costs ($130 to $175 thousand dollars per well) and low resources temperature (150-165°F), economic and operational advantages can be shown for the use of heat pumps to augment the resource temperature. The engineering and economic analysis of the Park of Commerce has begun, but is not complete.

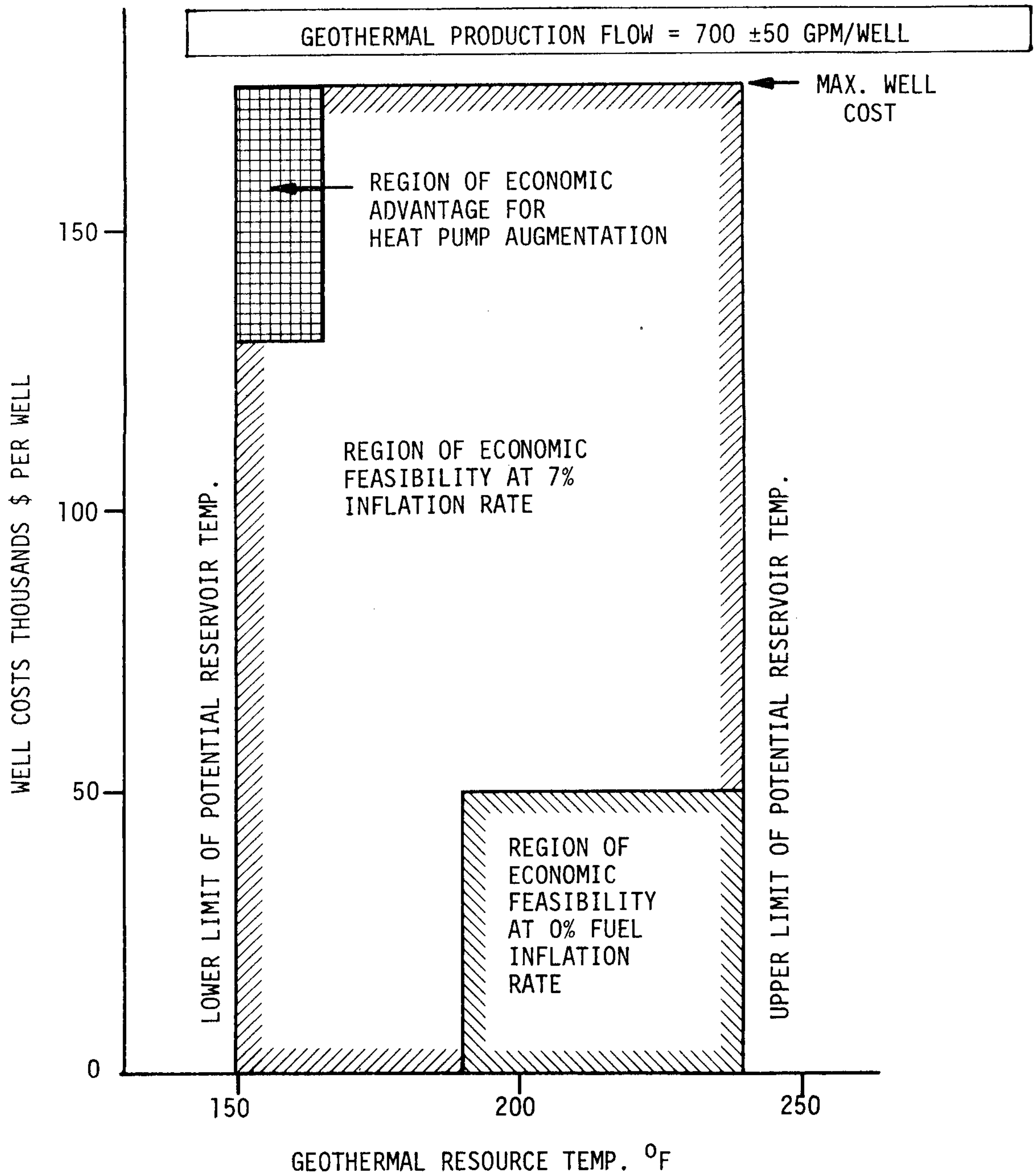


Figure 1. Susanville Geo-Heating District Conditions for Economic Feasibility at 10% Rate of Return.

Section I, (cont.)

B. PROJECT DESCRIPTION

The study of Multi-Use Geothermal Energy System with Augmentation for Enhanced Utilization is a study of a Geo-Heating District for Susanville, California. The work is being performed by Aerojet Energy Conversion Company under Department of Energy Contract Number ET-78-C-03-1740. This report covers the second quarterly period of the program.

The program is divided into five major tasks, with the following schedule:

Tasks	Scheduled Completion Date
1. Establish Requirements for Susanville Application	2/28/78
2. System Design Studies	8/31/78*
3. Recommended System Definition	9/29/78*
4. Application Plans	10/10/78
5. Reports (Draft Final Report to DOE)	11/3/78

The task definitions are as follows:

Task 1 - Establish Requirements for Susanville Application

Define the requirements for Susanville application, including user energy demands, prevailing energy costs and available resource data. The defined criteria shall be coordinated with the City of Susanville and the U. S. Bureau of Reclamation, the latter interface providing on-going Susanville reservoir definition. The Park of Commerce is also defined as part of this task.

Task 2 - System Design Study

Perform system evaluation studies including design, performance, and economic assessment for direct heat geothermal utilization, geothermal resource with energy augmentation, and non-geothermal approaches. The emphasis is on the evaluation of energy augmentation using electrically driven heat pumps.

*Tasks 2 and 3 have a revised completion date which will not affect the final report date.

Section I, B, Project Description (cont.)

Task 3 - Recommended System Definition

Select and define an economically viable system for application in a commercial Susanville geothermal energy system.

Task 4 - Application Plans

Prepare a system development plan describing further R&D needed (if any), field experiments, or other methods of achieving user acceptance in order to accelerate commercialization in the Susanville geothermal energy system.

Task 5 - Reports

Provide monthly project management reports, quarterly technical information reports, a management implementation plan, and a final report. A semi-annual review of program status with regard to technical, administrative and financial progress shall be conducted.

All of Task 1, the requirements definition phase, has been completed. Task 2, the system design study, is about 80% complete with the Park of Commerce design the largest remaining task. Also, the impact of air conditioning on system design will be studied in greater depth in July, both for the Park of Commerce and the Susanville Geo-Heating District.

SECTION II

A. REQUIREMENTS FOR SUSANVILLE APPLICATION

1. Geothermal Resource Data Update

No new resource data has been obtained from the Bureau of Reclamation drilling program since the last quarterly report. However, drilling of new test holes is underway now. The temperature range and flow rates initially adopted have not been changed. The temperature range studied is 150 to 239°F. The assumed flow rate per well is 700 ± 50 gpm.

2. Definition of a Park of Commerce

In the first quarterly report, the energy survey of the candidate buildings for the Susanville Geo-Heating District was completed. The buildings were grouped and their design heating loads, design cooling loads, and annual fuel consumption were determined. About the middle of this quarter, the planned Park of Commerce for the City of Susanville was defined and energy utilization data compiled (Reference 3).

Approximately 100 acres of land south of the City will constitute the Park area. At this time, it is likely that the Park will be composed of both private and public land. The Park area should overlay the Susanville Geothermal Anomaly.

For the first increment, the Park will contain two industries:

- Industry #1

A greenhouse operation producing potted plants , capable of either flowering or green plant production. This flexibility is required to meet the possibility of a shift in the product mix for the market. The facility will be owner-designed, steel framed, fiberglass covered with a thermal-internal blanket. Initially, three acres will be under "glass", increasing to five acres in two years and to 10 acres in five years. If the endeavor is successful and competitive with other sites, it will increase to 15 acres or more of "glass". The owner will want to purchase up to 20 acres of flat land. The 10 acre system will have 10,000 square feet of cold facility operating at 38°F from September through May. The greenhouses will operate at up to 80°F during the day and at 65°F at night. The greenhouse modules are nominally 168' wide (N-S) by 325' long (E-W), with seven units gable-connected, (peaks running East-West for 325' dimension). The initial three-acre system will operate as a satellite to a home plant. For this phase, the greenhouse units can be about 1/2 of 325' in length.

° Industry #2

A livestock feed and meat production facility will be capable of: (1) intensive growing of green grass, (2) purchase and drying of food constituents, (3) milling and processing of complete animal feeds, (4) feed sales, (5) confined feeding of livestock, (6) purchase of livestock, (7) slaughter, breaking to halves, (8) hide and pelt processing, (9) waste management, and (10) marketing. The feed production will yield, initially, 1,500 tons per month with growth to 6000 tons per month. Insulated buildings will house the feed growing (1/2 acre) and the processing and storage (1 acre). All structures are Butler-type, insulated metal buildings. All animal raising and waste management functions are confined, environmentally clean operations. Cattle will not be raised in this installation. A 36,000 square foot unit will raise 10,000 hogs per year with growth to 50,000 hogs per year. A 22,000 square foot unit will raise 120,000 rabbits per year with growth to 400,000 rabbits per year. Chickens are an alternative to rabbits and would utilize similar facilities. A two-acre slaughter facility will initially slaughter and break to halves 100 head per day of purchased cattle, 50-100 heads per day of hogs and 500 rabbits per day. With an optional addition of 1/2 acre, the slaughter facility will include processing to box ready, depending upon the market. A hide and pelt process and storage operation will require an additional 1/2 acre facility. The confined waste management facility will include methane production primarily from the hog wastes. The entire livestock complex will require about nine acres with growth to about 15 acres. The complex will employ about 200 people.

The feed production will require space conditioning (heat and evaporative cooling), process (drying) heat and cooling, and hydraulic drive energy. The animal raising will require heat and air conditioning for space conditioning. The slaughter facility will require hot water, space heat, refrigeration, and hydraulic energy. The hide and pelt processing will require space conditioning and hydraulic energy. The waste management facility will require process heat and hydraulic energy.

The Park of Commerce heating, air conditioning, and refrigeration requirements are summarized in Table 1. A five-acre greenhouse complex will have a design heat load of 16.0 million BTU/Hr., about 70% of the Susanville Geo-Heating District load of 23.4 million. Air conditioning is not required and only three tons of refrigeration for a cold conditioning box is needed when the greenhouse operation reaches 10 acres in size.

The greenhouse operation would either use low temperature well water directly or the effluent water from the district heating system. If a well flows 700 ± 50 gpm, the design limits for a five-acre module are shown in Figure 2. A small amount of higher temperature geothermal water could be used for soil sterilization (120°F). Soil sterilization is usually accomplished with steam.

In the integrated meat production facility, meat and by-products are produced from a process that starts with feed growing and processing and continues through meat production and organic waste utilization. The processes are all enclosed in insulated sheet metal buildings on one 9 to 15 acre site. These buildings have a very low heat loss because they will be totally enclosed and space conditioned with a minimum number of doors and windows. Calculations using ASHRAE methods indicate a heating load as low as 11.5 BTU/ft^2. However, unknown factors are anticipated such as snow load, wind load, and unexpected infiltration losses which would double this load to about 23.0 BTU/ft^2. This higher factor will be used in the overall system design. The total heating load for all buildings is set at about 4.0 million BTU/hr.

TABLE 1

PARK OF COMMERCE

NO.	INDUSTRY/BUILDING	SIZE FT^2	HEATING REQUIREMENTS: DESIGN HEAT LOAD MILLION BTU/HR	HEATING REQUIREMENTS: SPACE DESIGN TEMP °F	HEATING REQUIREMENTS: PROCESS WATER LOAD MILLION BTU/HR	HEATING REQUIREMENTS: HOT WATER TEMP °F	A/C REQUIREMENTS: DESIGN COOLING LOAD TONS	A/C REQUIREMENTS: DESIGN ROOM TEMP °F	REFRIG. REQ'MS: TONS	REFRIG. REQ'MS: TEMP. °F
1.0	GREENHOUSES					Sterile				
	1.25 ACRE MODULE	54,450	4.0	65	LOW	180	-	-	-	-
	3.00 ACRE MODULE	130,680	9.6	65	LOW	180	-	-	-	-
	5.00 ACRE MODULE	217,800	16.0	65	LOW	180	-	-	-	-
	10.00 ACRE MODULE	435,600	32.00	65	LOW	180	-	-	3.0	40
	15.0 ACRE MODULE	653,400	48.0	65	LOW	180	-	-	4.5	40
2.0	INTEGRATED MEAT PRODUCTION									
	INTENSIVE FEED GROWING	22,000	0.23-.46	65	NONE	-	EVAPORATIVE	80	-	-
	FEED PROCESS & STORAGE	44,000	0.35-.70	65	20	120-180	EVAPORATIVE	80	60	40
	CONFINED HOG RAISING	36,000	0.50-1.00	65	NONE	-	14	80		-
	CONFINED RABBIT RAISING	22,000	0.42-.84	65	NONE	-	12	80	-	-
	SLAUGHTER & BREAK	87,000	REFRIGERATED SPACE	50	16.8	180	IN REFRIGERATION	40-50	{60 {15	{10 {0
	HIDE & PELT PROCESSING & STORAGE	22,000	0.23-.46	65			12	80	-	-
	WASTE MANAGEMENTS & METHANE PRODUCTS	22,000	0.20-.40	65	LOW	82-90	NONE	-	-	-
	SUBTOTAL =	255,000	1.93-3.86		36.8		38		135	

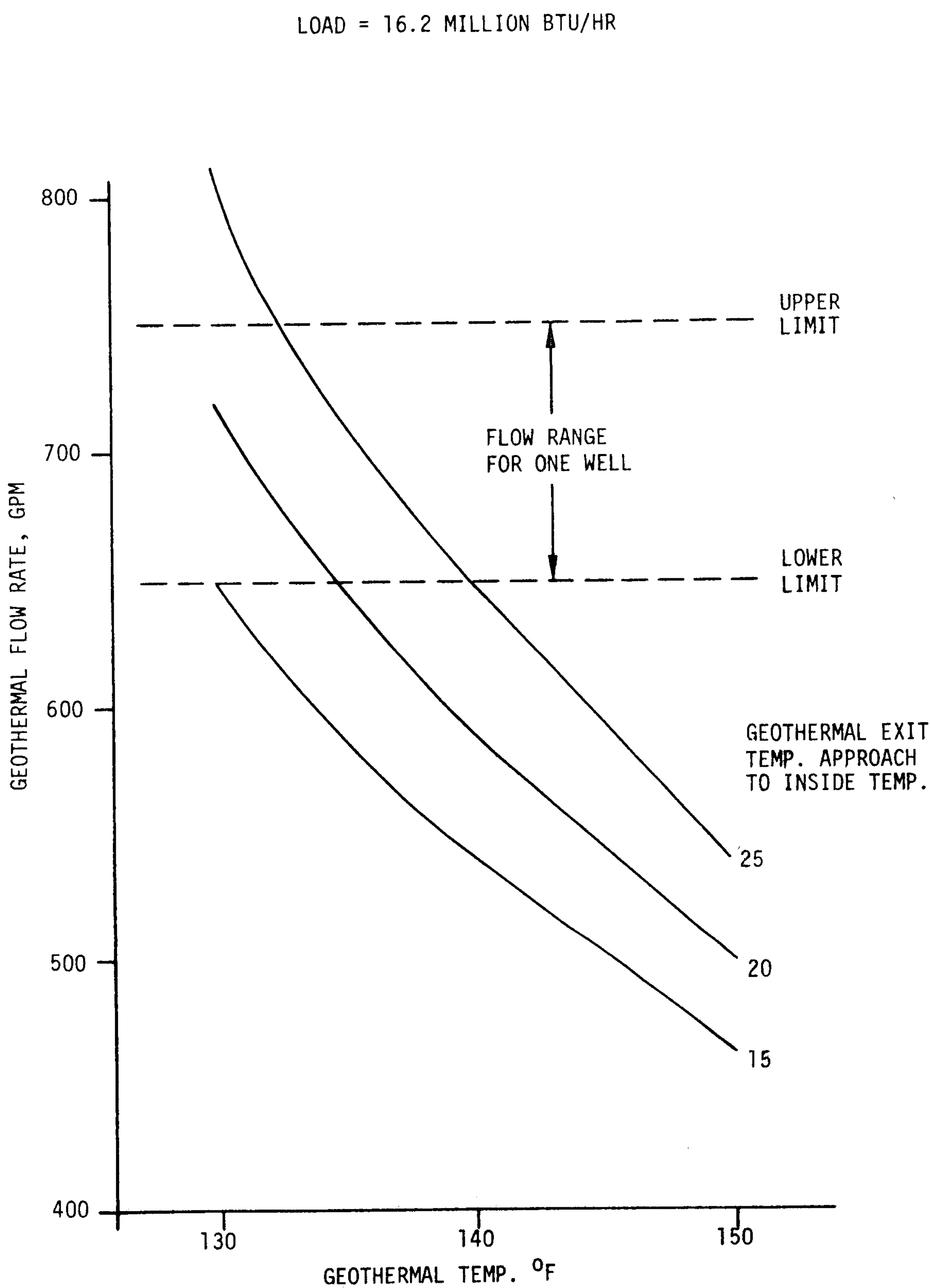


Figure 2. Geothermal Requirements for Five-Acre Greenhouse Module.

The slaughter house (87,000 square feet) is not included in the heating load because the majority of the plant would be refrigerated space. Excess process heat and lighting could be used to heat the small areas requiring it (Reference 1).

The space heating load could be supplied from very low temperature geothermal water. Water temperatures as low as 108°F are being used in Klamath Falls to heat a large wood processing building with a once-an-hour air turnover. Large, centrally located fan coils, suspended from the roof, are used for this purpose (Reference 2). Effluent water from the Park of Commerce process heat loads may best be used for this purpose.

A large amount of process heating is indicated in drying of the feed and the slaughter and break operations (Table 2). The feed will be cold-processed from its original moisture content into a pellitized form acceptable for storage. This will occur in a single pass apron conveyor dryer for certain raw ingredients. The geothermal water will flow through a series of water coils entering at 180"F and exiting at 100°F, and will supply a total heat load of 20 million BTU/Hr. to dry approximately 16,000 Lbs./Hr. of finished product. The product temperature will be cooled to 70°F in the last stage of the tunnel. When outside air is 32°-40°F, or below, this air will be used for cooling. Otherwise, a refrigeration system will be needed with a maximum capacity of 60 tons.

The maximum geothermal flow rate required would be 500 gpm if all the 20 million BTU/Hr. heat load were suplied directly with 180°F geothermal water. However, some of the drying air is mixed so the total load in the hot water coils is somewhat less. If the geothermal temperature is less than 180°F, then part of the flow (i.e., to the first drying section) would be heated with a heat pump or a hot water boiler.

If the geothermal water is 180°F or higher, the refrigeration required could be obtained with H_2O/LiBr absorption refrigeration at a capital cost of about $900 per ton. At 160°F, the cost would be almost 2.2 times greater, or $2000 per ton. The geothermal flow rate needed at 180°F would be 270 gpm for

TABLE 2

INDUSTRY #2

ENERGY REQUIREMENTS

Function	Energy	Temperatures °F
o Space Condition All Buildings	(see ASHRAE)	
o Feed Processing		
Drying	20M̄ BTU/Hr, growth to 56M̄ BTU/HR	ØI: 180-165 ØII: 145-150 ØIII:130 ØIV: 120
Cooling	National Dryer conveyor tunner 8 ft x 75 ft	+32
o Animal Raising	Space Conditioning	68-72
o Slaughter		
Refrigeration	50-75 Tons	80%= +10 20%= 0
Hot Water	500 Boiler HP (equiv)	180
o Hide & Pelt	Included in Slaughter	
o Waste Management and Methane	Space (process) Heat	82-90

60 tons, with a temperature drop of 8°F. At 160°F, a high flow rate of 600 gpm would be needed because the temperature drops only 3.9°F. The same augment would apply for any 40°F refrigeration required in the Park of Commerce. Absorption refrigeration is attractive at geothermal temperatures above 185°F. Refrigeration required for the slaughter and break operation at the lower temperatures, 0-10°F, will be provided by a conventional vapor compression system.

The slaughter and break operation requires about 16.8 million Btu/Hr. heat load (500 boiler HP). The temperature requirement is 180°F. Depending on the geothermal resource temperature, this heat can be supplied directly, or enhanced with heat pump or peaking boiler augmentation.

B. SYSTEM DESIGN STUDIES

1. Economics of Baseline Geothermal System Design

The geothermal system design was described in the first quarterly report. Figure 3 provides an overview of this system and the buildings it will serve. Using 1978 cost data, the cost of the various components of the system was estimated in order to obtain a budget cost of the system. The capital cost obtained is estimated to be accurate to ± 20%.

There are three major uncertainties on the economic analysis of the Susanville District System - (1) the geothermal flow rate that will be obtained per well, which affects the number of production wells required; (2) the geothermal temperature, which affects the size of geothermal components and type of system (direct use, indirect with a plate heat exchanger, type of augmentation, and amount of augmentation); and (3) well costs per production or reinjection well which is a function of the cost per foot, the depth of the well, and drilling success.

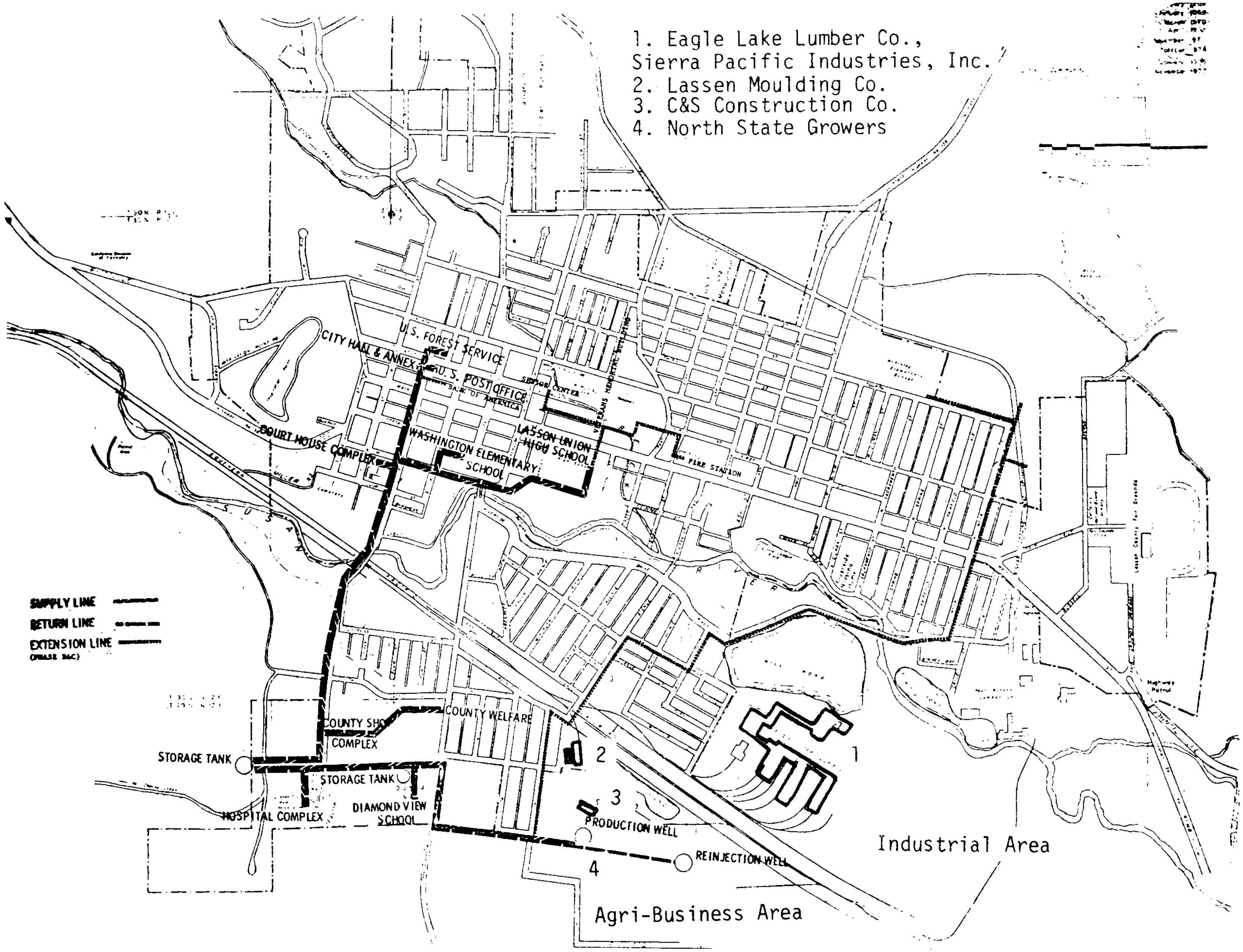


Figure 3. Susanville Energy System Piping/Routing Layout

Assumptions for the Purpose of Economic Analysis:

Susanville's production wells will probably be about 1000 feet deep. The geothermal flow rate per well is assumed to be 700 ± 50 gpm for production wells and 1000 ± 100 gpm for reinjection wells. Since the geothermal temperature could be anywhere in the range of from 150 to 239°F, the temperatures of the systems evaluated are 150, 165, 185, and 225°F. Based on the Bureau of Reclamation's data for similar programs, and using Klamath Falls data as a minimum, the well costs are varied from $50 to $175 per foot ($50,000 to $175,000 per 1,000 foot well). These well costs are assumed the same for production or reinjection wells.

The economic analysis is based on a geo-heating district system designed to provide 23.4 million Btu/Hr. and 4.07×10^{10} Btu/Yr. It is assumed that the fuel oil used in the peaking boilers would escalate at 7 to 10% per year from a 1978 price of $.50 per gallon. It is also assumed (based on data from the California Pacific Utility Company) that the electric rate will escalate at 7 to 10% per year from a 1978 price for a large commercial user of $0.04 per kilowatt-hour. Maintenance cost is also assumed to increase at the same rate due to labor costs and other factors. The project life is assumed to be 25 years and the value of money for a public entity set at 8 to 10% for municipal bonds.

The cost of equipment such as piping, pumps, tanks and heat exchanger is obtained directly from manufacturers and all costs are in 1978 dollars. The estimated building conversion cost is an educated guess using Klamath Falls experience. Building conversion costs are anticipated to lie in the $150,000 to $415,000 range, depending on the geothermal temperature utilized. This economic evaluation assumes that any amount over $150,000 would be obtained from separate funds not directly chargeable to the geothermal project economics.

The cost of engineering, fee, and contingency is 32% of the subtotal of capital cost items. This is an estimate based on engineering judgement and experience of the authors and other investigators.

Geothermal System Design:

Figure 4 graphically shows Suanville's estimated heat load vs possible design temperatures for the geothermal system. The peak heat load at the design condition of -5°F varies linearly with outside temperature to the inside design temperature of 65°F (dashed line). For example, if a design outside temperature of 25°F is selected for the geothermal system, 50% of the peak hourly heat load could be supplied. However, on a yearly basis, much more than 50% of the yearly load would be provided. 78% of all the Susanville's systems yearly space heating demand and approximately 91% of its total yearly heating demand (including domestic hot water) would be met with an installed capacity of 50% of peak load. For an average year in Susanville, only about 200 hours heating are required for temperatures below 25°F. There are about 61 days a year when the minimum is below 25°F. For severe winters, this might change dramatically. Figure 4 is used in the economic analysis as an average yearly load curve over 25 years. This curve is important because the amount and cost of fossil fuel peaking is determined by multiplying the yearly heating load provided by fossil fuel by the total average cost of fuel consumed annually by the system.

The design points over the temperature range are presented in Table 3. It is important to note that below 185°F, the system design concept changed from indirect use (isolation of heating system with plate heat exchangers) to direct use (geothermal directly into heating coils). Below 185°F, it is impractical to try to protect the existing heating coils. They would have to be replaced when they start to fail. This cost is assumed to be absorbed from other sources and not directly chargeable to the project. At 150°F, the maximum the geothermal system by itself can supply is calculated to be 53% of required installed capacity and 78% of the yearly heat load. At this temperature, no domestic hot water can be supplied. This accounts for the difference between the 165 and 150°F degree point.

TABLE 3

GEOTHERMAL DISTRICT HEATING SYSTEM
WITH FOSSIL FUEL PEAKING
(EXISTING BOILERS IN BUILDINGS)

SYSTEM OPERATING POINTS
VS
TEMPERATURE

BASIS: 4.068 x 10^{10} BTU/YEAR

1000 FT WELL

	Geothermal Temperature - °F				
Design Conditions	150	165	185	225°F	Units
DESIGN TOTAL HEATING LOAD	23,740,000	23,740,000	23,740,000	23,740,000	BTU/HR
DESIGN GEOTHERMAL HEATING LOAD	12,610,000	22,200,000	22,200,000	22,200,000	BTU/HR
FRACTION PEAK HEAT LOAD	0.53	0.93	0.93	0.93	-
FRACTION YEARLY HEAT LOAD WITH GEOTHERMAL	0.78	0.98	0.99	0.99	-
GEOTHERMAL FLOW	1058	1783	1081	602	GPM
AVERAGE EXIT TEMPERATURE	126	140	144	151	°F
NUMBER OF PLATE HEAT EXCHANGERS	0	0	6	6	-
NUMBER PRODUCTION WELLS	2	3	2	1	-
NUMBER RE-INJECTION WELLS	1	2	1	1	-
TOTAL WELLS	3	5	3	2	-

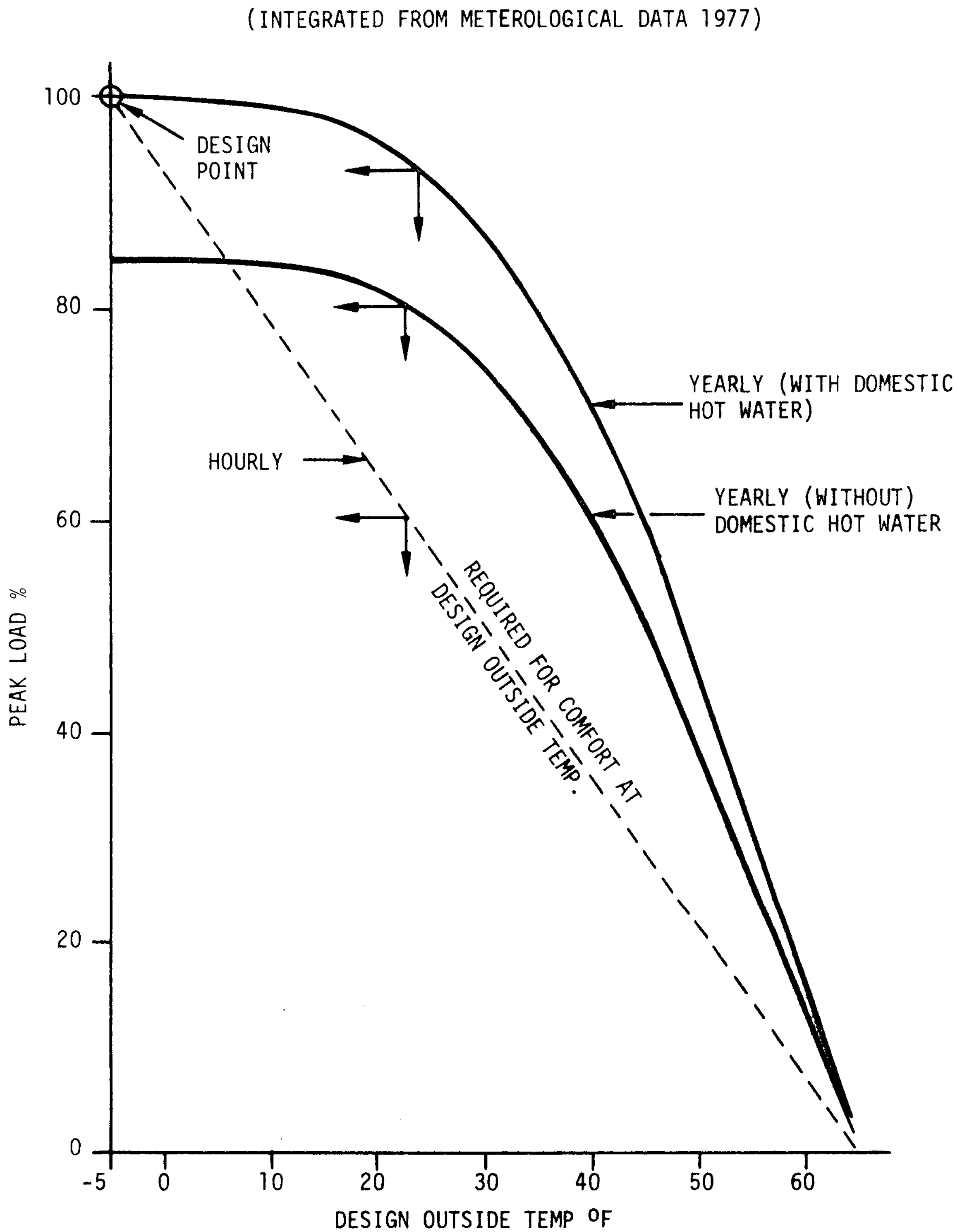


Figure 4. Susanville Estimated Heat Load vs. Design Temperature.

The capital costs for the baseline system versus resource temperature are presented in Table 4 and Figure 5. The lower total investment cost at 150°F is a result of the lower heat load being supplied at this temperature. This results in two less wells than at 165°F, one production and one reinjection, because of a flow rate 700 gpm lower. These curves assume that the total building conversion cost is a constant (independent of temperature) and that costs above $150,000 for lower temperature systems would be not directly chargeable to the system. Also, as the geothermal temperature decreases, more peaking is needed. At 150°F, 47% of the installed heat load is provided by peaking hot water boilers.

The economic analysis of the baseline geothermal system provided the before-tax rate of return presented in Figure 6. This curve is based on the previously mentioned assumptions. The desired rate of return (ROR) is 8 to 10% to qualify for the financing method available (a 25-year or longer municipal bond). Above 8% ROR, the geothermal system with peaking compares favorably with the currently installed fossil fuel systems in each building. This comparison does not include a replacement capital cost charge against the current building systems. A replacement charge would increase the ROR obtained in the comparison of these alternatives--all fossil fuel system vs geothermal system with peaking.

2. Approaches to Integration of Heat Pump Into Geothermal System

Two geothermal resource temperatures were chosen for integrating the heat pump into the geothermal system. Temperatures of 185°F and 150°F were used to investigate the use of heat pumps in the geothermal district heating system. The 185°F temperature represents a median temperature in the range of possible temperatures of Susanville. The 150°F temperature is a known temperature at Susanville, and represents the lowest probable temperature.

The heat pump was investigated in terms of the working fluid, inter-cooling, and staging of machines in series. Table 5 shows the critical point constants of the various working fluids investigated. The first four fluids listed are Freons, R-600a is isobutane, and R-717 is ammonia. Although

TABLE 4

GEOTHERMAL DISTRICT HEATING SYSTEM
WITH FOSSIL FUEL PEAKING
(EXISTING BOILERS IN BUILDINGS)

CAPITAL COSTS VS TEMPERATURE

	Geothermal Temperature															
	150°F				165°F				185°F				225°F			
CAPITAL COSTS	1000 $				1000$				1000 $				1000 $			
WELL COSTS - $/FT	50	100	130	175	50	100	130	175	50	100	130	175	50	100	130	175
CAPITAL COST SYSTEMS																
1.0 TOTAL WELL COST	150	300	390	525	250	500	650	875	150	300	390	525	100	200	260	350
2.0 PUMP COSTS	47	→	→	→	65	→	→	→	43	→	→	→	26	→	→	→
3.0 SUPPLY & DISPOSAL PIPING	459	→	→	→	537	→	→	→	459	→	→	→	385	→	→	→
4.0 TANK	54	→	→	→	68	→	→	→	54	→	→	→	46	→	→	→
5.0 PLATE HEAT EXCHANGERS	0	→	→	→	0	→	→	→	49	→	→	→	24	→	→	→
6.0 BUILDING CONVERSION	150	→	→	→	150	→	→	→	150	→	→	→	150	→	→	→
SUBTOTAL	860	1010	1100	1235	1070				905				731			
2.0 ENGINE, FEE & CONTINGENCY (32% of SUBTOTAL)	275	323	352	395	343				290				234			
LOW TOTAL =	1135	1333	1452	1650	1413	1743	1941	2238	1195	1393	1512	1690	965	1097	1176	1295
HIGH BUILDING CONVERSION	415	→	→	→	365	→	→	→	315	→	→	→	315	→	→	→
HIGH TOTAL =	1485	1683	1802	2000	1699	2027	2225	2522	1412	1611	1730	1908	1184	1315	1394	1513

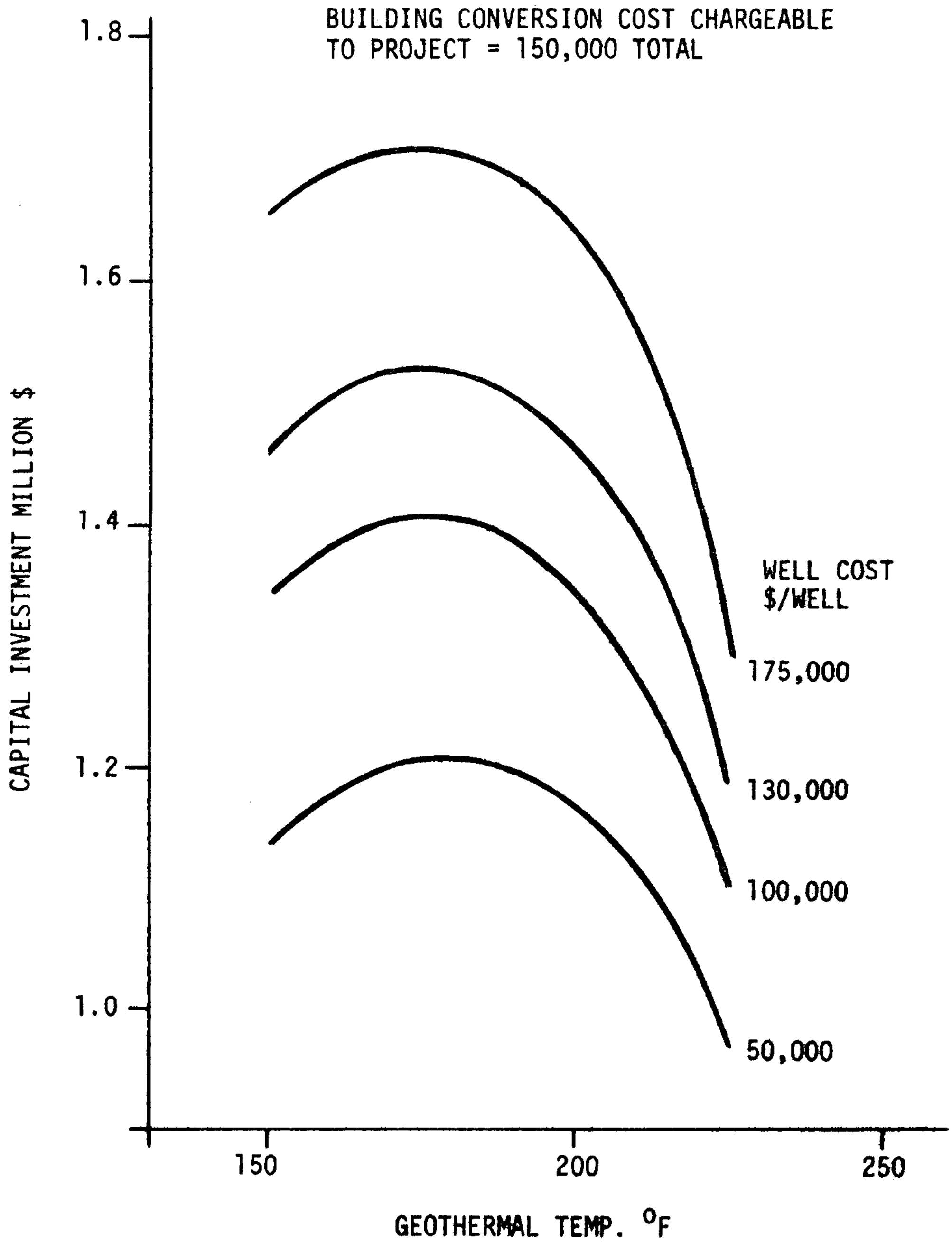


Figure 5. Investment for Geothermal System with Fossil Fuel Peaking.

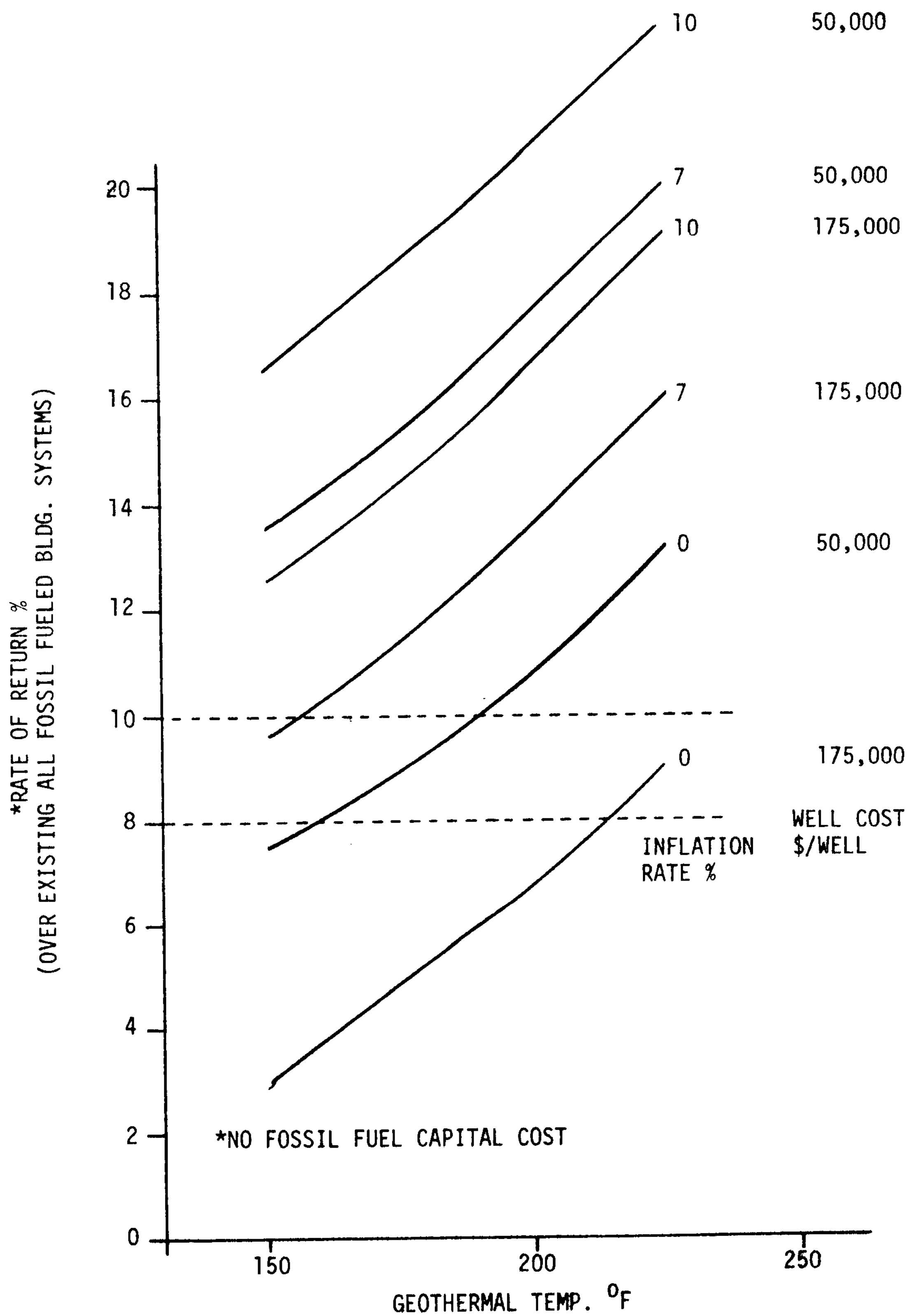


Figure 6. Geothermal System with Fossil Fuel Peaking.

TABLE 5

WORKING FLUIDS CRITICAL POINT CONSTANTS

Refrigerant	T_c °F	P_c psia	V_c ft^3/lb
R-22	204.8	721.9	0.0305
R-32	173.1	833.3	0.040
R-114	294.3	473	0.0275
R-115	175.9	457.6	0.0261
R-600a	275.0	529.1	0.0725
R-717	271.4	1657.0	0.068

there is nothing thermodynamically undesirable about supercritical heat rejection the process does require a larger condenser than that required for subcritical heat rejection. There is a possibility that R-22, R-3, and R-115 would require supercritical heat rejection in a heat pump at Susanville. In addition, supercritical heat rejection requires significantly more compressor power, and entails more complex compressor design.

Parametric evaluation of the candidate working fluid, using an in-house developed heat pump performance computer code, showed that R-114 has the best overall performance in the geothermal temperature range of interest at Susanville. It was also determined that subcooling markedly increases the heat pump performance. Increasing the condenser outlet or heated fluid exit temperature decreases the heat pump performance, so that the cost and electric power input increase. Decreasing the evaporator exit or geothermal effluent temperature also reduces the heat pump performance, while increasing the cost and electric power input. The greater the temperature difference between heated fluid outlet temperature and geothermal fluid effluent temperature, the lower the heat pump performance and, therefore, the higher its capital and operating cost.

The approach used in the 185°F case was to replace the flow from one geothermal well and its associated cost with heat pumps at each building complex,reducing the costs of the associated pipeline, pump station, and storage tank. For the 185°F geothermal resource temperature case, it was proposed that heat pumps be installed at five locations: Lassen County Hospital Complex (five buildings), Diamond View School, U. S. Post Office and Masonic Temple, Lassen County Court House Complex (three buildings) and Lassen Union High School. The remaining buildings would either use the geothermal water directly, or would be retrofitted with geothermal fan coils.

Since the heat pumped buildings would use winter fuel peaking, it was decided that plate-type heat exchangers would be used to isolate the building heating systems from the geothermal water. The geothermal side of the plate heat exchanger would cool the water from 185°F to 150°F. The water would then enter the evaporator of the heat pump and be cooled further to 125°F, and would be reinjected. The water leaving the building heating system would enter the plate heat exchanger at 145°F and would enter the building heating system.

Table 6 is a summary of the integration of the heat pumps at 185°F geothermal resource temperature. At this temperature, no added fuel oil is saved over the baseline system by adding heat pumps. The heat load supplied by the heat pumps would be designed at 37% of the peak. The annual operating cost would be higher than the geothermal system with peaking. The total cost for five heat pumps is approximately $220,100. The overall coefficient of performance is 5.8.

Table 7 is a summary of the economic impact of heat pump augmentation on the 185°F geothermal resource. The heat pump system would cost about $55,000 less due to the associated savings of the well costs, pipelines pumping station and tank at a $175,000 cost per well. However, due to the higher operating cost, the present worth of the capital cost savings is about $165,000 less than the present worth of the higher annual operating cost when evaluated at 10% interest for 25 years. Therefore, the heat pump alternative is not economical since it results in a higher total annual cost over the life of the project.

For the 150°F geothermal resource case, first a central heat pump plant located at or near the well site was investigated. The plant would provide heated water throughout the system at a peak demand temperature of 185°F. It was found that three heat pumps arranged in series would provide a higher coefficient of performance than would a single large heat pump.

Some of the buildings would continue to use their existing fossil fuel peaking and so would need to be isolated from the geothermal water, via a plate-type heat exchanger, as in the 185°F case. The remaining buildings could use the geothermal water directly or would be retrofitted with new fan coils and use the geothermal water directly.

TABLE 6

INTEGRATION OF HEAT PUMP WITH
185°F GEOTHERMAL SYSTEM

LOCATION	HEAT LOAD MILLION BTU/HR.	COMPRESSOR MOTOR SIZE HP	ANNUAL OPERATING COST $	TOTAL MODULE COST $	COPH
HOSPITAL	1.3	87.5	4,500	42,500	5.83
DIAMOND VIEW SCHOOL	0.87	59.1	3,045	32,100	5.83
POST OFFICE	0.24	16.3	840	18,000	5.83
COURT HOUSE	0.87	59.1	3,045	32,100	5.83
LASSEN HIGH SCHOOL	4.89	332.4	17,125	95,400	5.83
TOTALS	8.17 (37%)	554.4	28,555 (20%)	220,100	

TABLE 7

IMPACT OF HEAT PUMPS AUGMENTATION OF 185°F GEOTHERMAL SYSTEM

WELLCOST = $175,000/WELL

CAPITAL COST IMPACTS

1.	REDUCE WELLS BY ONE	= $175,000
2.	REDUCTION IN PUMPING STATION	= 17,000
3.	REDUCTION IN PIPING	= 74,200
4.	REDUCTION IN TANK	= 8,500
		$275,000
5.	ADDED HEAT PUMP MODULE COSTS	= 220,100
	CAPITAL COST REDUCTION	**= $ 54,900**

OPERATING COST IMPACTS

1.	REDUCTION IN PUMPING POWER	= $ 4,256
2.	REDUCTION IN FUEL OIL COST	0
3.	ADDED HEAT PUMP POWER	= 28,555
	ANNUAL OPERATING COST INCREASE DUE TO HEAT PUMPS	=+$ 24,300

PRESENT WORTH OF INCREASED ANNUAL OPERATING COST FOR 25 YEARS @ 10% INTEREST, ZERO INFLATION = $220,600

During periods when the weather is relatively mild, the 150°F geothermal water would be circulated through the system. The system could supply up to 53% (12.3 x 10^6 Btu/Hr.) of the peak demand by using 150°F water in fan coils rated for 185°F inlet temperature. As the demand increased beyond 53% of the peak, the geothermal flow would be increased and part of it diverted to the heat pump plant. With the three heat pumps connected serially, first one, then the second, and finally the third heat pump would be turned on as demand increased. At the maximum heat load, the condenser inlet water, which consists of a mixture of water from the fan coils and 150°F water from the plate heat exchangers, would be 140°F. The condenser leaving water would be 185°F which would mix with 150°F geothermal water and would circulate throughout the district heating system.

The same basic scheme was used for the other heat pump alternatives evaluated at 150°F. These alternatives were locating a heat pump at each building complex or only at the high school. The same buildings were serviced as the 185°F case except that the county shop complex was included for a total of six heat pumps. Also, because the heat load for each heat pump was much lower, the series arrangement was not used.

3. Economic Comparison of Alternatives for the Susanville Geo-Heating District

The Susanville Geo-Heating District was compared with the existing all fossil-fueled building systems in a previous section. The conditions favorably to using geothermal with peaking were obtained assuming an 8 to 10% municipal bond as a financing vehicle. The geothermal system looks like a good project for Susanville under the anticipated range of resource conditions, well costs, and inflation rates (Figure 4). It is only at the lower temperatures, high well costs and low inflation rates, that the project looks less attractive.

The addition of heat pumps to the system was considered from 185°F down to 150°F. At 185°F, the heat pumps showed no economic advantage. Therefore, they were not given further consideration for temperatures at 185°F or above. The economics and engineering analysis focused on the lowest temperature range, 150 to 165°F. The lowest temperature chosen for detailed analysis of alternative systems was 150°F because all indications are that 150°F is the lowest expectation for the resource.

The alternative systems considered were: (1) geothermal system with peaking from existing hot water or steam boilers; (2) replacing one production well from alternative (1) by using a central heat pump plant at the well site, splitting the design heat load 37% geothermal, 48% heat pump, and 15% boiler peaking; (3) replacing one production well from alternative (1) by using six heat pumps - one at each building complex with a 37% geothermal, 33% heat pump and 30% boiler split; and (4) replacing one production well from alternative (1) by a single heat pump at the high school, giving a 37% geothermal, 21% heat pump, and 42% boiler split.

The comparison of the design points is presented in Table 8. The distribution of the design heat loads was optimized. The maximum heat load from the required geothermal flow at the average obtainable heating system temperature drop (24°F) was used to set the design geothermal heating load. For alternatives (2) through (4), this heat load is fixed by the temperature drop and the maximum flow rate from one well (730 gpm). The heat pump design load was optimized to provide the lowest total annual operating cost between the peaking and heat pump electric power. In general, this occurs by providing between 97 to 99% of the yearly heat load with a combination of geothermal and heat pump augmetation for any given building or building complex. The peaking design heat load makes up the remainder to the total yearly load of 40,700 million BTU/Yr.

Table 9 presents the capital cost of the alternatives evaluated at the highest well cost, $175,000 per well. These costs range from about 1.4 to 1.65 million 1978 dollars. Heat pump costs were obtained from suppliers or extrapolated using equipment supplier's data.

TABLE 8

COMPARISON OF SYSTEM DESIGNS

AT 150°F

TOTAL LOAD = 23,800,000 BTU/HR

	(1) Geothermal With Fossil Fuel Peaking	(2) Central Heat Pump at Well Complex (Three Heat Pumps in Series)	(3) Heat Pumps at Each Building Complex (Six Heat Pumps)	(4) Heat Pump at High School Only
TOTAL NUMBER WELLS	3	2	2	2
DESIGN GEOTHERMAL HEATING LOAD, BTU/HR	12,600,000	8,800,000	8,800,000	8,800,000
DESIGN GEOTHERMAL HEATING LOAD, %	53	37	37	37
HEAT PUMP DESIGN LOAD, BTU/HR	0	11,400,000	7,800,000	5,000,000
HEAT PUMP DESIGN LOAD, %	0	48	33	21
FOSSIL FUEL LOAD, BTU/HR	11,200,000	3,600,000	7,200,000	10,000,000
FOSSIL FUEL LOAD, %	47	15	30	42
GEOTHERMAL FLOWRATE, GPM	1058	730	730	730
*AVERAGE EXIT TEMP, °F	126	120	121	122
FRACTION YEARLY HEAT LOAD GEOTHERMAL PLUS HEAT PUMP, %	76	99	97	79

* EXCLUDES EFFECT OF FOSSIL FUEL PEAKING

TABLE 9

CAPITAL COST COMPARISON

AT 150°F

WELL COST = $175,000/WELL

	1978 $			
	(1) Geothermal With Fossil Fuel Peaking	(2) Central Heat Pump at Well Complex (Three Heat Pumps in Series)	(3) Heat Pumps at Each Building Complex (Six Heat Pumps)	(4) Heat Pump at High School Only
TOTAL WELL COST	525,000	350,000	350,000	350,000
PIPELINE COSTS	459,000	385,000	385,000	385,000
PUMP COSTS	47,000	26,000	26,000	26,000
TANK COSTS	54,000	46,000	46,000	46,000
BUILDING CONVERSION	150,000	150,000	150,000	150,000
HEAT PUMP COST	0	170,000	201,000	100,000
ENGINEERING, FEE CONTINGENCY	395,000	360,000	360,000	338,000
TOTAL	1,630,000	1,487,000	1,518,000	1,395,000

Table 10 presents the 1978 operating cost for the alternative systems. The pump power cost is based on $0.04 per kilowatt hour. The maintenance cost is an engineering estimate. Fuel oil costs are based on C-2 fuel oil at $0.50 per gallon. The heat pump power consumption is based on AECC predicted heat pump performance at the optimized design point. The heat pump design is discussed elsewhere in this report.

Table 11 presents the rate of return before taxes obtained by replacing the existing all fossil-fueled building systems with one of the alternatives. Taxes are assumed to have only a minor effect for the municipal system. At 150°F, the economics of the heat pump augmented system and the straight geothermal system with boiler peaking are about equal. The 0.8% difference in the ROR is worth about $11,000 to $13,000 a year in return.

There are other less tangible advantages of using heat pumps instead of boiler peaked loads. They are: (1) decreased dependency on fuel (oil, wood, etc.), (2) operating flexibility -- heat pumps can vary their load down to 10% of design using inlet guide vane control, (3) decreased sensitivity of system to resource temperature changes or degradation -- the heat pump operating point is very flexible and high performance (COP) can be maintained over a wide range of conditions.

4. Maximizing Heat Pump Performance

Determination of Optimum Cycle

The AECC original heat pump computer code predicted performance, designed components, and calculated costs for a given heat pump, but it did not optimize the heat pump performance. It also calculated only a simple Rankine cycle, without intercooling or staging. In staged cycles, the working fluid is partially expanded, and then the vapor is introduced to an intermediate compressor stage. The computer code did allow for subcooling the refrigerant out of the condenser.

TABLE 10

OPERATING COST COMPARISON

AT 1[illegible]°F

FIRST YEAR COSTS

	1978 $			
	(1)	(2)	(3)	(4)
	Geothermal With Fossil Fuel Peaking	Central Heat Pump at Well Complex (Three Heat Pumps in Series)	Heat Pumps at Each Building Complex (Six Heat Pumps)	Heat Pump at High School Only
PUMPING POWER	10,100	4,800	4,800	4,800
MAINTENANCE	7,500	12,500	12,500	10,000
FUEL COSTS - OIL	35,000	1,500	4,400	30,500
HEAT PUMP POWER - ELECTRIC	0	43,500	33,300	13,100
	52,600	62,300	55,000	58,400

TABLE 11

RATE OF RETURN

FOR REPLACING THE EXISTING ALL FOSSIL FUEL SYSTEM

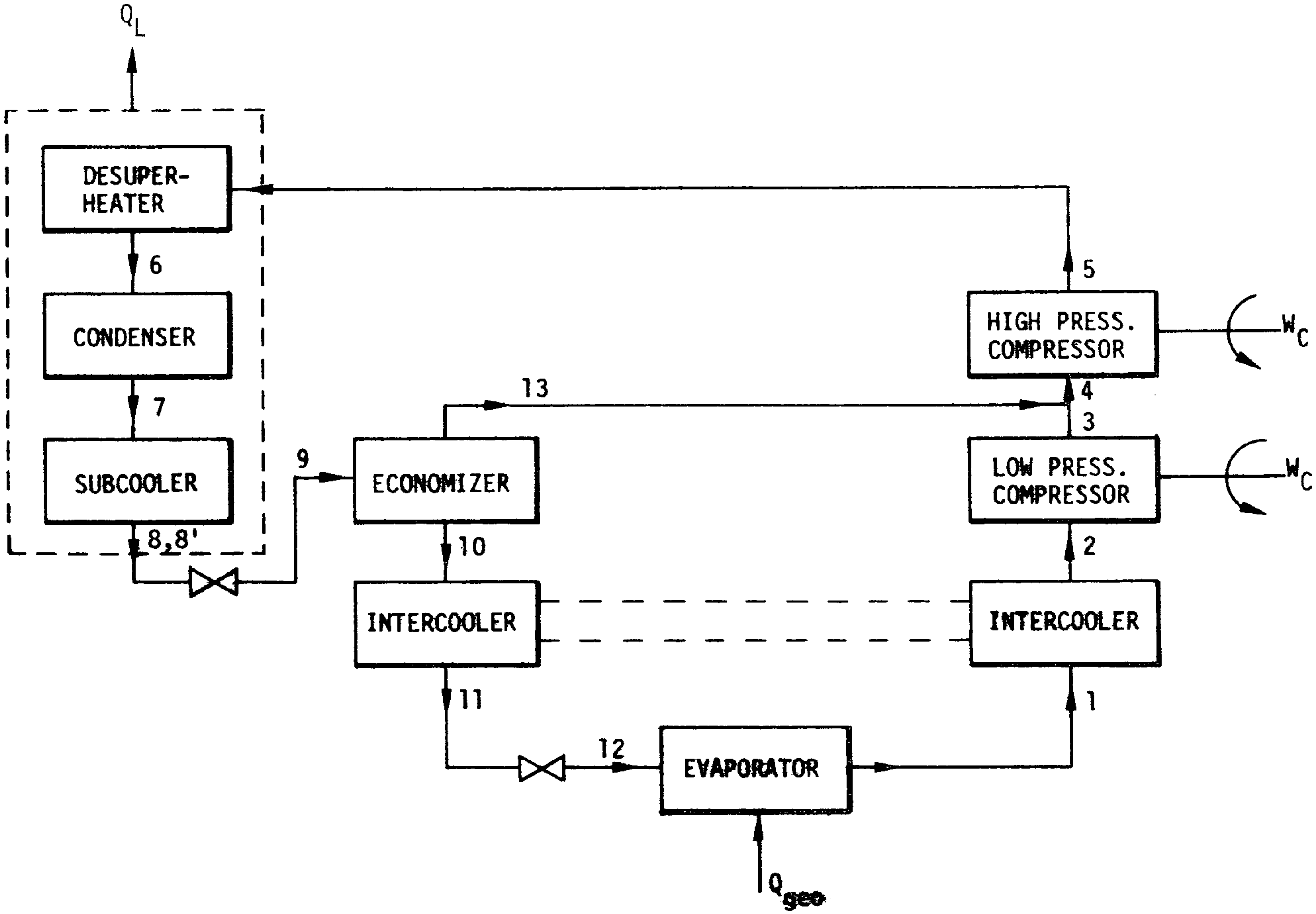
	*Rate of Return - %			
	(1)	(2)	(3)	(4)
Energy Inflation Rate (%)	Geothermal with Fossil Fuel Peaking	Central Heat Pump at Well Complex (Three Heat Pumps in Series)	Heat Pumps at Each Building Complex (Six Heat Pumps)	Heat Pump at High School Only
0	2.8	2.6	3.3	3.8
7	9.4	9.3	9.8	10.2
10	12.2	12.1	12.6	13.0

* Before Tax ROR

After examining the literature provided by Carrier and Trane, it was determined that besides subcooling, some intercooling and staging were used commercially. It was decided to examine these other cycles and determine their effects on the heat pump performance.

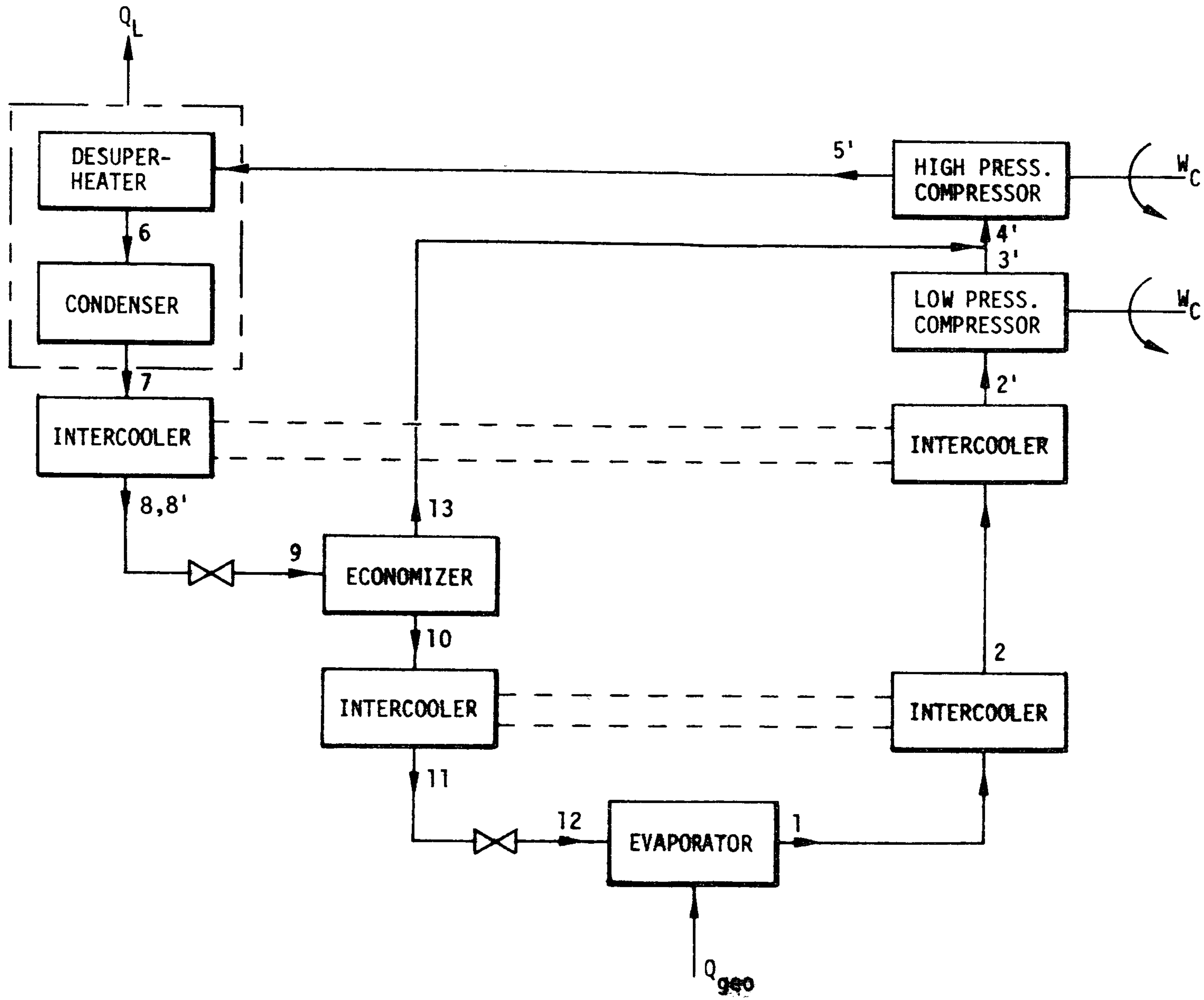
Figures 7 and 8 show two possible concepts that were examined. The numbers refer to state points which are shown in Figure 9. The unprimed state numbers 2, 3, 4, and 5 refer to Case 1. The primed state numbers 2', 3', 4', and 5' refer to Case 2. Case 1 starts with desuperheating of the vapor leaving the compressor, from 5-6, condensation from 6-7, subcooling from 7-8 and expansion from 8-9. At the intermediate pressure, state 9, the vapor is removed and sent to the compressor where it enters between the second compressor stage. The remaining liquid from state 9 is cooled to 10 and intercooled to 11, with the heat from 10-11 used to heat the vapor entering the compressor first stage from 1-2. First stage compression occurs from 2-3 and the second stage compression occurs from 4-5. Case 2 is similar to Case 1 except that no subcooling occurs and the refrigerant is intercooled from 7-8, with the heating being added from 2-2'. Compression occurs from 2'-3' and 4'-5', and desuperheating occurs from 5'-6. Carrier uses a system similar to Case 1, with less subcooling.

Hand calculations to determine the cycle coefficient of performance were performed for Cases 1 and 2 for a condenser inlet temperature of 150°F, condenser leaving temperature of 185°F, evaporator entering temprature of 150°F and evaporating leaving temperatures of 120°F and 90°F temperatures, respectively. The results are shown in Table 12, along with the single stage computer generated results. For Case 1, with subcooling and intercooling, significant increases in coefficient of performance are realized, with the amount increasing with decreasing evaporator exit temprature, as would be expected. For Case 2 with no subcooling but intercooling for both compressor stages, the opposite occurs. No increase in performance is observed at the lower temperature while a slight increase is observed at the higher temperature over the single stage cycle.



CASE NO. 1

Figure 7. Subcooled Load Rejection Staged Cycle



CASE NO. 2

Figure 8. Intercooler Staged Cycle.

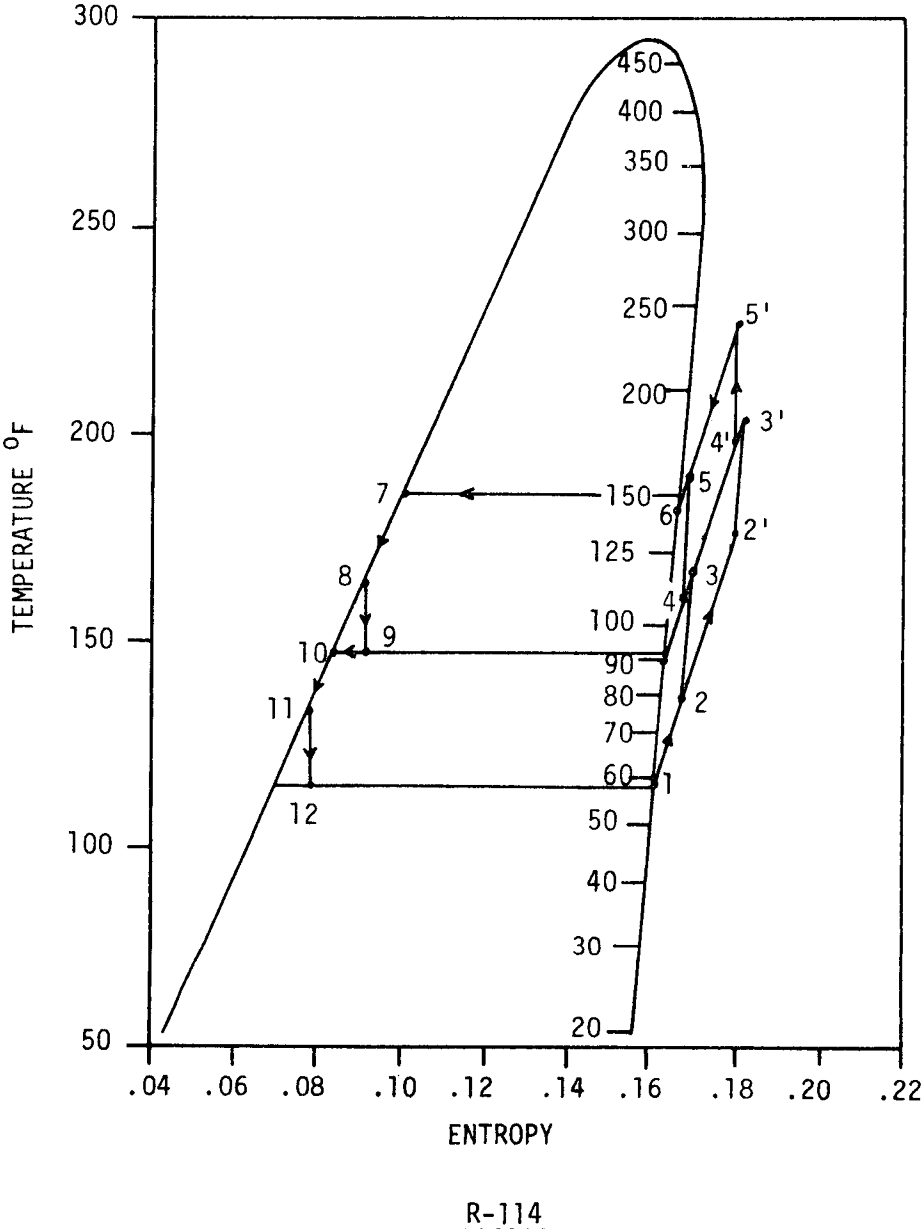


Figure 9. State Point Diagram for Cycle Analysis.

TABLE 12

COMPARISON OF STAGED CYCLES
COEFFICIENT OF PERFORMANCE

EVAPORATOR EXIT TEMPERATURE

	120°F	90°F
STAGED CYCLE: CASE 1	7.0	5.2
STAGED CYCLE: CASE 2	6.7	4.6
SINGLE STAGE	6.5	4.6
COPH INCREASE OVER SINGLE STAGE, CASE 1, %	8	12.0
COPH INCREASE OVER SINGLE STAGE, CASE 2, %	3	0

Because of these cycle analysis results, the heat pump performance computer code was modified to calculate two stage compression with intercooling in the bottom stage and subcooling to the load in the upper stage. Since the machine performance is a function of the intermediate pressure, it was allowed to vary. The computer results verified the original cycle calculations.

- Determination of the Optimum Evaporator Exit Temperature

Since the coefficient of performance of any heat pump is a function of the evaporating temperature, it is necessary to optimize the hot water temperature exiting the evaporator in order to minimize the annual cost of the heating system. The normal method of optimizing a heating system is to apply the first law of thermodynamics to the system to obtain efficiencies. This is frequently done for many thermodynamic systems, and gives meaningful results when comparing two systems with like inputs and like outputs, which would have similar irreversibilities associated with them. When comparing systems with different inputs and different outputs, a second law of thermodynamics based effectiveness is the preferred parameter. Available energy, which is the maximum useful work transport associated with energy and the surroundings, is an equivalent measure regardless of the qualitites of the energies being compared.

When high quality energy, such as fossil fuel, is converted to a low quality energy, with no product other than low quality energy, irreversibilities or destruction of available energy occur. The usual first law of thermodynamics efficiencies do not reflect the availability loss since energy and not availability is conserved. The second law of thermodynamics effectiveness does reflect the irreversibilities associated with a change of quality of energy.

Geothermal energy, which is energy at temperatures relatively close to that of the surroundings, is thermodynamically different from conventional energy sources such as fossil fuel, hydroelectric, nuclear, etc. The difference arises from the fact that the available energy of a geothermal resource is substantially lower than its energy as commonly defined, whereas conventional energy sources have available energy and energy values quite close. Thus, for comparing a geothermal resource with a conventional energy source the effectiveness gives more meaningful results. In addition, the effectiveness allows the optimum use of energy resources to be evaluated whereas first law efficiencies do not.

A comparison is made between a Geothermal Direct Heating System (GDHS) and a Geothermal Assisted Heat Pump System (GAHPS). Both are shown schematically in Figure 10. The following assumptions are made for this analysis:

(1) The availability of the geothermal fluid leaving the heating system is at the sink conditions. This is the same as assuming that the fluid is discarded, and has no useful energy remaining. This assumption does not change the discharge temperature at which the maximum effectiveness occurs, but it does result in an effectiveness that is slightly low.

(2) The geothermal fluid leaving the direct heating system is cooled to the heating temperature (T_H). Although this would require an infinite area heat exchange, in reality, the error is small.

(3) For the geothermal assisted heat pump system, the heat pump is assumed to require twice the electrical input of a Carnot heat pump operating between T_H and T_L where T_L is the temperature at which the geothermal fluid is rejected. The heat pump effectiveness, $\varepsilon_{HP} = 0.5$ and the power plant effectiveness $\varepsilon_{pp} = 0.3$ assumed are typical of U. S. averages today.

<u>Effectiveness is defined as the increase in available energy of the desired output relative to the decrease in available energy of the input.</u>
Geothermal Direct Heating System (GDHS) effectiveness is

$$\varepsilon = \frac{(1 - T_0/T_H)\,\dot{Q}_H}{\dot{m}_R\, A_R}$$

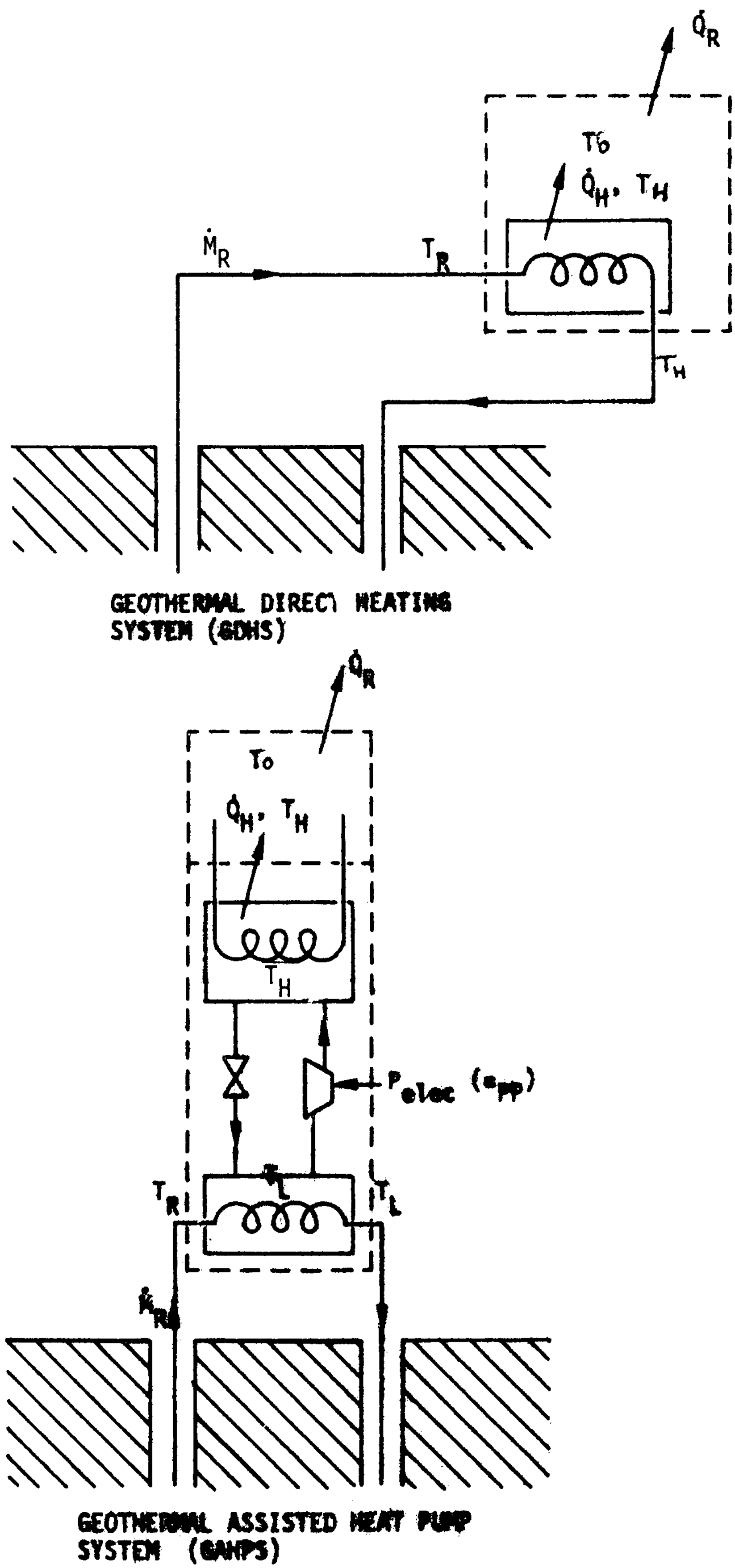


Figure 10. Second Law Comparison of Systems

where T_o is the sink temperature, T_H is temperature at which the heating occurs, $\dot{Q}_H$ is the heat added at T_H, $\dot{m}_R$ is the geothermal flow rate, and a_R is the availability of the geothermal resource fluid. The availability is the classical availability function for useful work obtainable from a steady flow system.

$$a_R = h_R - h_o - T_o\ (S_R - S_o)$$

where h_R is the enthalpy at the resource temperature, h_o is the enthalpy at the sink temperature, s_R is the entropy at the resource temperature and s_o is the entropy at the sink temperature. The required geothermal flow rate is

$$\dot{m}_R = \frac{Q_H}{C_p\ (T_R - T_H)}$$

where T_R = resource temperature, and C_p = heat capacity of resource.

Geothermal Assisted Heat Pump System

The effectiveness for the geothermal assisted heat pump system is given by:

$$\varepsilon = \frac{(1 - T_o/T_H)\ \dot{Q}_H}{m_R\ a_R + M_{AR}\ \ a_{AR}}$$

where $\dot{m}_{AR}\ a_{AR}$ is the available energy of the alternate energy resource and is given by

$$\dot{m}_{AR}\ a_{AR} = \frac{(1 - T_L/T_H)\ \dot{Q}_H}{\varepsilon_{pp}\ \ \varepsilon_{Hp}}$$

The required geothermal flow rate is given by

$$\dot{m}_{AR} = \frac{(1 - \frac{1}{\varepsilon_{HP}}\ (1 - T_L/T_H))\ \dot{Q}_H}{C_p\ (T_R - T_L)}$$

Figure 11 is a plot of effectiveness versus evaporator outlet temperature (Teo) for a heat pump delivering heat from a resource at T_R = 150°F to a heating distribution system at T_H = 185°F. Also plotted is the geothermal flow rate versus evaporator outlet temperature. From the figure it can be seen that the maximum effectiveness occurs at about T_{eo} = 125°F, with a flow rate of about 325 gpm. This maximum evaporator outlet temperature, besides yielding the best thermodynamic performance of the system, also yields the best overall utilization of the energy resources used. A previous first law analysis indicates that the optimum evaporator outlet temperature occurs at about 115°F.

Figure 12 is a comparison of the geothermal assisted heat pump system with the geothermal direct heating system for two different resource temperatures, plotted against the heating temperature (the temperature supplied to heating coils). Also shown are the effectiveness for a fossil fuel furnace and an electric resistance heater. For a 150°F resource temperature, TE, the GAHPS and the GDHS are the same for heating temperatures less than about 125°F. For heating temperatures greater than about 135°F the GAHPS becomes rapidly more effective. For a resource temperature of 185°F the GAHPS and GDHS are identical at a heating temperature up to 150°F. For heating temperatures greater than about 165°F the GAHPS is again much more effective.

Now that the best heat pump thermodynamic cycle has been determined and the best operating points determined, the remaining work to be done with regards to maximizing the heat pump performance will center around fine tuning of the cycle and enhancing the performance of the various heat exchangers in the heat pump system.

5. Industry Survey of Commercially Available Heat Pumps

The major U. S. manufacturers of vapor compression refrigeration equipment were contacted in order to determine the availability of heat pump equipment and the equipment costs. Information regarding component selection, budget costs, coefficient of performance, power requirement and size were requested of the various manufacturers.

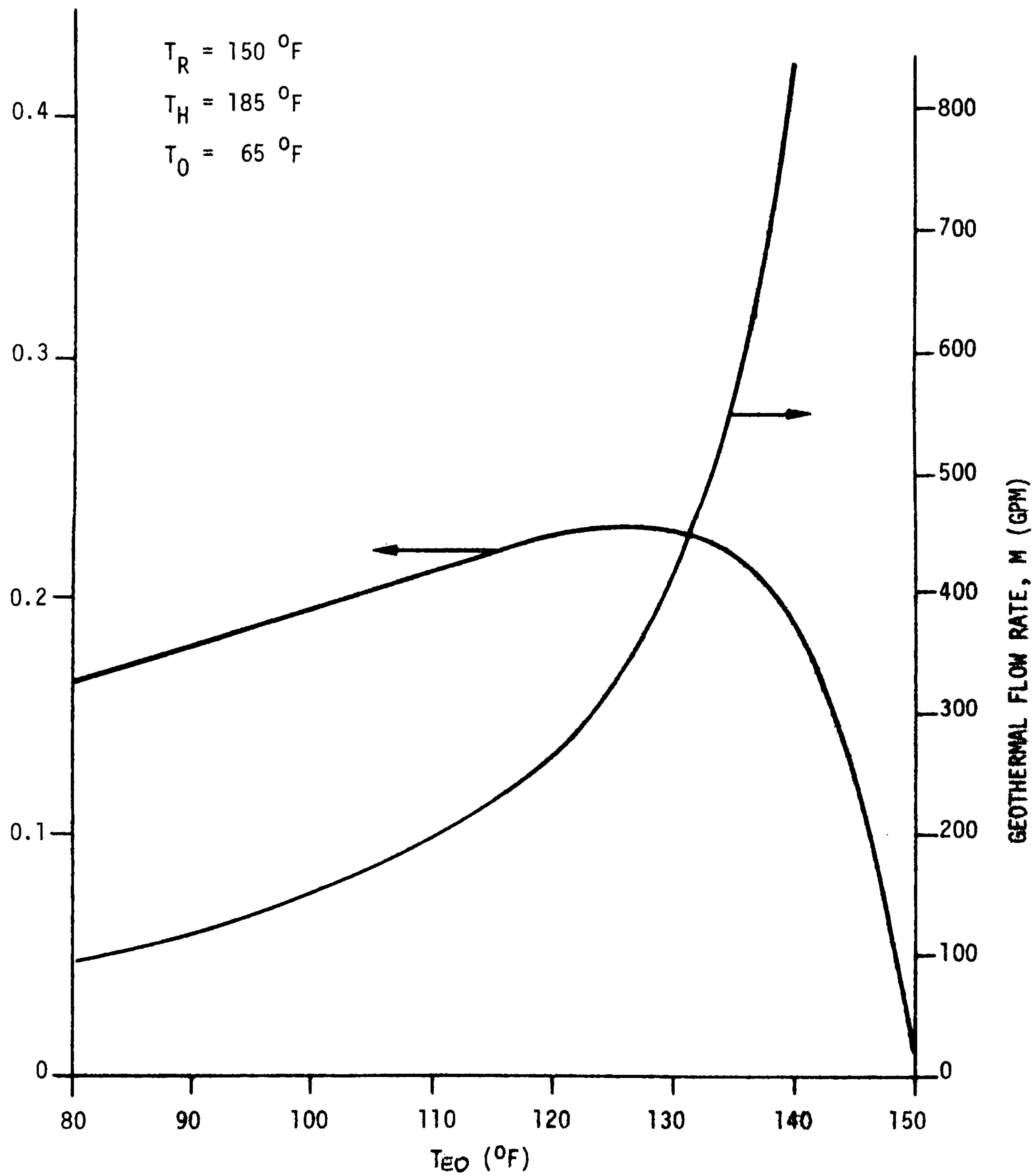


Figure 11. Second Law Effectiveness vs Evaporator Outlet Temperature

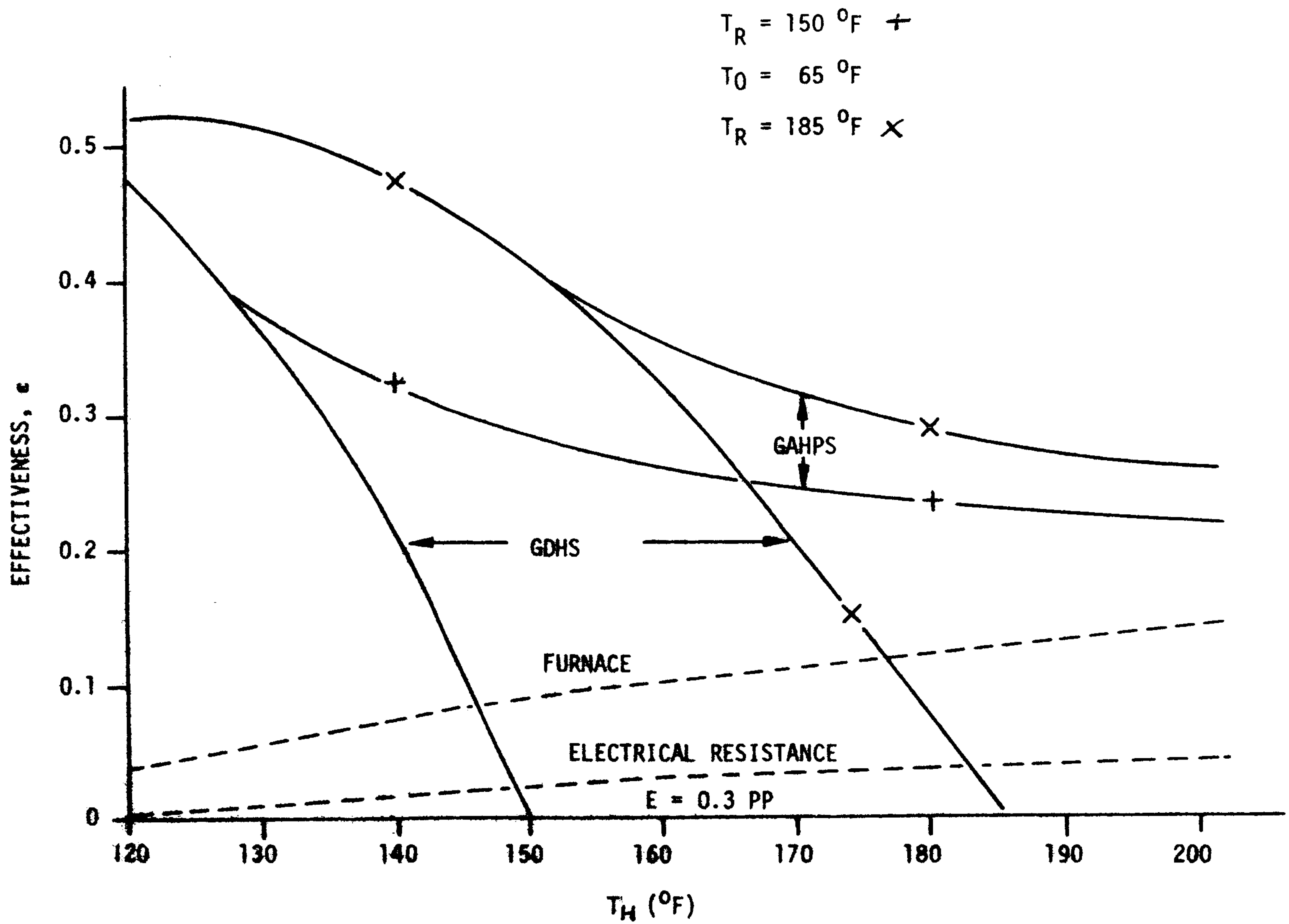


Figure 12. Second Law Effectiveness vs Heating Temperature

The following design point was specified for the manufacturers (1) R-114 as the refrigerant, (2) condensor heat lead of 500 tons (6 x 10^6 BTU/Hr.), (3) condensor inlet temperature of 150°F (4) condensor leaving temperature of 185°F, and (4) evaporator inlet temperature inlet temperature of 150°F. The evaporator leaving temperature was not specified so as not to limit the geothermal flow rate, nor penalize the coefficient of performance. In addition, the manufacturers were requested to investigate using two or more heat pumps arranged serially.

Table 13 lists the manufacturers contacted, along with the dates contacted. These are the major U. S. heat pump manufacturers. No foreign heat pump manufacturers were contacted. At this time, the foreign heat pump availability is unknown. However, the French have been contacted and data is expected shortly.

Table 14 lists those manufacturers who responded negatively, their response, and the date of response. Three of the manufacturers contacted said they would not or could not provide the desired information. The remaining manufacturers stated they would provide the desired information as soon as possible.

Table 15 is a list of those manufacturers who responded with the desired information, the date of response, and the information supplied.

TABLE 13

COMMERCIAL HEAT PUMP MANUFACTURERS CONTACTED

	Manufacturer	Date Contacted
1.	Trane Company	5/9/78
2.	Carrier Corporation	5/10/78
3.	Dunham-Bush Corporation	5/10/78
4.	General Electric Corporation	5/10/78
5.	York Division, Borg-Warner Corporation	5/11/78
6.	Westinghouse Corporation	5/15/78

TABLE 14

NEGATIVE RESPONSES FROM HEAT PUMP MANUFACTURERS CONTACTED

	Manufacturer	Response	Date
1.	Trane Company	Currently, do not manufacture heat pumps in 500 ton category in our temperature range. Suggest we contact Westinghouse.	5/10/78
2.	General Electric Corp.	Manufacture only reciprocating machines, which will not work with R-114, as its specific volume is too large in our temperature range.	5/10/78
3.	Dunham-Bush	Cannot provide equipment at this time. Machine is possible with a screw compressor. Development costs excessive at high temperatures. This item is on their future development plan.	5/15/78

TABLE 15

POSITIVE RESPONSES FROM HEAT PUMP MANUFACTURERS CONTACTED

Manufacturer	Response	Date
1. Westinghouse Corp.	Selection #1	6/15/78
	Model - TPE079	
	Evaporator leaving temperature - 140°F	
	Coefficient of performance - 6.8	
	Power requirement - 258 KWI	
	Budget cost - $86,000	
	Selection #2	
	Model - TPE100	
	Evaporator leaving temperature - 112.5°F	
	Coefficient of performance - 4.8	
	Power requirement - 365 KWI	
	Budget cost - $98,000	
	Selection #3	
	Model - TPE100	
	Evaporator leaving temperature - 100°F	
	Coefficient of performance - 4.1	
	Power requirement - 426 KWI	
	Budget cost - $99,000	
	Selection includes single stage hermetic centrifugal compressor complete with lubrication system and control panel. Shell and tube evaporator and condensor (insulated) are used. 1300 lb of refrigerant for TPE100. Machine is skid mounted and has all interconnecting refrigerant, lubrication system and piping. Start-up supervision is provided by a qualified Westinghouse engineer.	

TABLE 15 (cont.)

Manufacturer	Response	Date
2. Carrier Corp.	All Carrier selections based on 800 tons condenser	7/16/78
	Selection #1 Model - 17FA, single piece Evaporator leaving temperature - 130°F Power requirement - 380 KWI Budget cost - $130,000	
	Selection #2 Model - 17FA, single piece Evaporator leaving temperature - 100°F Power requirement - 545 KWI Budget cost - $160,000	
	Carrier indicated that a 500 ton condenser machine will not change their budget costs significantly.	
3. York Division Borg-Warner Corp.	Model - M225B two stage compression Evaporator leaving temperature - 130°F Power requirement - 380 KWI Budget cost - $200,000 A machine with an evaporator leaving temperature of 100°F is minimally more expensive than the above machine. Three stage compression is used.	6/16/78

SECTION III

A. FUTURE ACTIVITIES

1. Next Quarter Activities

During the next quarter, the heat pump design studies will be completed and documented. In addition, the impact of using low temperature geothermal water for Water-Lithium Bromide Absorption Air Conditioning will be examined for application in the District System particularly at the Hospital Complex. The Park of Commerce geothermal system will be designed and economically compared to the fossil fueled alternative system. This will complete all work scheduled for Task 2, System Design Studies.

The recommended system for Susanville will be designed and documented, including its performance, economics, and basic specifications and drawings. The design point will be selected based on best available resource data as of 1 September 1978. This work activity comprises Task 3, Recommended System Definition. Task 4, Application Plans, is scheduled to begin about mid-September.

2. Reports and Reviews

A mid-point program review will be held on 19 July with DOE. AECC in-house Preliminary Design Review (PDR) has been scheduled for 1 September 1978, at the end of the System Design Studies (Task 2), but before the final system is recommended for Susanville (Task 3). The draft of the final report and the final review are scheduled for the first of November.

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