MULTI-USE GEOTHERMAL ENERGY SYSTEM WITH AUGMENTATION FOR ENHANCED UTILIZATION

A NON-ELECTRIC APPLICATION OF GEOTHERMAL ENERGY IN SUSANVILLE, CALIFORNIA

FINAL REPORT

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ABSTRACT

Aerojet Energy Conversion Company has completed a site specific engineering and economic study of multi-use, augmented geothermal space/water heating and cooling systems. The study was conducted in cooperation with the City of Susanville, California.

The overall benefits to the City of Susanville, in both the public and private sectors, of using low temperature (150°F-240°F) geothermal resources are explored. Options considered, alone and in combination, include heat pumps, fossil-fuel peaking, user load balancing, and cascading from the geothermal system serving the public buildings into a private Park of Commerce development.

A range of well temperatures, depths, flow rates, and drilling costs are considered to provide system cost sensitivities and to make the study more widely useful to other sites. A planned development is emphasized for ease of financing and expansion.

A preliminary design of Phase A of a Susanville Public Building Energy System and a conceptual design of an integrated Park of Commerce, Phase I, are included. This system was designed for a 150°F resource and can be used as a model for other communities with similar resource temperatures.

ACKNOWLEDGEMENTS

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SECTION I. EXECUTIVE SUMMARY

A. INTRODUCTION

Dedicated citizens in Susanville, the U.S. Department of Energy (then the Energy Research and Development Administration), and several private companies and consultants have been working since the early 1970's to make the utilization of Susanville's geothermal resource a reality. The effort began with an ERDA sponsored study to assess the options available to the City, including electrical generation, space heating, and agri-business use. At that time, the reservoir geology (quartz analysis) pointed to the possibility of temperatures above 137°C (279°F). Over the years, as exploration of the resource continued, it became apparent that the resource in and close around the City of Susanville was more apt to be low temperature -65° to 120°C (150°-250°F), with 65°C being the most likely. Because these temperatures are too low to economically generate electricity using current technology, Susanville began to explore the direct-use choices.

For any geothermal project where the KGRA has been defined but the production wells have not been drilled, the actual temperatures and flows that will be obtained from the well system are unknown, as are drilling costs. In these cases, the most economical method of applying geothermal water for direct uses, such as space conditioning and process heat, are not determinable ahead of time and must be approached in a stepwise fashion that would permit economical utilization, regardless of the outcome of drilling. This situation has prompted Aerojet engineers to design flexible systems that permit utilization of geothermal energy at any temperature in the range of 150-250°F. The Northern California Community of Susanville is used as a prototype in this study. Various augmentation combinations were explored, seeking to make a low temperature resource useable over a wider range of applications. Options considered, alone and in concert, include heat pumps, fossil-fuel peaking, user load balancing, and cascading.

B. SUMMARY

The Susanville Public Building Energy System was conceptually designed at resource temperatures of 150°F, 165°F, 185°F, and 225°F in the 150°F to 250°F temperature range. A preliminary design was performed for 150°F. The Park of Commerce conceptual design was for a 150°F resource only. The 150°F resource is the most probable reservoir condition based on current drilling data.

The seventeen public buildings selected for inclusion in the geothermal system were chosen for their relative location to the anomaly. These buildings annually utilize about 40,000 million BTU of fossil energy at a current cost of $140,000. The Park of Commerce industries were selected from an industry survey conducted by the Fred Longyear Company under contract with AECC. They are: (1) a 5-acre greenhouse operation, and (2) an integrated meat production and processing plant. The greenhouse operation and the meat plant together would require a total of 116,200 million BTU per year at a current fuel cost of $415,000. The design objective for the integrated Park of Commerce is to minimize dependence on fossil fuel by economically utilizing the effluent from the public buildings along with additional geothermal energy from another well.

Conceptually, three production wells, producing 350 gpm each, supply the public buildings. The water is pumped to an elevated storage tank located on a hill above town for system pressure control and system emergency capacity. The delivery and disposal piping are laid in a common trench.

The delivery and disposal system chosen, after the evaluation of many alternatives, is an elevated tank feed system with asbestos cement supply and return pipes in a common trench. The supply line would be factory insulated pipe. Downhole constant speed pumps would feed the vented tank with gravity flow to all the buildings and to the Park of Commerce. Pipe sizes required vary from 3 to 12". Reinjection will be in cased wells under residual system pressure.

The effluent from this system nominally leaves at 120°F. One-third of it is mixed with the flow from a Park of Commerce production well to provide 135°F boiler-feed water to the Park of Commerce. The other two-thirds are mixed with the effluent from the meat production and processing industry. This mixture, about 116°F, is supplied to a heat pump which provides 350 gpm of 150°F water to five acres of greenhouses. Approximately 1,400 gpm of effluent leaves the Park of Commerce at 105°F and is reinjected into the ground in two wells at roughly 40 psig.

Part of the Park of Commerce uses heating energy all year long, which helps to balance the load utilization on the geothermal system between summer and winter. With resource temperatures greater than 185°F, the system utilization could be further increased by using the geothermal water to produce air conditioning in the summer, using water/LiBr absorption water chillers. At 160°F and below, the cost of producing air conditioning with geothermal is prohibitive.

The water chemistry, as currently defined, does not indicate a need to isolate the heating system from the geothermal when retrofitting the public buildings. Isolation by plate heat exchangers would be the conservative approach with a resource temperature greater than 165°F. At lower temperatures, a flow-through system is recommended unless water chemistry studies conclusively determine that the system life will be significantly shortened by scaling and corrosion. Protection against galvanic cell activity between iron and copper must be provided in the direct flow-through system.

The minimum economically acceptable rate of return considered in this study is one that would pay back a long-term loan with operating revenues at an interest rate of 8% for a 25-year life. The project rate of return is based on an average inflation rate of 7% per year for all operating costs - fossil fuel, electricity, manpower, and replacement costs.

The cost and size of the geothermal system are dependent on the geothermal flow rate required. The required flow rate rapidly decreases with increasing temperature. The heat load which can be obtained from an existing building heating system decreases to between 50 to 70% with 150°F water for a system designed for 200°F. Service hot water heating is not practical with the existing equipment with geothermal temperatures below 165°F.

Heat pumps are in direct competition with hot water heaters (boilers) and can be used to economically replace these fossil-fueled heaters whenever a heat source is available of sufficient quantity and temperature. As a replacement for fossil-fueled heaters, the heat pump must have a high COP to minimize its operating cost (electricity costs) over the year to pay back the four to five times higher initial capital investment. The heat pump should be designed and installed in the heating system in such a way as to maximize its performance over the year. There will be an optimum heat source exit temperature in the evaporator to maximize this performance. At the 150°F design point for Susanville, this will be close to 125°F.

Heat pumps can be integrated into a geothermal system in many ways. The best method for a particular application will usually be selected based on the arrangement which has the lowest annual cost - a combination of annual operating cost and capital recovery. Several locations within the City of Susanville were evaluated for possible heat pump application. The most promising locations identified were the hospital complex and the Lassen Union High School. They represent large concentrated loads in the energy system. For this preliminary design, the high school was selected as the heat pump site as it is the largest energy user in the system. Several heat pumps were evaluated for the high school site. A commercially available unit was selected which would have a 500 ton condenser heat output with 150°F evaporator geothermal inlet temperature and a 185°F condenser outlet heating loop temperature. During the final design of the system, positioning the heat pump at the high school should be re-evaluated as additional data becomes available on high school retrofit costs.

C. CONCLUSIONS AND RECOMMENDATIONS

The encouraging conclusion reached during this study is that low temperature (150-240°F) geothermal fluid can be augmented in ways that make direct utilization of this energy economically acceptable for various applications.

For Susanville specifically, the Public Building Energy System would show between 8-10% rate of return on an investment of about two million dollars, including the injection wells. By implementing this system, about 70% of the current fossil fuel bills for these buildings can be saved annually. If integrated with the proposed Park of Commerce, the rate of return can be increased to about 20% on the total investment and the simple payback period is decreased from 20 to 7 years.

Susanville is ready to implement the use of geothermal energy. There are no known institutional impediments to implementation at this time. The community's attitude is positive - no problems are anticipated from special interest groups or other citizen factions. Local permitting is straightforward and it is expected that Lassen County will handle permitting as expeditiously as it has in the past. All rights of way for the first module of the proposed energy system are under the control of the City and County. Previous environmental impact work indicates no problem or conflict with proposed energy system.

The best procedure toward development of the Susanville Geothermal Energy System is to demonstrate the viability of the resource and concept by designing, constructing and testing the first module of an integrated system. It would consist of the two elements described in this study: (1) a field experiment for development of the Public Buildings Energy System, initially retrofitting 17 buildings for geothermal heating, and (2) a concurrent commercial/private development of a Park of Commerce, initially providing an augmented geothermal energy system for the first increment of the integrated meat production plant and five acres of greenhouses.

It is recommended that the City of Susanville own and operate the geothermal extraction, delivery, and disposal system and the central utility plant for the Park of Commerce. The system can be operated as a municipally owned, non-profit agency. Funding for implementation would come from sources discussed in Section F.

The transferability of the technology of heat pumps as applied to low temperature hydrothermal resources has been assessed for twelve communities in the Western United States. Based upon these representative communities, it has been estimated that such applications could be considered for about 70% of the hydrothermal sites in the Western U.S. (approximately 110 sites). The greatest degree of transferability of the heat pump technology will occur in communities that can plan for a reasonable degree of cascading.

If the field experiment is initiated in 1979, in less than three years after start date Susanville could have an integrated energy system servicing 17 public buildings, five acres of greenhouses, and a meat production facility. By the end of 1981, they could be successfully negotiating for private and public financing for system expansion, and the system could be generating revenue for payback, expansion, and other community projects.

SECTION II. TECHNICAL DISCUSSION

A. REQUIREMENTS FOR SUSANVILLE APPLICATION

Exploratory drilling in the Susanville Geothermal Anomaly, located in the southern section of the City of Susanville, has been in progress for several years. Temperature gradient holes have been drilled there and one 50-year old well was, until last year, used to heat a small greenhouse operation. Production wells for the proposed Susanville Geothermal Energy System have not been drilled. Therefore, the actual production flow rates per well and the production resource temperatures are unknown. However, previous reservoir testing and chemical analysis indicate that the most conservative assumptions for these variables are 350 gpm and 150°F per production well. Reinjection appears possible at about twice that rate.

Susanville is located on the semi-arid Eastern slope of the Sierra Nevada mountains in California. It experiences an average of 6400 heating degree-days, 275 days in the heating season, and an annual heating load factor of 25%. Air conditioning is not provided in many older buildings and homes. Susanville experiences only 640 hours a year when the temperature exceeds 80°F (dry bulb).

A survey of the heating and cooling loads, and energy consumption of the major public buildings in Susanville and geographical proximity to possible pipeline routes led to the selection of seventeen buildings for geothermal heating. These buildings utilize about 40,000 million BTU per year of fossil energy at a current cost of $140,000. The objective of the geothermal system design is to replace a high percentage of this fossil energy.

The proposed Park of Commerce consists of two major industries: (1) a 5-acre greenhouse operation, and (2) an integrated meat production and processing plant. The greenhouse operation and the meat plant together would require a total of 116,200 BTU per year of fossil energy at a current cost of

$415,000. The design objective for the integrated Park of Commerce is to minimize dependence on fossil fuel by economically utilizing the effluent from the public buildings along with additional geothermal energy from another well.

The City of Susanville will own and operate the geothermal extraction, delivery, and disposal system and the central utility plant for the Park of Commerce. The system will be operated as a municipally owned, non-profit agency. The minimum economically acceptable rate of return is one that would pay back a long-term loan with operating revenues at an interest rate of 8 to 10% for a 25-year life. The project rate of return will be based on an average inflation rate of 7% per year for all operating costs - fossil fuel, electricity, manpower, and replacement costs.

1. Space Conditioning Requirements for Public Buildings

Candidate public buildings for inclusion in the Susanville Energy System were grouped by location in the City (Figure A-1). Buildings in Groups I and II were selected for an energy survey because of their proximity to the Susanville Anomaly. As a result of this survey (Reference 4), eight buildings in Group I and nine buildings in Group II were selected for inclusion in the Phase A development. These buildings are described in detail in Appendix A.

The fuel consumption and installed heating capacity for Phase A buildings were obtained from an energy survey. Fossil fuel and electrical heating costs for the Phase A buildings currently amount to about $140,000 per year (Table A-1). After taking into account fossil fuel used for peaking on the few very cold days, implementation of the Phase A geothermal energy system potentially will save about 94% of the fuel oil costs. Part of this savings will be spent on operation, maintenance, and electrical costs, bringing the overall dollar savings to about 70% of what is currently being spent.

CITY OF SUSANVILLE

GROUP IIA

IIA-1 City Hall and Annex
IIA-2 US Post Office
IIA-3 Masonic Hall and Sanitary Dist.
IIA-4 US Forest Service
IIA-5 Calif. Dept. Motor Vehicles
IIA-6 Bank of America
IIA-7 Court House Complex
IIA-7a Court House
IIA-7b Court House Annex
IIA-7c Jail
IIA-8 Washington School

GROUP I

I-1 Hospital Complex (4 buildings)
I-1a Lassen Memorial Hospital
I-1b Hospital Warehouse
I-1c Emergency Addition
I-1d Hospital Annex
I-1e Co. Health Center
I-2 Co. Welfare Building
I-3 Co. Shop Complex
I-4 City Shop
I-5 Roosevelt Pool
I-6 Diamond View School

GROUP IIB

IIB-1 Lassen High School Complex
IIB-1a High School (7 buildings)
IIB-1b School District Office
IIB-2 Silver Tops, Sr. Center & Chamber of Commerce
IIB-3 Veterans Memorial Building
IIB-4 Fire Station

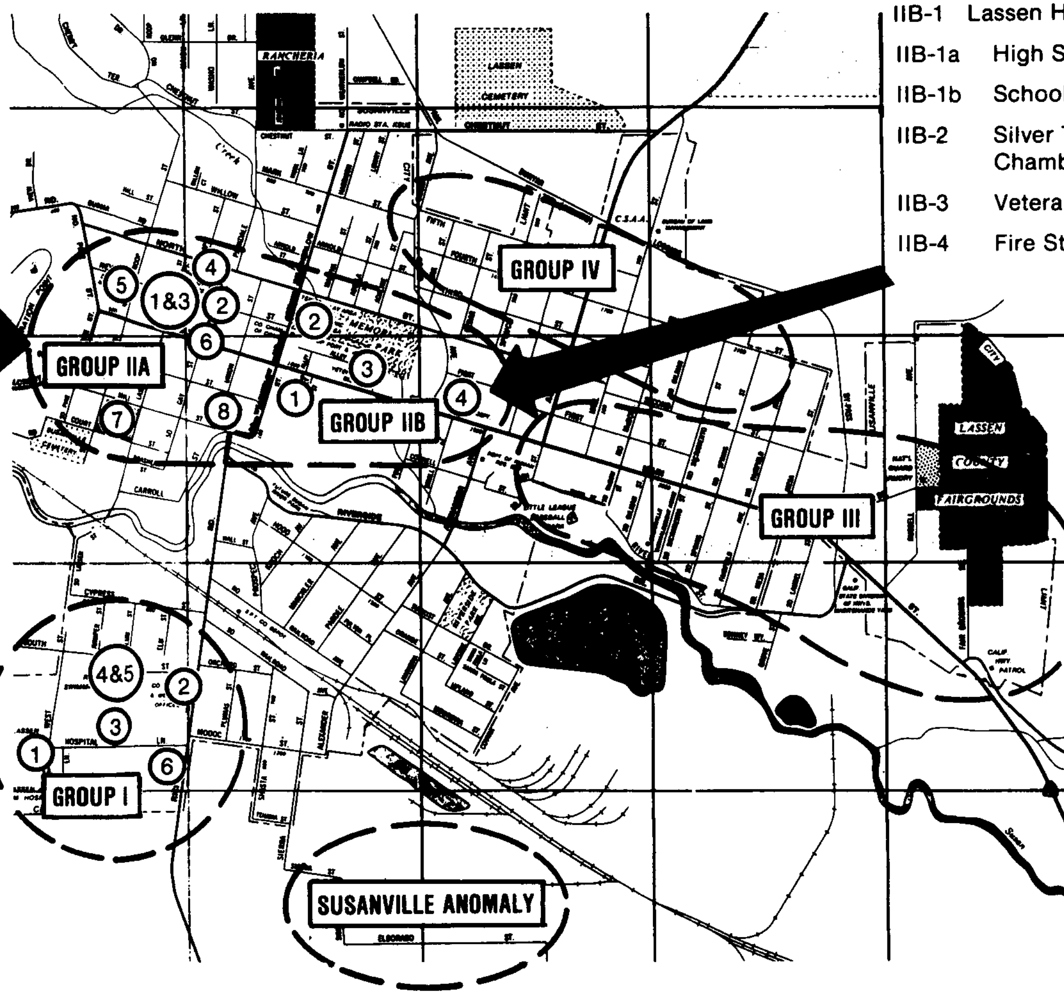


Figure A-1. Grouping of Candidate Buildings for Geothermal Heating System

A, 1, Space Conditioning Requirements for Public Buildings (cont.)

Table A-1

Susanville Fuel Consumption, Phase A

	Group I	Group II	Total
Number of Buildings	8	9	17
Fuel Oil, Gallons/Year	96,000	157,000	253,000
Propane, Gallons/Year	30,000	4,000	34,000
Energy Used, Million BTU/Year	17,000	23,000	40,000
Cost of Fuel (January 1978 $)	60,000	80,000	140,000

The 17 buildings selected for Phase A development have a total floor space of about 320,000 square feet and a peak heat load of 19.2 million BTU per hour, yielding an average peak heat load per square foot of 60 $BTU/Hr/Ft^2$. This peak heat load was derived from the installed capacity of the existing heating equipment in the buildings and from fuel utilization data. A significant part of the heat load in the hospital complex, the county jail, and the high school is used for domestic hot water supply (bathing) as well as for space heating.

Details of fuel consumption and installed boiler capacity are presented for the 17 public buildings in Table A-2. Also presented are the peak heat loads calculated from average yearly energy load by the degree-day method. Note that for the Group II buildings, the calculated peak heat load differs significantly from the installed boiler capacity; the most significant difference occurs in the Lassen High School numbers. In this case, building heating coil data was obtained and found to correlate with the lower, calculated value. At the high school it was decided to adopt the calculated peak heat load value for use in the energy system design. Installed capacity numbers were used elsewhere, as indicated in the assumed design peak heat loads given in Table A-2.

Compression air conditioning equipment is installed in the hospital complex (72.25 tons), the U. S. Post Office (15 tons), and the U. S. Forest Service (25 tons). Only the hospital complex equipment would be a candidate for replacement with geothermal absorption refrigeration and then only with a resource temperature of 185°F or greater. The low annual utilization of the equipment at the other locations would not warrant their replacement at this time.

TABLE A-2

Peak Heat Loads for Public Building Heating System, Phase A

Building No.	Building	Yearly Fuel Consumption Oil Gal.	Yearly Fuel Consumption Propane Gal.	Average Yearly Energy Load Million BTU	Calculated Design Peak Heat Load Million BTU/Hr	Installed Boiler Operating Capacity Million BTU/Hr	Assumed Design Peak Heat Load Million BTUH
I-1a&c	Lassen Hospital & Emergency Addition	43,116	14,559	7,531	3.01	3.01	2.03
I-1b	Warehouse	---	---	---	---	---	0.12
I-1d	Annex						0.98
I-1e	County Health Center	---	---	---	---	---	0.30
I-2	CountyWelfare Bldg.	16,240	---	2,319	0.93	1.28	1.28
I-3	County Shop	---	14,270	1,313	0.53	0.68	0.68
I-4	City Shop	---	---	---	---	---	0.33
I-6	Diamond View School	36,552	1,125	5,220	2.09	1.95	1.95
	SUBTOTAL	95,968	29,954	16,383	6.56	6.92	7.67
IIA-1	City Hall & Annex	3,033	---	433	0.17	0.52	0.52
IIA-2	Post Office	1,611	---	230	0.09	0.32	0.32
IIA-3	Masonic Temple	3,780	---	540	0.22	0.36	0.36
IIA-4	US Forest Service	8,631	---	1,233	0.49	0.61	0.61
IIA-7a	County Courthouse	10,255	---	1,465	0.59	1.26	1.26
IIA-7c	Jail	7,670	---	1,095	0.44	1.24	1.24
IIA-8	Washington School	7,174	---	1,024	0.41	0.50	0.50
	SUBTOTAL	42,154		6,020	2.41	4.81	4.81
IIB-1a	Lassen Union High School	114,449	---	16,343	6.54	11.10	6.54
IIB-1b	School District Office	---	3,966	372	0.15	0.21	0.21
	SUBTOTAL	114,449	3,966	16,715	6.69	11.31	6.75
	TOTAL	252,571	33,920	39,118	15.66	23.04	19.23

A, 1, Space Conditioning Requirements for Public Buildings (cont.)

Heating is supplied to the public buildings today primarily with oil fired boilers. The fuel oil used in the boilers is diesel (C-2) except at the Lassen Union High School where C-3 (P-300) is used. About 10% of the energy is supplied by LPG (propane). Electrical baseboard heating is used to a limited extent in the City Hall and Annex. The County Courthouse Annex, which is not included in Phase A, uses electric baseboard heating exclusively. No natural gas is available.

2. Geothermal Resource Data

The Susanville geothermal resource has a known temperature of 150°F at a well depth of about 500 feet, but the reservoir chemistry (silica content) indicates a temperature potential of 239°F. The Bureau of Reclamation is continuing to map the reservoir, searching for higher temperatures. The production wells for the project have not yet been drilled.

The water quality at Susanville is very good. Total dissolved solids (TDS) levels are 680, and the PH is 7.6. The production wells in the Susanville Anomaly are expected to have the following composition:

Ions	Symbol	PPM
Anions		
Calcium	Ca^{++}	32
Potassium	K^{+}	8
Magnesium	Mg^{++}	1
Sodium	Na^{+}	177
Boron	B^{+++}	2
Total Anions		220
Cations		
Cloride	Cl^{-}	98
Sulfate	$SO_4^{=}$	260
Bicarbonate	HCO_3^{-}	36
Silicon Oxide	SiO	66
Total Cations		460
Total Dissolved Solids		680

The water quality data comes from a producing well in the general area (south of the town) earmarked for the development of the production wells for this project. It has been used for several years for greenhouse operations by the North Coast Growers Association. There are also two temperature gradient holes in this area.

The North Coast Growers Association well has been used for a reservoir evaluation test by the Bureau of Reclamation. It was pumped with a 15 HP turbine pump set at 50 feet for a total of 89 hours. The well was pumped at 332 to 317 gpm with an 18 foot drawdown. The temperature varied from 147 to 140°F. (Figure A-2) The condition of the well casing is unknown. It is an old well, and much of it may have been completed with nonperforated casing (Reference 1).

The two temperature gradient holes have not been flowed. The hole in the Lassen County Maintenance yard was drilled to 2000 feet and showed a stabilized downhole temperature of 131°F. The hole closer to the sawmill produced a temperature of 147°F at 425 feet, but the temperature inverted below this level. Additional temperature gradient holes, capable of being flow tested, are currently being drilled.

3. Extraction and Injection

The minimum flow rate per production well assumed for this study was 350 gpm. The potential exists for 500 to 700 gpm wells similar to those in production at Klamath Falls (Reference 2). This study included production well flows at 350 and 700 gpm. The injection well flows were assumed to be double the production well flows. Reservoir data will be available later this year to check out these assumptions.

It is assumed that injection of the water will be required. However, the City is surrounded by agricultural land and might want to consider using the effluent water for irrigation. Reservoir testing should define whether injection is required to maintain the life of the reservoir and to avoid subsidence.

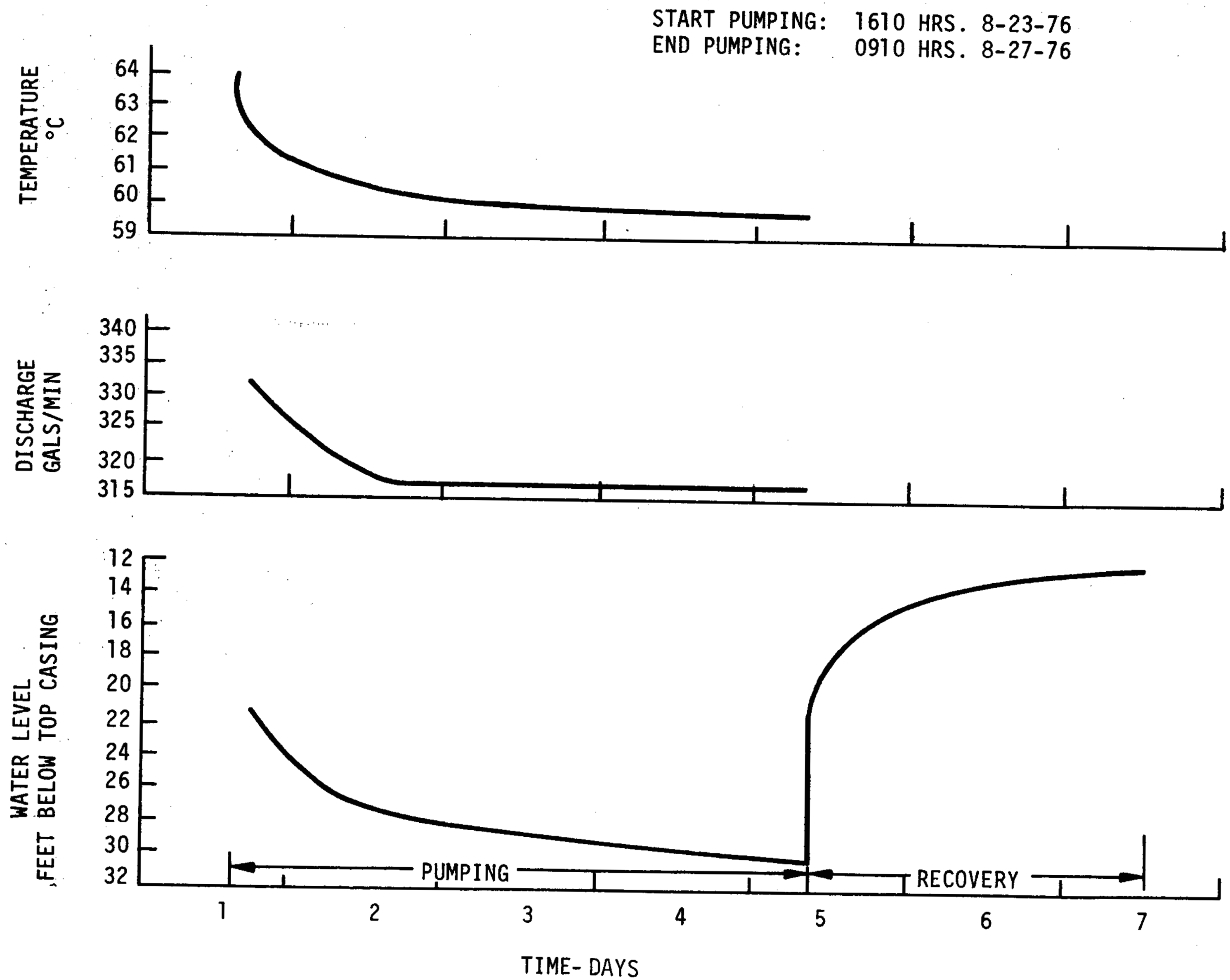


Figure A-2. Susanville Geothermal Investigations: Reservoir Evaluation Test, North State Growers' Well

A, Requirements for Susanville Application (cont.)

4. Climatological Data

Susanville is located on the semi-arid Eastern slope of the Sierra Nevada mountains. The area experiences evenings cold enough to require some heating throughout the year. A U. S. National Oceanic and Atmospheric weather station is located at the Susanville Airport, and design weather data for heating and cooling presented in the following table was obtained from records kept at this station (Reference 3).

Table A-3

Susanville Design Weather Data

Heating Data	
Average Heating Degree-Days	= 6400
Number of Days in Heating Season	= 275
Design Outside Temperature	= -5°F
Mean Temperature for Year	= 49.5°F
Mean Temperature for January	= 30.3°F
Mean Temperature for July	= 70.6°F
Lowest Extreme Temperature on Record	= -16°F
Seasonal Load Factor	= 33.2%
Annual Load Factor	= 25.0%
Operating Hours for Intermittent Plant	= 2200 Hours
Cooling Data	
Design Dry Bulb Temperature, 2-1/2% Basis	= 91°F
Design Wet Bulb Temperature, 2-1/2% Basis	= 61°F
Hours 80°F Dry Bulb Exceeded	= 640 Hours
Relative Humidity in July @ 1:00 P.M.	= 25%
Wind Speed, July Mean	= 6.8 MPH
Sunshine July, % of Possible	= 91%

A, 4, Climatological Data (cont.)

Using averaged weather data from the Susanville Airport, a curve of the estimated yearly heating load versus ambient temperature was constructed for the heating season (Figure A-3). This curve is an approximation, since hourly data was not available for Susanville. The significance of this curve is that for about 95% of the year, the temperature exceeds 25°F. Therefore, an outside temperature of 25°F is a good design value for a geothermal system which will use peaking for the coldest days.

5. Energy Costs

The latest fossil fuel costs, shown in Table A-4, were obtained from the City of Susanville's records and include 6% sales tax. Susanville fuel oil cost is currently escalating at about 7% per year while the propane cost is increasing at the rate of 18% per year.

Table A-4
Susanville Fossil Fuel Costs

Fuel	Date	Cost $/Gal	Cost $/Million BTU
C-2 (Diesel)	1/77	0.440	3.1
C-2 (Diesel)	1/78	0.470	3.36
LPG (Propane)	1/77	0.402	4.37
LPG (Propane)	1/78	0.470	5.11

Since Phase A system development is not replacing electric baseboard heating to a significant extent, the electric rates specifically for this purpose are not quoted. However, electricity would be used for operating the geothermal system pumps, compressors, etc. The California-Pacific Utilities Company was contacted to determine the rate for a large user. As of August 1978, the applicable electricity cost schedule was the Time of Day Rate Schedule, T-170. The total electric power charge (including base service charge, base charge, and energy charge) is $0.04/KWh. The energy charge represents 75% of this total; this charge is expected to escalate at an estimated 7% to 10% per year. The base charge will escalate at an average of about 7% over the next three years. The minimum antici-

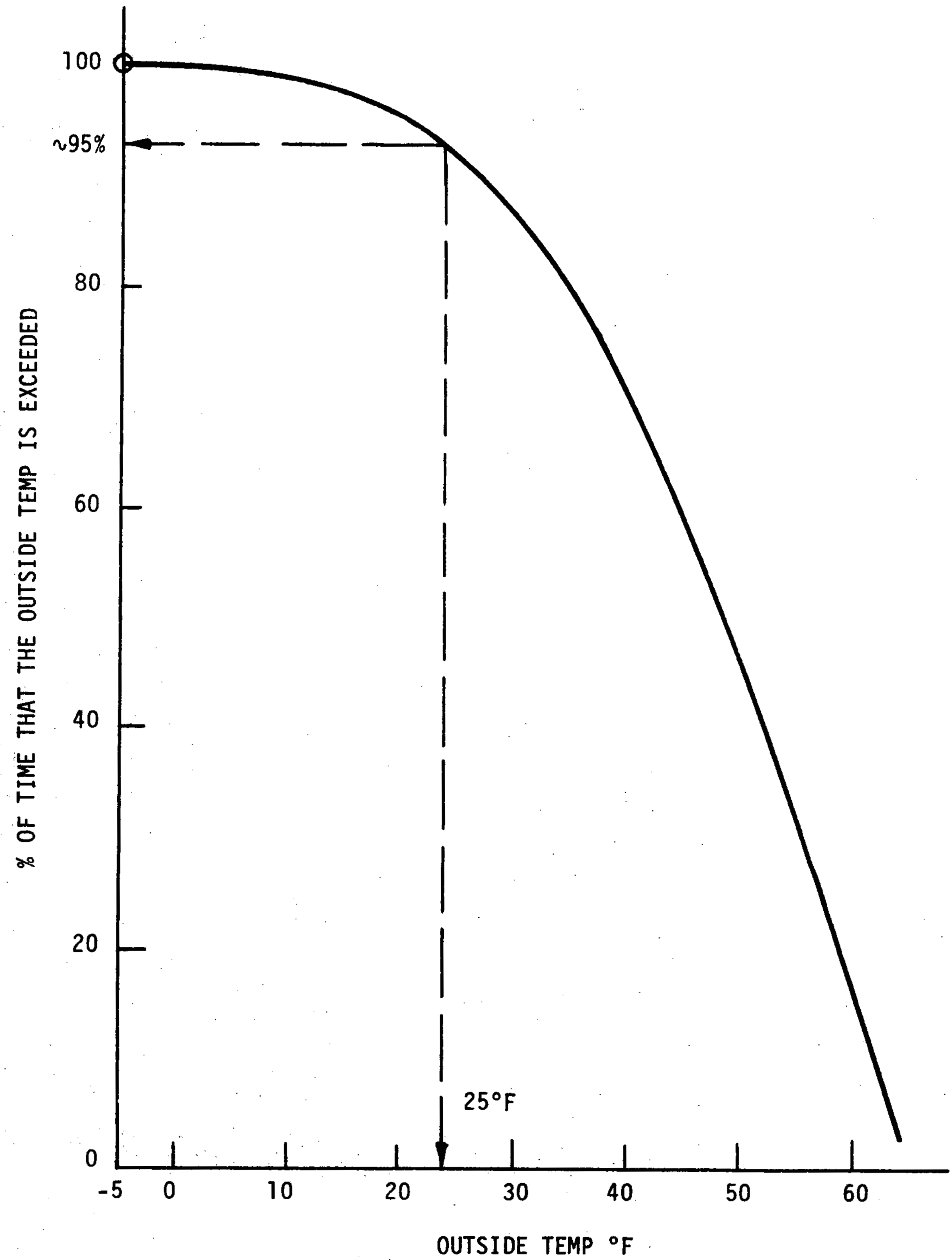


Figure A-3. Susanville Climatological Data, Yearly Distribution Of Outside Temperatures (Proportional To Yearly Heating Load) pated overall rate escalation is therefore assumed to be 7%.

6. Park of Commerce Heat Load

Approximately 100 acres of land south of the City will constitute the Park area. At this time, indications are that the Park will be composed of both private and public land. The Park area should overlay the Susanville Geothermal Anomaly. A conceptual layout of the Park of Commerce is presented in Figure A-4.

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

- Industry #1, Greenhouse Operation

A greenhouse operation is envisioned, producing potted plants and 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 greenhouses will be steel framed fiberglass covered with a thermal-internal blanket. In the first phase, five acres will be under "glass", increasing to 10 acres in five years (Phase II). If the endeavor is successful and competitive with other sites, it will increase to 15 acres (Phase III) or more of "glass" (Figure A-4). 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 40°F from September through May. The greenhouses will operate at up to 80°F during the day and at 65°F at night. The 1.25 acre greenhouse modules are nominally 168' wide (N-s) by 325' long (E-W), with seven 24' wide gable-connected segments.

- Industry #2, Integrated Meat Production Facility

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. Initially, the feed production will yield 1,500 tons per month with growth to 6,000 tons per month. Insulated buildings will house the feed growing (1/2 acre)

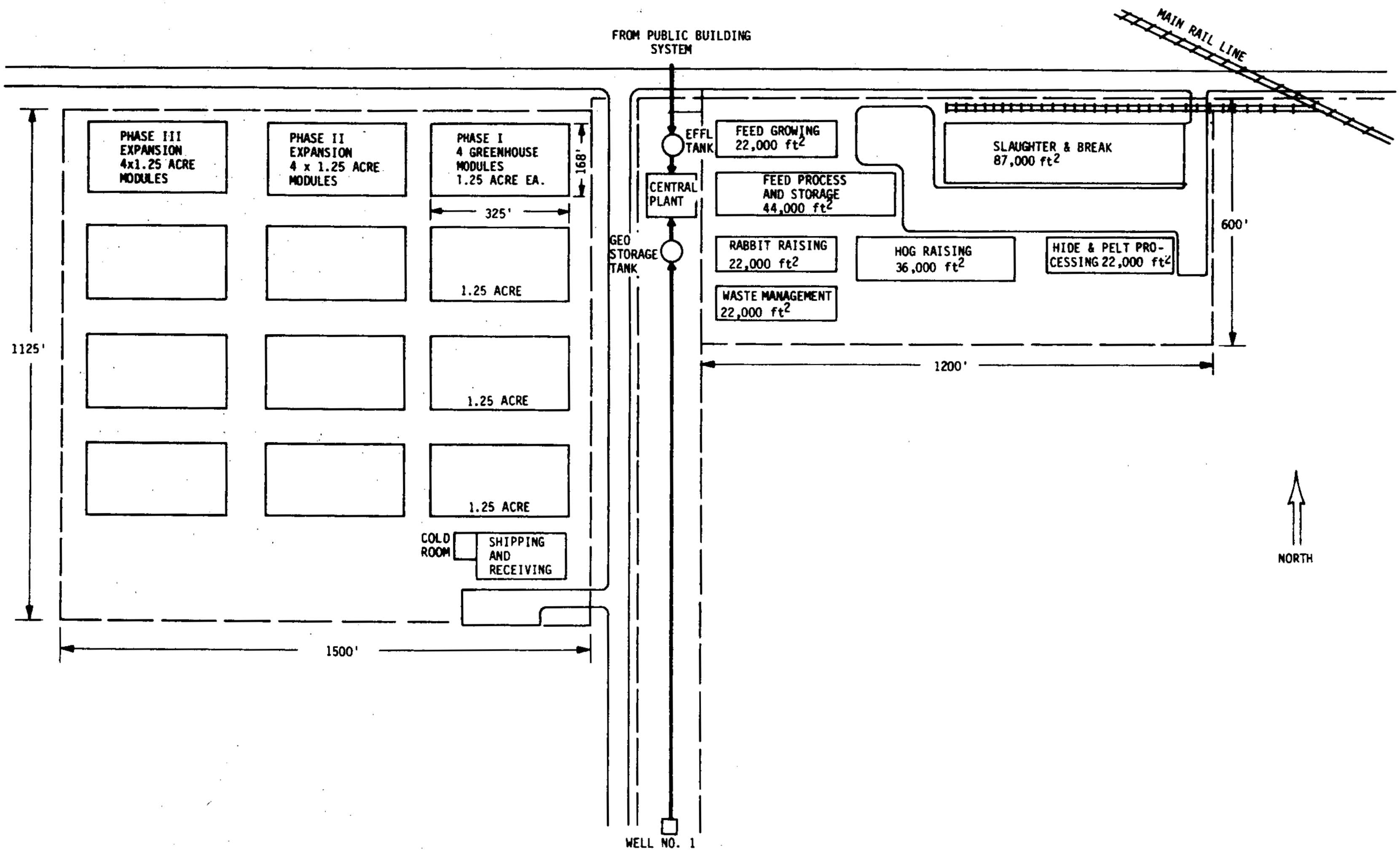


Figure A-4. Plot Plan For Susanville Park of Commerce and the processing and storage (1 acre). All structures are Butler-type, insulated metal buildings. All animal raising and waste management functions are confined, environmentally clean operations. A 36,000 square foot unit will raise 10,000 hogs 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. Cattle will not be raised in this installation. A two-acre slaughter facility will provide for slaughter and break-to-halves at an initial rate of 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 market requirements. 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 local 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 A-5.

A five-acre greenhouse complex will have a design heat load of 16.0 million BTU/hr. 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 will use the effluent water from the public building energy system. A small amount of higher temperature geothermal water (180°F) could be used for soil sterilization, a process usually accomplished with steam.

TABLE A-5

Park of Commerce Space Conditioning & Refrigeration Requirements

		Heating Requirements					A/C Requirements		Refrig. Req'ms.	
No.	Industry/Building	Size ft^2	Design Heat Load Million BTU/hr	Space Design Temp °F	Process Water Load Million BTU/hr	Hot Water Temp °F	Design Cooling Load Tons	Design Room Temp °F	Tons	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	32.0	65	Low	180	-	-	3.0	38
	15.00 Acre Module	653,400	48.0	65	Low	180	-	-	4.5	38
2.0	Integrated Meat Production									
	Intensive Feed Growing	22,000	8.5	65	None	-	Evaporative	80	-	-
	Feed Process & Storage	44,000	0.7	65	20.0	120-180	Evaporative	80	60*	40
	Confined Hog Raising	36,000	1.0	65	None	-	14*	80		-
	Confined Rabbit Raising	22,000	0.9	65	None	-	12*	80	-	-
	Slaughter & Break	87,000	(Refrigerated Space)	-	16.8	180	(In Refrigeration)	-	{60 {15	{10 {0
	Hide & Pelt Processing & Storage	22,000	0.5	65			12*	80	-	-
	Waste Management & Methane Products	22,000	0.4	65	Low	82-90	None	-	-	-
	SUBTOTAL =	255,500	4.0		36.8		38		135	

*Potential for absorption refrigeration application.

In the integrated meat production facility, meat and by-products are derived from a process that starts with feed growing and continues through meat cutting and organic waste utilization. The processes are all enclosed in insulated sheet metal buildings on a 15-acre site. These buildings will have a very low heat loss because they will be totally enclosed and space conditioned with a minimum number of doors and windows within OSHA standards. Calculations using ASHRAE methods indicate a heating load as low as 11.5 BTU/ft^2. However, unknown factors anticipated such as snow load, wind load, and unexpected infiltration losses are assumed to double this load to 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.

The space heating load of 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 this building (Reference 5).

The meat production facility 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 6). Effluent water from the Park of Commerce process heat loads may best be used for space heating.

A large amount of process heating is needed for feed drying and the slaughter and break operations. 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 will be cooled to 70°F in the last stage of the tunnel. When outside air is 32°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 hot water load for the Park of Commerce would be supplied by a central plant (see Figure A-4). The requirements for this central plant are summarized in Table A-6 for the 5 and 15-acre greenhouse operations (Phases I and III, respectively). The air conditioning load refers to that portion of the cooling requirement that might be supplied by absorption refrigeration equipment (see Table A-5).

7. Economic Criteria

The Susanville Energy System will be owned by the City of Susanville. The City would own and operate the extraction, delivery, and disposal system and the central utility plant for the Park of Commerce. The system would be operated as a non-taxable government agency.

This study was conducted under the assumption that the project would be financed by long-term revenue bonds. Interest rates of 8 to 10% are anticipated on these revenue bonds with a life of 25 years. This interest rate represents the minimum economically acceptable rate of return (before taxes) on the investment in the system.

The economic analysis of this project is based on a comparison of a new geothermal system with the fossil fueled system that would be required to do the same job. An investment and operating cost comparison of these alternatives was used to obtain the system rate of return. The investment was determined from budget cost estimates of major equipment, installation costs, and factored cost estimates for engineering, fee, contingencies and other miscellaneous costs. The annual operating costs are based on 1978 utility, manpower and replacement costs escalated at an average of 7% over the life of the project. The inflation rate of 7% was supplied by the local utility companies as an average expected yearly increase over the next 20 years, and is probably a conservative number. It could be as high as 10% per year. Manpower costs and replacement costs are small in relation to other system costs and were inflated at 7% also as a best present estimate.

Table A-6

Park of Commerce Central Plant Requirements

	Design Load Million BTU/Hr.	Yearly Load Million BTU
Integrated Meat Production		
Space Heating	4.0	8,400
Process Water	16.8	35,000
Drying	20.0	36,700
Absorption Cooling	1.2	2,500
Subtotal	42.0	82,600
Greenhouse Industry		
5-Acre Facility Heating	16.0	33,600
15-Acre Facility Heating	48.0	100,800
Central Plant Requirements		
With 5-Acre Greenhouse	58.0	116,200
With 15-Acre Greenhouse	90.0	183,400

The accuracy of the estimated investment cost for equipment obtained directly from the manufacturers is good and should remain valid for one year to January 1980. The overall accuracy is expected to be about ±20% for the project based on this preliminary design. The annual operating cost estimate accuracy is in the same range due to unknown fluctuations in operation over the year.

B. SELECTION OF SUSANVILLE SYSTEM DESIGN

The Integrated Susanville Geothermal Energy System consists of a Public Building System and a Park of Commerce (Figure B-1). In the Public Building System, 150°F geothermal water is used to replace about 94% of the fossil fuel currently used by the buildings to be served. Ten percent of the fuel is replaced due to a heat pump installed at the Lassen Union High School, the largest single energy user in the system. Taking into account the costs associated with the operation of the geothermal system, about 70% of the annual operating cost of the current fossil fuel equipment can be saved.

Three production wells, producing 350 gpm each, supply the public buildings. The water is pumped to an elevated storage tank located on a hill above town for system pressure control and system emergency capacity. The delivery and disposal piping are laid in a common trench.

The effluent from this system nomally leaves at 120°F. One-third of it is mixed with the flow from a Park of Commerce production well to provide 135°F boiler-feed water to the Park of Commerce. The other two-thirds are mixed with the effluent from the meat production and processing industry. This mixture, about 116°F, is supplied to a heat pump which provides 350 gpm of 150°F water to five acres of greenhouses. Approximately 1,400 gpm of effluent leaves the Park of Commerce at 105°F and is injected into the ground in two wells at roughly 40 psig.

The Public Building Energy System would show between 8-10% rate of return on an investment of about two million dollars, including the injection

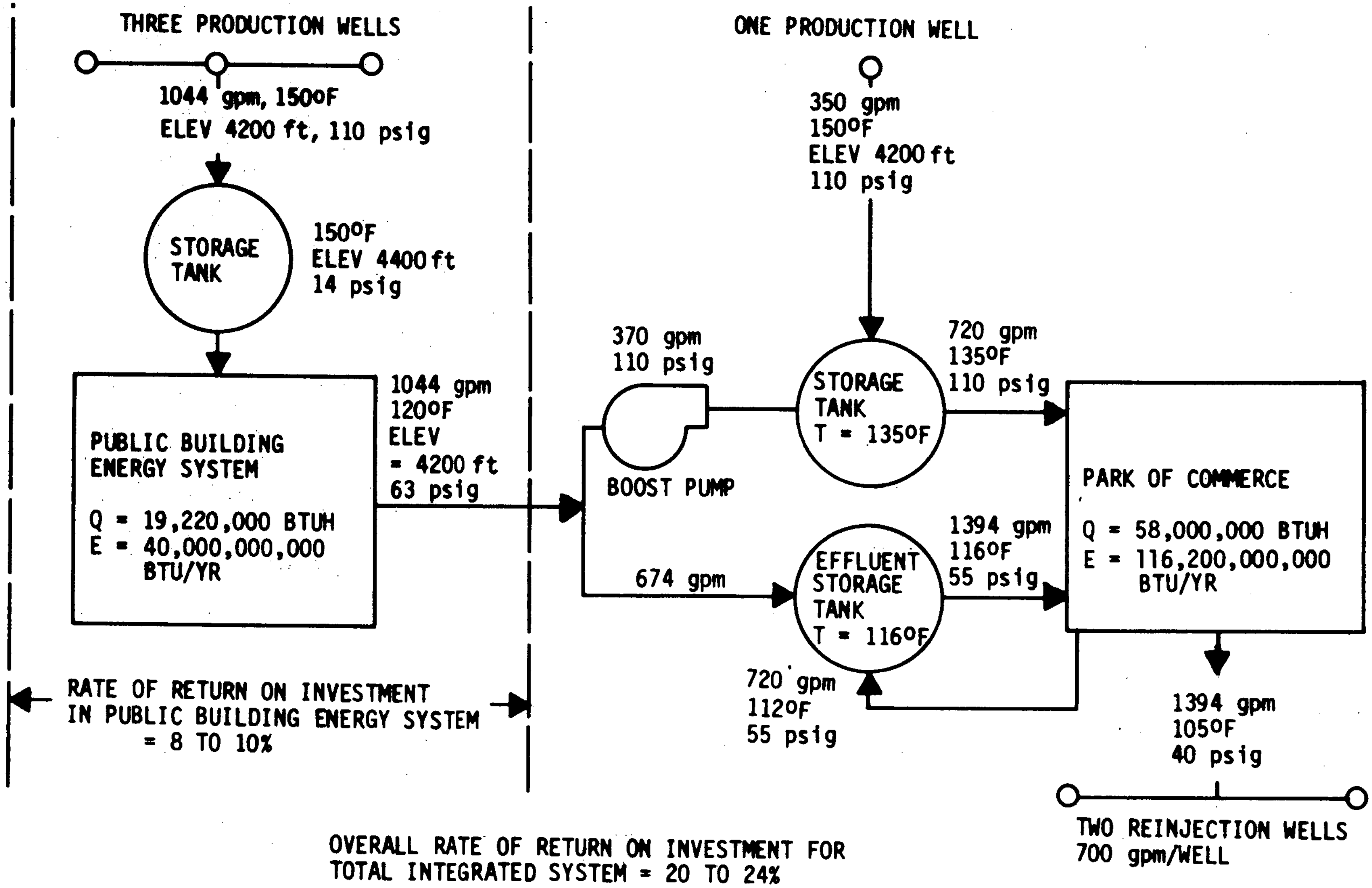


Figure B-1. Susanville Integrated Geothermal Energy System wells. By integrating this system with the proposed Park of Commerce, the rate of return can be increased to about 20% on a total added investment of 2.4 million dollars. The simple payback period is decreased from 20 to 7 years by integrating the system.

1. Design Basis and Criteria

The system design studies and resource evaluation led to the selection of the following design basis for the integrated Susanville Geothermal System (Table B-1).

At 150°F, the geothermal energy system is designed to provide about 60% of the peak design heat load, replacing about 94% of the fossil fuel consumed annually for space heating. This selection was based on the annual distribution of the heating load obtained from meteorological data (Figure A-2). The 60% peak design heat load corresponds to an outside design temperature of about 25°F. The same design point was selected for the Park of Commerce greenhouse and space heating load. The other Park of Commerce loads provided by geothermal were the maximum that could be obtained with the 150°F resource temperature. The 150°F resource was not used for the heating of service hot water for the public buildings because the temperature is too low to be economical.

Overall, the 150°F geothermal system with the heat pump at the high school can replace 94% of the fossil fuel energy used in the public buildings and 65% of the energy needed in the Park of Commerce. Table B-2 presents the selected design points for the public buildings and Table B-3 presents those for the various components of the Park of Commerce.

The Public Building System is baselined with the geothermal water being used directly in the existing or modified building heating systems. This assumption is made because the use of heat exchangers to isolate the geothermal

Table B-1

Susanville System Design Basis

Design Parameter	Units	Value
Resource Parameters		
Well Output Temperature	°F	150
Flow Rate per Production Well	GPM	350
Flow Rate per Injection Well	GPM	700
Energy Loads		
Public Buildings Peak Heating Load	BTU/Hr.	19,200,000
Public Buildings Yearly Energy Use	BTU/Yr.	$40,000 \times 10^6$
Park of Commerce Peak Heating Load	BTU/Hr.	58,000,000
Park of Commerce Yearly Energy Use	BTU/Yr.	$116,200 \times 10^6$
Economic Factors		
Design Life	Years	25
Utilization of Public Building Heating System	Hours/Year	2200
Utilization of Park of Commerce System	Hours/Year	2000
Inflation Rate of Energy	%	7.0

Table B-2

Fossil Fuel Conservation by Public Buildings Geothermal System

Building No.	Building	Design Heat Load Million BTUH	Yearly Energy Use Heating Million BTU	Yearly Energy Use Hot Water Million BTU	% Design Heat Load Geothermal %	% Design Heat Load Boilers %	Annual Energy Supplied By Geothermal Heating %	Annual Energy Supplied By Geothermal Hot Water %	Current Annual Cost Fossil Fuel $	Geothermal System Annual Cost Fossil Fuel $
I-1a&c	Lassen Hospital & Emergency Addition	2.03	6401	1130	60	40	95	0	27,713	5,182
I-1b	Warehouse	0.12	-	-	100	0	100	-	-	-
I-1d	Annex	0.98	-	-	(Included in 1a&c)				-	-
I-1e	County Health Center	0.30	216	-	65	35	97	-	726	22
I-2	County Welfare Bldg.	1.28	2319	-	65	35	97	-	7,792	234
I-3	County Shop	0.68	1313	-	100	0	100	-	6,788	0
I-4	City Shop	0.33	-	-	100	0	100	-	-	-
I-6	Diamond View School	1.95	5220	-	60	40	95	-	18,085	904
	SUBTOTAL	7.67	15,469	1130					61,104	6,342
IIA-1	City Hall & Annex	0.52	433	-	60	40	95	-	2,463	123
IIA-2	Post Office	0.32	230	-	60	40	95	-	773	39
IIA-3	Masconic Temple	0.36	540	-	60	40	95	-	1,814	91
IIA-4	US Forest Service	0.61	1,233	-	65	35	97	-	4,143	124
IIA-7a	County Courthouse	1.26	1,465	-	60	40	95	-	4,922	246
IIA-7b	Jail	1.24	930	164	60	40	95	0	3,676	707
IIA-8	Washington School	0.50	1,024	-	60	40	95	-	3,441	172
	SUBTOTAL	4.81	5,856	164					21,232	1,502
IIB-1a	Lassen Union High School	6.54	13,891	2451	50	50	87	-	54,788	14,302*
IIB-1b	School District Office	0.21	372	-	100	0	100	-	1,923	0
	SUBTOTAL	6.74	14,264	2451					56,711	14,302
	TOTAL	19.22	35,589	3745					139,047	22,146*

*Without heat pump at high school.

Table B-3

Park of Commerce Central Plant Design Point

Design Requirement	Meat Production Plus 5-Acre Greenhouse	Meat Production Plus 15-Acre Greenhouse	Units (Millions)
Greenhouse Load	16.0	48.0	BTUH
Meat Production Load	42.0	42.0	BTUH
Total Load	58.0	90.0	BTUH
Total Geothermal Load @ 150°F	30.9	50.1	BTUH
Boiler/Heat Pump Load	27.1	39.9	BTUH
% Design Load by Geothermal	53%	56%	
Geothermal Load			
Greenhouses	9.6	28.8	BTUH
Meat Production	21.3	21.3	BTUH
Space Heating	(2.4)	(2.4)	BTUH
Process Heat	(3.9)	(3.9)	BTUH
Drying	(15.0)	(15.0)	BTUH
A/C	(0)	(0)	

YEARLY LOAD	116,200	183,400	BTU/Yr
Total Geothermal Load @ 150°F	75,500	138,500	BTU/Yr
% Design Load by Geothermal	65%	76%	
Total Boiler Heat Pump Load	40,700	44,900	BTU/Yr
Greenhouses	32,000	95,000	BTU/Yr
Integrated Heat Production	43,500	43,500	BTU/Yr
Space Heating	(8,000)	(8,000)	BTU/Yr
Process Heat Load	(8,000)	(8,000)	BTU/Yr
Drying	(27,500)	(27,500)	BTU/Yr
A/C	(0)	(0)	

TABLE B-4

SUSANVILLE PUBLIC BUILDING SYSTEM
OPTIONAL GEOTHERMAL OPERATING FLOW RATES

					Optional Operating Points				
No.	Building	Design Heat Load 10^6 BTUH	Min. Temp. Drop °F	Design Flow Rate gpm	% Design Flow Rate %	Geothermal Flow gpm	% Design Flow Rate %	Geothermal Flow gpm	Conversion Process To Geothermal
I-1a & C	Lassen Hospital & Emergency Addition	2.03	30	136	50	68	75	102	Direct connection to existing hot water system
I-1b	Warehouse	0.12	30	8	100	8	100	8	New hot water fan coils required
I-1d	Annex	0.98	30	65	50	33	75	49	Replace existing radiators; hot air or finned convector option
I-1e	County Health Center	0.30	30	20	50	10	75	15	Direct connection to existing hot water system
I-2	County Welfare Bldg.	1.28	60	43	50	22	75	32	Replace existing radiators; hot air or finned convector option
I-3	County Shop	0.68	20	68	100	68	100	68	Connect geo-water to existing hot water system
I-4	City Shop	0.33	40	16	100	16	100	16	New hot water fan coils required
I-6	Diamond View School	1.95	30	130	50	65	75	98	Direct connection to existing hot water system
	SUBTOTAL	7.67		486		290		388	
II.A-1	City Hall & Annex	0.52	40	26	50	13	75	20	Extensive modification including replacing radiators with convectors
II.A-2	Post Office	0.32	30	21	50	11	75	16	Direct connection to existing hot water system
II.A-3	Masonic Temple	0.36	30	24	50	12	75	18	Direct connection to existing hot water system
II.A-4	US Forest Service	0.61	40	31	50	16	75	23	Add hot water coils to existing hot air ducting
II.A-7a	County Courthouse	1.26	30	84	50	42	75	63	Replace inoperative coolers with heat pump
I.A-7b	Jail	1.24	30	82	50	40	75	62	Add hot water coils to existing hot air ducting
II.A-8	Washington School	0.50	30	33	50	17	75	25	Connecto geo-water to existing hot water system
	SUBTOTAL	4.81		301		150		227	
II.B-1a	Lassen High School	6.54	Option I	415	Option I	415	Option I	415	Heat pump (Fig. 9) or Direct geo-water options
II.B-1b	School District Ofc.	0.21	30	14	100	14	100	14	Add hot water coils to existing hot air ducting
	TOTAL	19.22		1216		869		1044	

water from the building heating loops would impose another 10 to 15°F temperature drop on the relatively low 150°F resource. Although scaling does not seem to be a threat for a direct flow through system (low dissolved solids in the Susanville water), there is the potential for solids buildup during recirculation when peaking with the boilers. The corrosion potential appears very small. These areas need careful review in the next design phase of the Susanville geothermal development. Factors to be considered are: (1) chemical evaluation of the production well water; (2) assessment of life expectancy of existing copper components in individual buildings; and (3) impact of system economics if isolation heat exchangers are used.

2. Description of the Design

a. Public Building System

Many different types of heating systems in the Public Building System must be converted to geothermal. The economics of the system favor operation at less than 100% of design flow rate for these systems. Based on systems studied, the 60% heat load design point can be obtained from most existing heating units by using 75% of the design flow rate. This flow rate was selected for twelve of the seventeen buildings (Table B-4). The heating loops in the buildings are designed for a total flow rate of 1,216 gpm, but the geothermal system would be sized for about 86% of this overall maximum for energy and resource conservation.

The Public Building System was routed through town to provide the lowest cost delivery and disposal system (Figure B-2). The geothermal water is pumped from three production wells to a water storage tank located above the hospital and next to the City water supply tanks. From this tank, the water flows by gravity throughout the remainder of the system. The system temperatures, elevations, pressures and flows are summarized in Figure B-3.

Factory insulated asbestos cement pipe is recommended for baseline system supply piping. It is recognized that others (Reference 7)

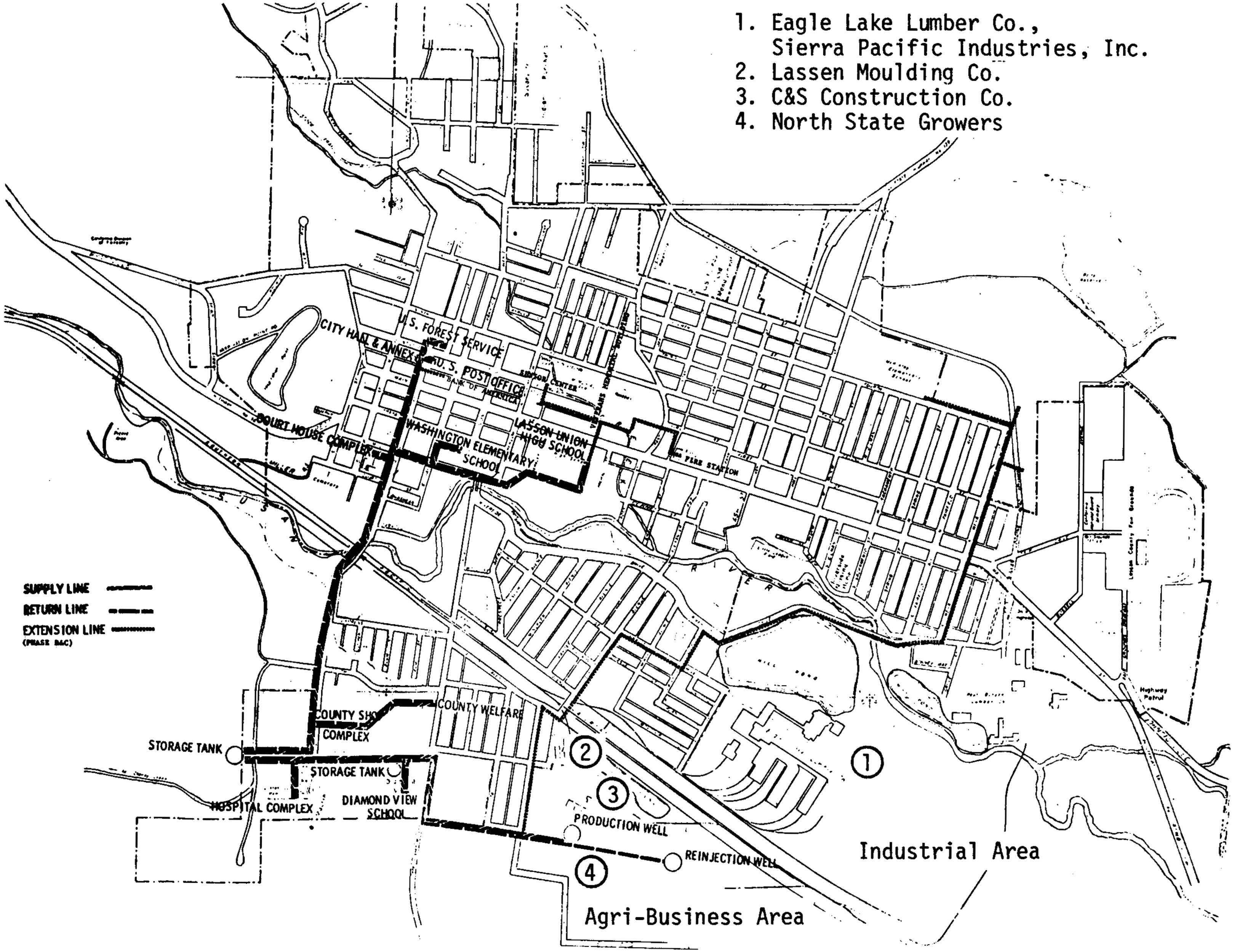


Figure B-2. Susanville Energy System Piping/Routing Layout

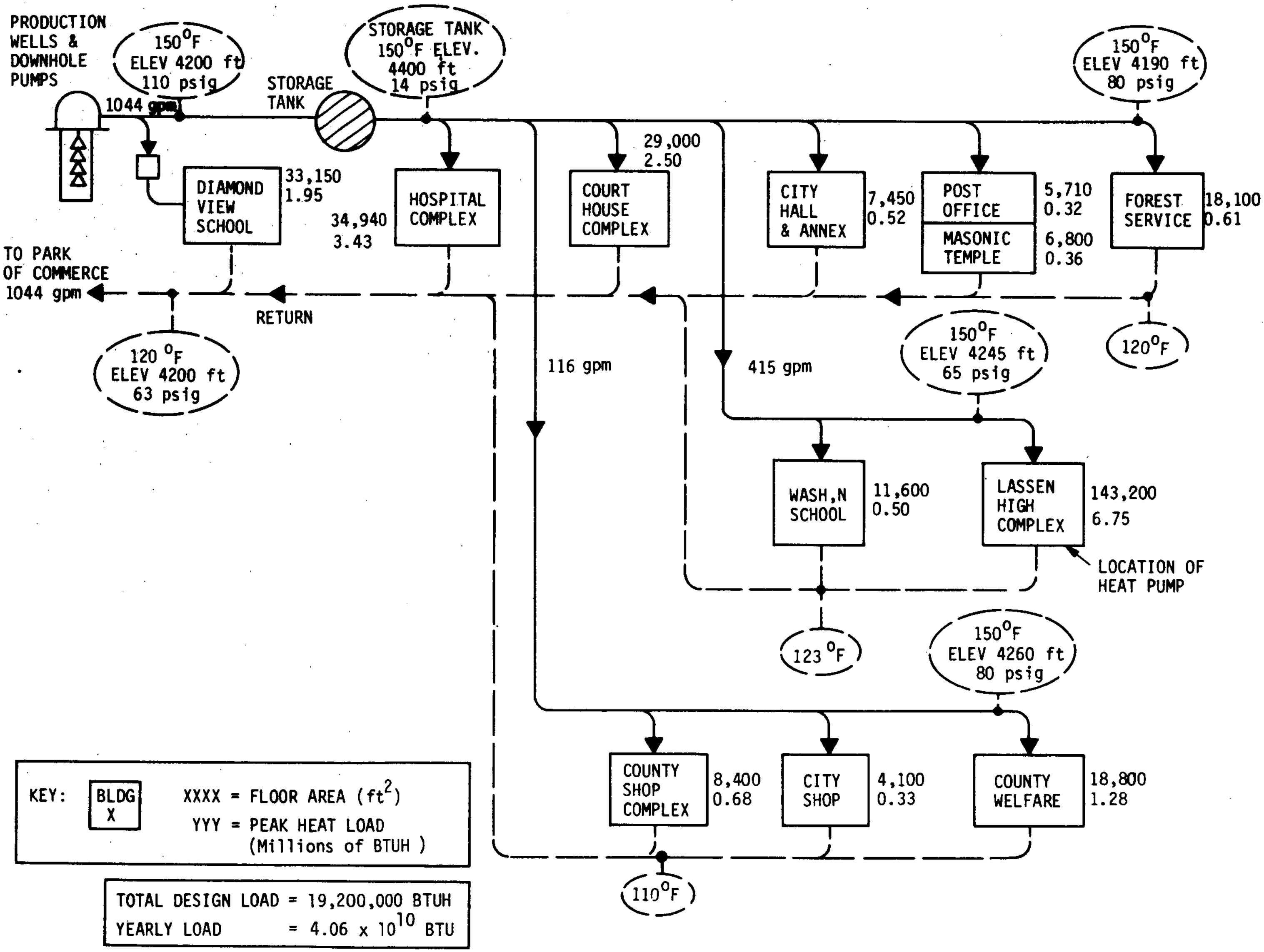


Figure B-3. Susanville Public Building System Flow Diagram have determined that it is cheaper to insulate asbestos cement pipe in the trench. However, Susanville's distribution system will be installed in a hilly section of town. The potential for high heat loss due to accumulation of underground water in the sloping trenches would warrant the added initial cost of double-walled, insulated pipe such as Temptite (Johns-Mansville). Return lines will be uninsulated Transite.

Uninsulated vented tanks are selected to control system pressure because the production wells are a lower elevation than the buildings and the terrain is very hilly. The criteria used to size these uninsulated tanks is taken from Iceland geothermal experience. They are sized to hold 20% of peak flow over a 24-hour interval.

The geothermal water would flow directly through the terminal heating units and through the existing boilers when used for peaking. Protection of the heating coils and boilers by a secondary loop and plate heat exchangers was not selected in this preliminary design. However, testing of the production resource water may indicate material or scaling problems exist requiring this added cost. A filter may be required to prevent erosion but was not included at this point.

The 150°F geothermal water would not be used to provide energy to drive absorption water chillers for A/C because it would not be economical at this temperature (Section II.C.3). Also, amplifying the temperature with boilers and then using it for A/C is not practical because of the low temperature drop (8-12°F) in the absorption generator.

Corrosion of copper heating coils should not be a problem unless galvanic activity exists. A more complete discussion of corrosion, erosion, and fouling is presented in Section C.

B, 2, Description of the Design (cont.)

b. Park of Commerce System

This system has its own production well and would also utilize the effluent from the Public Buildings System to provide hot water to the selected industries. The effluent water is split. About two-thirds of the flow is mixed with the effluent from the integrated meat production and processing industry and used to operate a heat pump to heat five acres of greenhouses. The remainder is mixed with flow from the additional production well to produce feed water to the oil or wood fired hot water heaters and a steam boiler (Figure B-4). Again, a flow through system was selected for the initial design. The water could be treated in the storage tank if necessary. Heat pumps could also be used in place of the oil fired heaters and should be considered in the next design phase. Heat pumps which can produce 230°F discharge water temperatures are commercially available.

The additional geothermal well is used to decrease the boilers' energy consumption and to provide some emergency resource supply independent of the effluent from the Public Building System.

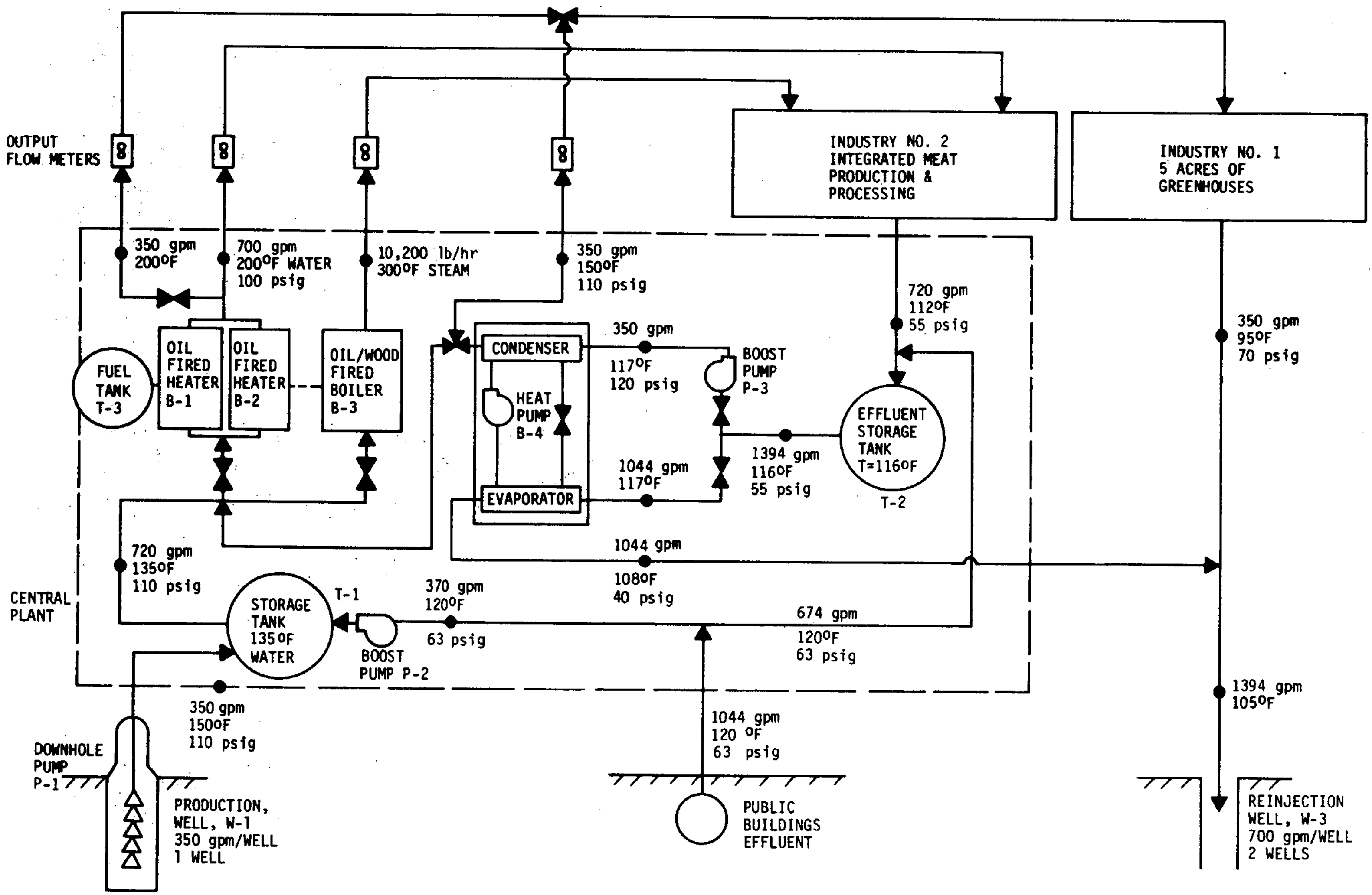


Figure B-4. Susanville Park of Commerce Conceptual Geothermal Plant Flow Diagram

3. System Economics

The economic analysis is based on an integrated geothermal system designed to provide 77 million BTU/hr and 15 x 10^{10} BTU/Yr. It is assumed that the fuel oil used in the boilers would escalate at 7 to 10% per year from a 1978 price of $.47 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 $.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, boilers, heat pumps, and heat exchanger were 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 installed capital cost items. This is an estimate based on engineering judgement and experience of the authors and other investigators.

The system economics are based on a comparison of two alternatives: (1) using all fossil-fueled equipment in the public buildings and Park of Commerce; or (2) using geothermal directly up to its design point and then augmenting or peaking with heat pumps or fossil fueled boilers. For the Integrated Susanville Geothermal Energy System, fossil-fueled boilers are used for peaking except at the Lassen Union High School and the greenhouse complex. Here, heat pumps are recommended to increase operating flexibility. The heat pump at the high school does not improve the overall system rate of but does more to remove the dependence on fossil fuel. With the heat pump at the high school, the system could still produce the total heat load with a drop of geothermal flow rate, and the system's operation is less sensitive to geothermal temperature changes.

The best method of installing the heat pump at the high school was determined from a study of several options. The recommended approach and the options evaluated are discussed in more detail in Section C.

The economic analysis is presented both with and without the heat pump at the high school. The capital cost estimate for the Public Building System varies from about 1.5 to 2.0 million depending on the well flow rate and heat pump option (Table B-5). The well costs are based on three production wells and two reinjection wells at 350 gpm/well and two production wells and one reinjection well at 500 gpm. As specified previously, the 350 gpm/well flow rate was selected as the design value until further data are obtained.

The annual operating cost was calculated at the design point for the Public Building System (Table B-6) and the Park of Commerce. The Park of Commerce data are available in Appendix B. The addition of the heat pump at the high school decreases the operating cost less than $4,000. Since the accuracy of these numbers is expected to be ±20%, this difference is insignificant.

The summary for the overall system (Table B-7) shows the total added investment (over a fossil fuel system) for the geothermal system would be in the 2 to 2.4 million dollar range. The net annual operating cost savings is roughly $320,000. The Public Building System by itself has a simple payback period of 16 to 20 years, but when integrated with the Park of Commerce this drops to 6 to 7 years.

The economic criteria of 8 to 10% ROR is achieved by the Public Building System alone, both with or without using the heat pump at the high school. The integrated system makes the overall project more ecnomically attractive by increasing the ROR to 20 to 24% on the total investment.

Table B-5

Public Building System

Capital Cost Comparison of Alternatives
With 150°F Resource

Design Geo-Flow = 1044 gpm

Thousand of 1978 $

Capital Cost Items	Geothermal With Fossil Fuel Peaking		Geothermal With Heat Pump at High School and Fossil Fuel Peaking	
	350-450 gpm/well	500-700 gpm/well	350-450 gpm/well	500-700 gpm/well
Well (Production and Disposal, $130,000/Well)	650	390	650	390
Delivery and Disposal Piping	460	460	460	460
Downhole Pumps	47	34	47	34
Storage Tank	54	54	54	54
Conversion of Buildings to Geothermal (Budgeted Value)	150	150	150	150
Augmentation Equipment (Heat Pump)	0	0	130	130
Engineering, Fee, & Contingency (Budgeted Value = 32% Equipment Cost)	435	348	477	390
TOTAL INVESTMENT	1796	1436	1968	1608

TABLE B-6

Public Building System

Operating Cost Comparison of Alternatives
With 150°F Resource
Design Geo-Flow = 1044 gpm

Operating Costs	Cost Factor	Geothermal With Fossil Fuel Peaking			Geothermal With Heat Pump At High School and Fossil Peaking		
		Item	Unit	1978 $ Cost	Item	Unit	1978 $ Cost
Electric Costs							
Downhole Pumps	$11.07/10^6 BTU	$912X10^6$	BTU/YR	10,100	$912X10^6$	BTU/YR	10,100
Building Circulation Pumps	$11.07/10^6 BTU	$130X10^6$	BTU/YR	1,440	$130X10^6$	BTU/YR	1,440
Heat Pump (Cop = 6.5)	$11.07/10^6 BTU						
Service Hot Water		-	-	-	$2451X10^6$	BTU/YR	4,415
Heating		-	-	-	$1806X10^6$	BTU/YR	3,254
Fuel Costs							
Service Hot Water	$3.57/10^6 BTU	$3745X10^6$	BTU/YR	12,584	$1294X10^6$	BTU/YR	4,348
Heating	$3.57/10^6 BTU	$2733X10^6$	BTU/YR	9,183	$927X10^6$	BTU/YR	3,115
Operation & Maintenance							
Manpower	$14,400/Man	1/2	Man	7,200	1/2	Man	7,200
Heat Pump Main. Insurance	$2,000/Yr	-	-	-	1	Policy	2,000
Equipment Replacement	1% of Equipment	$548,000	Dollars	5,500	$678,000	Dollars	6,800
TOTAL				46,007			42,672

Table B-7

Summary of Economics for Susanville Integrated Geothermal System

	With Heat Pump at High School 350-450 gpm/well	With Heat Pump at High School 500-700 gpm/well	Without Heat Pump at High School 350-450 gpm/well	Without Heat Pump at High School 500-700 gpm/well
Capital Cost of Geo-Heating System	1,968,000	1,608,000	1,796,000	1,436,000
Capital Cost of P.O.C. Geothermal Plant	750,500	750,500	750,500	750,500
Less Capital Cost of Equiv. Fossil Plant for P.O.C.	-368,800	-368,800	-368,800	-368,800
Total Added Investment for Geothermal	2,349,700	1,989,700	2,177,700	1,817,700
Current Fuel Cost for Public Buildings	139,047	139,047	139,047	139,047
Less Protected AOC of New Geo-Heating System	-42,633	-42,633	-46,386	-46,386
Net Savings in AOC for Public Buildings	96,414	96,414	92,661	92,661
Projected AOC of Fossil Plant for POC	457,600	457,600	457,600	457,600
Less Projected AOC of Geothermal System for POC	-232,200	-232,200	-232,200	-232,200
Net Savings in AOC for POC	225,400	225,400	225,400	225,400
Total Net Savings in AOC for Integrated System	321,814	321,814	318,061	318,061
Simple Payback Period,Public Buildings	20.4	16.6	19.4	15.5
Simple Payback Period, Integrated System	7.3	6.2	6.8	5.7
ROR Without Fuel Inflation, Public Buildings	1.7	3.4	2.0	4.0
ROR Without Fuel Inflation, Integrated System	13.0	15.8	14.0	17.0
ROR With 7% Fuel Inflation, Public Buildings	8.1	10.0	8.6	10.6
ROR With 7% Fuel Inflation, Integrated System	19.8	22.7	21.0	24.0

C. SUSANVILLE DESIGN STUDIES

The Susanville Public Building Energy System was conceptually designed at resource temperatures of 150°F, 165°F, 185°F, and 225°F in the 150°F to 239°F temperature range. The Park of Commerce conceptual design was only for a 150°F resource. The 150°F resource is the most probable reservoir condition based on current drilling data.

The public buildings selected for inclusion in the geothermal system were chosen for their relative location to the anomaly. The Park of Commerce industries were selected from an industry survey conducted by the Fred Longyear Company under contract with AECC.

The delivery and disposal system chosen, after the evaluation of many alternatives, is an elevated tank feed system with asbestos cement supply and return pipes in a common trench. The supply line would be factory insulated pipe. Downhole constant speed pumps would feed the vented tank with gravity flow to all the buildings and to the Park of Commerce. Pipe sizes required vary from 3 to 12" at a cost from $18.50 to $43.50 per trench foot, respectively. Reinjection will be in cased wells under residual system pressure.

Part of the Park of Commerce uses heating energy all year long which helps to balance the load utilization on the geothermal system between summer and winter. With resource temperatures greater than 185°F, the system utilization could be further increased by using the geothermal water to produce air conditioning in the summer, using water/LiBr absorption water chillers. At 160°F and below, the cost of producing air conditioning with geothermal is prohibitive.

The water chemistry, as currently defined, does not indicate a need to isolate the heating system from the geothermal when retrofitting the public buildings. Isolation by plate heat exchangers would be the conservative approach with a resource temperature greater than 165°F. At lower temperatures flow-through system is recommended unless water chemistry studies conclusively determine that the system life will be significantly shortened by scaling and corrosion. Protection against galvanic cell activity between iron and copper must be provided in the direct flow-through system.

The cost and size of the geothermal system are dependent on the geothermal flow rate required. The required flow rate rapidly decreases with increasing temperature. The heat load which can be obtained from an existing building heating system decreases to between 50 to 70% with 150°F water for a system designed for 200°F. Service hot water heating is not practical with the existing equipment with geothermal temperatures below 165°F.

Heat pumps are Rankine cycle machines which amplify the temperature from a heat source (normally hot water) by the addition of power (usually electric). As such, heat pumps are in direct competition with hot water heaters (boilers) and can be used to economically replace these fossil-fueled heaters whenever a heat source is available of sufficient quantity and temperature. The higher the Coefficient of Performance (COP), the greater the operating hours per year, and the lower the cost, the better the heat pumps compete with boilers.

As a replacement for fossil-fueled heaters, the heat pump must have a high COP to minimize its operating cost (electricity costs) over the year to pay back the four to five times higher initial capital investment. The heat pump should be designed and installed in the heating system in such a way as to maximize its performance over the year. There will be an optimum heat source exit temperature in the evaporator to maximize this performance. At the 150°F design point for Susanville, this will be close to 125°F.

Heat pumps can be integrated into a geothermal system in many ways. The best method for a particular application will usually be selected based on the arrangement which has the lowest annual cost - a combination of annual operating cost and capital recovery. Annual operating cost is minimized by the arrangement which produces the lowest power consumption over the year. The initial cost is dependent on the cost of the installation and the cost of the heat pump. Several options for the Lassen Union High School were evaluated.

Heat pumps are commercially available from several major manufacturers for the 150°F design point. For an installation at the Lassen Union High School, the heat pump would have a 500 ton condenser heat output with 150°F evaporator geothermal inlet temperature and a 185°F condenser outlet heating loop temperature.

At the 125°F evaporator outlet temperature, the design COP will be in the range from 6.1 to 6.5. The budget cost of this unit, depending on the manufacturer, ranges from $86,000 to $200,000.

1. Building and Industry Selection

Candidate buildings for the energy system were selected from among the buildings surveyed (after discussion with community officials) and were grouped according to their proximity to the Susanville Anomaly (Figure A-3). The surveyed buildings have been numbered as follows with the seventeen buildings selected for Phase A marked with an asterisk and described in Appendix A:

Group I	
Hospital Complex (four buildings)	I-1
*Lassen Memorial Hospital (L.M.H.)	I-1a
*Hospital Warehouse	I-1b
*Emergency Addition (Included in L.M.H.)	I-1c
*Hospital Annex	I-1d
*Co. Health Center	I-1e
*Co. Welfare Building	I-2
*Co. Shop Complex	I-3
*City Shop	I-4
Roosevelt Pool	I-5
*Diamond View School	I-6
Group IIA	
*City Hall and Annex	IIA-1
*U.S. Post Office	IIA-2
*Masonic Hall and Sanitary District	IIA-3
*U. S. Forest Service	IIA-4
California Department of Motor Vehicles	IIA-5
Bank of America	IIA-6
Court House Complex	IIA-7
*Court House	IIA-7a
Court House Annex	IIA-7b
*Jail	IIA-7c
*Washington School	IIA-8

C, 1, Building and Industry Selection (cont.)

Group IIB	
Lassen High School Complex	IIB-1
*High School (seven buildings)	IIB-1a
*School District Office	IIB-1b
Silver Tops, Sr. Center & Chamber of Commerce	IIB-2
Veterans Memorial Building	IIB-3
Fire Station	IIB-4

The hospital complex contains four separate parts. The main hospital and emergency addition are combined, while the rest are separate buildings with separate heating and cooling plants. The high school's seven major buildings have a common heating plant and have been counted as one unit. If each building in the high school is counted separately, the Public Building Energy System in Phase A will serve 23 buildings.

The buildings for Phase A were selected based on their location to the geothermal resource and their contribution to the total yearly fossil fuel consumption. The form used in the energy survey is presented as Figure C-1 (Reference 4). The energy consumption data were obtained by reviewing the energy procurement records of the City and the County and by requesting the same information from the building managers in the other facilities. The data were available in tabulated form in the City. The actual warrants and sales slips from the delivery trucks were reviewed in the offices of the County and the School District.

The Park of Commerce Industries were selected based on an industry survey by the Fred Longyear Company for the Aerojet Energy Conversion Company (Reference 8). This survey led to the selection of the two major industries. The survey also provided some background energy consumption and industry standards data which was used in defining the requirements for the project. A more complete description of the Park of Commerce and its design is presented in Section A.5 and Appendix B.

CONTACT:

Facility Type:

Address: Phone:

Person Contacted: Position:

Facility Description: shape, size, no. floors, construction, insulation, age

SPACE HEAT: design data from drawings/specifications

Equipment Listing:

Nameplate Data: mfr. , model no. , input - output ratings (Btu/hr

Fuel Type Water Supply Pump: mfr., model no., flow rate , press. rise

Air Fan: manufacturer, model no. , rating (H.P.,Amps, Watts)

HOT WATER SUPPLY: design data from drawings/specifications

Equipment Listing:

Nameplate Data: mfr. , model no. , capacity (gal.), rating (Btu/hr.)

SPACE COOLING: design data from drawings/specifications

Equipment Listing:

Nameplate Data: CHILLER mfr., model no., refrigerant, flow rate, press. rise

capacity (Tons); WATER PUMP mfr., model no., flow rate , press. rise

AIR HANDLING SYSTEM: Type (variable vol., multizone, reheat)

CONDENSING SYSTEM: mfr., type (wet, air, evap. tower), model no.

load (Btu/hr.), fan power

ENERGY CONSUMPTION: ☐ HEATING, ☐ COOLING, ☐ ____________, ☐ TOTAL

Fuel Type(s): Unit Cost(s)

Annual Quantities Costs

Peak Load Quan.(s) Costs/_______

Consumption by month

Duty Cycle Data: thermostats settings, seasonal operations/variations

Figure C-1. Susanville Energy Survey Form

2. Delivery and Disposal System

The number of wells is determined by the required geothermal flow rate, which in turn is determined by the peak heating load, the geothermal water temperature, and the heating system temperature drop. Factory insulated asbestos cement piping was selected for the supply line and uninsulated asbestos cement for the return lines. The sizes of the various lines in the distribution system are determined by the geothermal flow rate, line temperature losses, and pressure drop constraints. A velocity of 5 ft/sec was found to be a good design number. The storage tank selected was a standard vented type. Where heat exchangers would be needed, the APV type paraflow plate design was selected due to their small size and low cost (Reference 2). Table C-1 presents the options studied and the selections made.

Table C-1

Delivery and Disposal System Options

Component	Options Studied	Selection
Supply Water Piping	Insulated Steel	Temptite
	Field Insulated Asbestos Cement	
	Factory Insulated Asbestos Cement (Temptite)	
Return Water Piping	Steel	Transite
	Asbestos Cement (Transite)	
	PVC	
Downhole Pump/Flow and Pressure Control	Variable Speed Pump with Torque Converter	Fixed Speed Pump and Elevated Tanks
	Fixed Speed Pump/Tanks	
Tanks	Vented Cone Roof Tanks	Vented Tanks
	Floating Roof Tanks	
Heat Exchangers (if needed)	Shell and Tube Standard Designs	Plate Designs
	APV Paraflow Plate Designs	

Temptite was chosen in order to minimize heat losses from the supply pipe. The pipe buried depth of 3 feet with 1 foot spacing between pipe and walls was recommended by Johns-Manville Corporation. Approximate trenching/installation costs were obtained from Susanville's Public Works Director. The total installed cost is based on supply and return pipes in a common trench (Table C-2).

Table C-2
Piping System Costs
(Supply and Return Pipes in Common Trench)

Pipe Size Dia., In.	Transite $/Ft.	Temptite $/Ft.	Total Installed Cost $/Ft.
3	2.0	10	18.50
4	2.25	12	20.75
6	3.25	14	23.75
8	4.50	20	31.00
10	5.75	24	36.25
12	7.00	30	43.50

Trenching/Installation Cost = $6.50 per foot

The calculated pipe sizes and lengths necessary for the four well temperature assumptions are in Table C-3. The Phase A system requires 3.01 miles of trench. The total installed cost as a function of system flow rate presented in Figure C-2.

Table C-3
Geothermal Pipeline Parametrics

	Geothermal Temperature			
	150°F	165°F	185°F	225°F
Nominal Pipe Size	Length of Pipe - Miles			
3"	0.75	0.62	0.75	0.88
4"	0.13	0.06	0.13	--
6"	--	0.13	--	1.29
8"	1.29	--	1.29	0.84
10"	.84	1.37	0.84	--
12"	--	0.84	--	--
Total Transite	3.01	3.01	3.01	3.01
Total Temptite	3.01	3.01	3.01	3.01

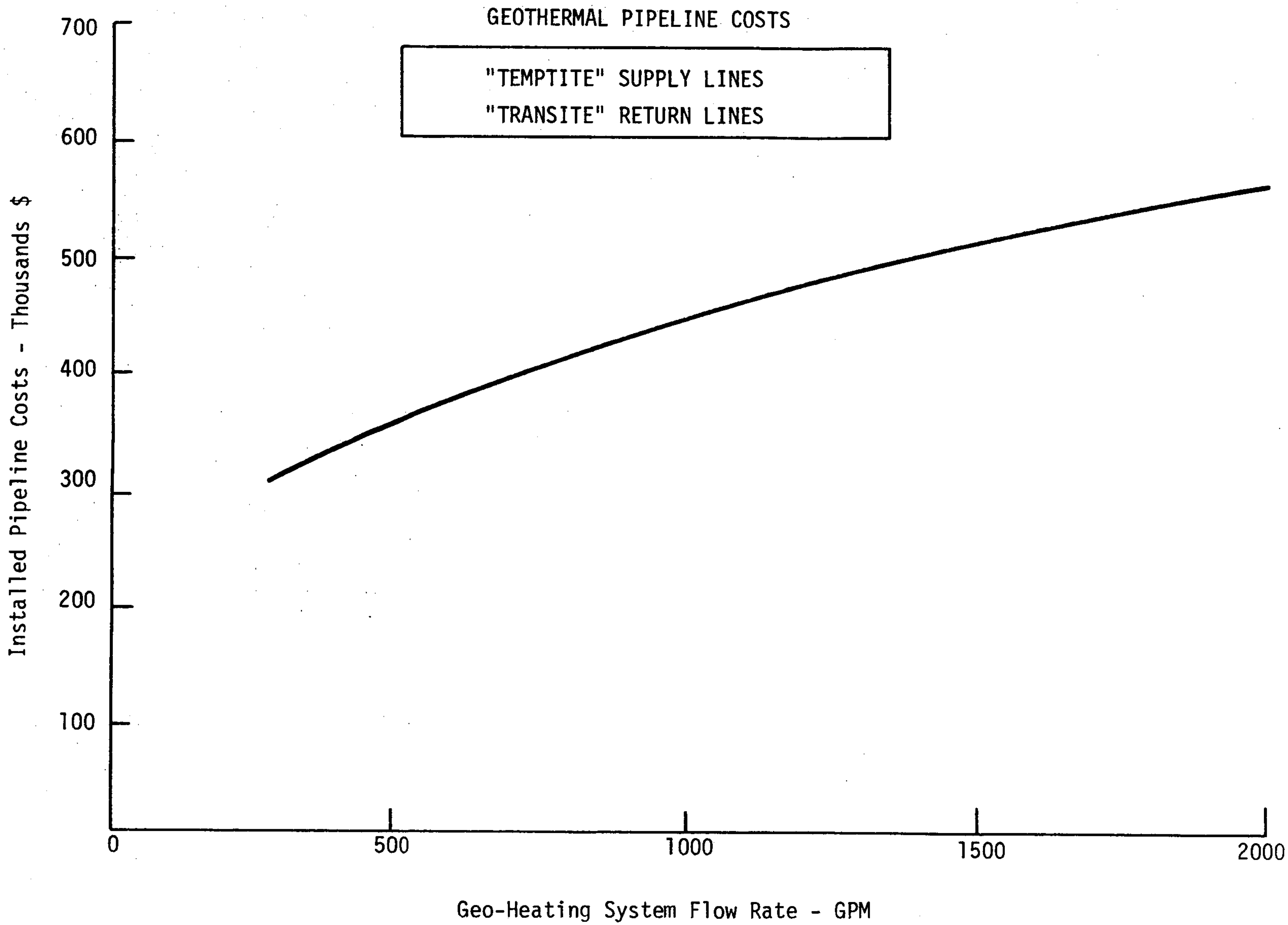


Figure C-2. Susanville Public Building System, Geothermal Pipeline Costs

The variable speed downhole pump is not needed with a tank fed system. The tank capacity selected was based on Iceland experience. A vented tank was selected because it is less costly than a pressurized tank. The tank does not require insulation. However, insulation or fencing around the tank might be considered as a safety measure. The APV paraflow plate heat exchanger design was selected based upon a design study comparing the cost of shell and tube and plate heat exchangers which showed the plate heat exchanger to be more economical

3. Balancing Load Utilization Between Summer and Winter

For the public buildings, the geothermal system utilization could be increased about 640 hours a year or about 30%, by using the geothermal water to drive absorption water chillers for air conditioning. Geothermal air conditioning would help to balance the load between summer and winter. Using the geothermal water for process heating in the Park of Commerce also helps to balance the load. The meat production and processing industry will use hot water for various slaughter and break operations and feed drying all year long.

The usefulness of the geothermal water for absorption air conditioning or refrigeration is dependent on the resource temperature. Commercial data on small absorption units which could be used on Susanville's system is used to show the relationship between geothermal temperature and unit output, temperature utilization, and capital cost per ton (Figure C-3).

As an example, a study was made of the economics of replacing 50 tons of old vapor compression A/C equipment at the hospital with either (1) hot water driven absorption water chillers, or (2) new vapor compression equipment. A comparison of absorption and vapor compression equipment capital and operating costs for this size load is shown in Table C-4.

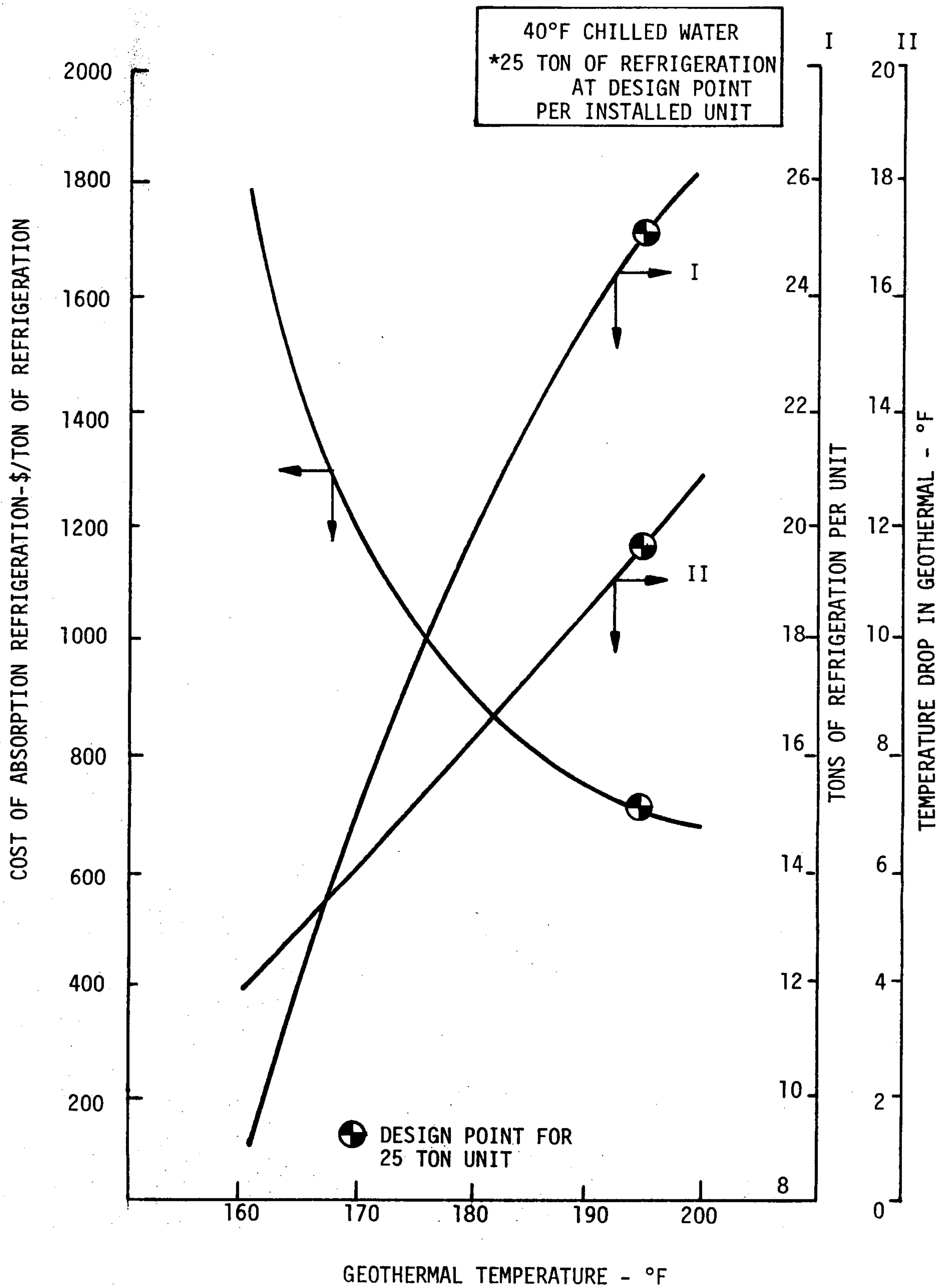


Figure C-3. H_2O/LiBr Absorption Refrigeration

Table C-4

A/C ALTERNATIVES FOR LASSEN MEMORIAL HOSPITAL

TOTAL A/C REQUIRED = 50 TONS
COOLING HOURS PER YEAR = 640 HRS

	HOT WATER ABSORPTION					VAPOR COMPRESSION COP = 3.6	
HOT WATER TEMP °F	COP	CAPITAL COST $	GEO-FLOW GPM	CONDENSER FLOW GPM	PUMPING POWER COST $	CAPITAL COST $	POWER COST $
160	0.58	97,500	520	520	926	19,500	1,300
185	0.72	40,000	183	183	325	19,500	1,300
200	0.73	34,000	129	129	230	19,500	1,300

At 160°F, the hot water pumping power cost would be about 70% of the compressor power cost, therefore, the return on the large incremental investment in capital equipment is very low. It is not until the geothermal temperature reaches 185°F that modest rates of return are achieved and that it would begin to pay to pump the water from the wells uphill to the hospital for use in air conditioning (Table C-5).

Table C-5

ROR for Selecting Absorption
Over Vapor Compression Equipment for A/C
For Lassen Memorial Hospital

°F Geothermal Temperature	Incremental Investment (Absorption-Compression)	Incremental Annual Operating Cost (Compression-Absorption)	ROR* %
160	78,000	374	1.0
185	20,500	975	8.0
200	24,500	1,070	12.0

*Assumes 7% electricity costs inflation rate.

In the Park of Commerce refrigeration and air conditioning are needed in both the greenhouse and the integrated meat production industries. Table C-6 presents the impact of the geothermal temperature on the utilization of the resource for refrigeration or air conditioning. Again, in general, 185°F or greater resource temperature can be used to produce chilled water at 40°F for refrigeration or air conditioning. The 225°F temperature resource is marginal for use in producing evaporator temperatures in the 0 to 10°F range.

4. Conversion to Geothermal (Retrofit)

There are two general options available for retrofitting an existing building's hot water heating system to geothermal. The first is to simply add a countercurrent plate heat exchanger to the heating water loop such that the geothermal water heats the recirculating water to within 5 to 10°F of the geothermal water temperature. In this system, the geothermal water is never mixed with the circulated water, therefore, material compatibility and scaling problems, if any, are isolated in this heat exchanger. For geothermal temperatures greater than 165°F, this approach will normally be preferred.

With 150°F or lower temperature, the 10°F loss in the water temperature becomes more significant, and it becomes more desirable to use the geothermal directly in the heating coils. At these resource temperatures, the questions regarding coil corrosion, erosion, and scaling become important to the design.

Most buildings with hot water heating systems contain copper coils. Some evidence has been accumulated in Klamath Falls, Oregon, which shows that geothermal water, even with low TDS, can shorten the life of the copper coils to about 12 years. Coil life would normally be 20 to 25 years or greater in a normal closed hot water system. In this particular situation at the Oregon Institute of Technology in Klamath Falls, Oregon, the four copper coils which failed did so at the connection between the black iron headers and the copper tubes. The tubes failed at this joint due to a thinning of the tube wall. The failure can be attributed to two effects. First, a continuous metal union between these

Table C-6

Impact of Geothermal Temperature On Utilization in Park of Commerce

RESOURCE TEMP.	GREENHOUSE OPERATION		INTEGRATED MEAT PRODUCTION				
	SPACE HEATING	REFRIGERATION	SPACE HEATING	PROCESS HOT WATER	AIR CONDITIONING	REFRIGERATION	
°F	T_R = 65-80°F	T = 40°F	T = 68-90°F	T = 120-180°F	T = 50-65°F	T = 0-10°F	T = 40°F
150	Yes *Can be used directly (350gpm/5 acres)	No *Cannot be used (temp too low)	Yes *Can be used directly or in cascade- (115°F min. temp)	Yes/No *Can be used directly for 75% of dryer load *Cannot be used for slaughter hot water load (180°F)	No *Cannot be used (temp too low)	No *Cannot be Used (temp too low)	No *Cannot be used (temp too low)
165	Yes *Can be used directly (350 gpm/5 acres)	Marginal *Can be used at a high cost per ton	Yes *Can be used directly or in cascade	Yes/No *Can be used directly for 75% of dryer load *Cannot be used for slaughter hot water load	Marginal *Can be used at a high cost per ton	No *Cannot be used (temp too low)	Marginal *Can be used at a high cost per ton
185	Yes *Directly or cascade	Yes *Can be used at top of cascade	Yes *Directly or cascade	Yes Can be used at top of cascade	Yes *Can be used at top of cascade	No *Cannot be used (temp too low)	Yes *Can be used at top of cascade
225	Yes Used at bottom of cascade	Yes *Can be used at top or middle of cascade	Yes *Used at bottom of cascade	Yes Used at top or middle of cascade	Yes Used at top or middle of cascade	Marginal *Can be used with NH_3/H_2O absorption units at high capital cost	Yes *Can be used at top or middle of cascade

dissimilar metals creates a galvanic cell in which the copper is the sacrificial metal. The galvanic cell activity is increased due to the elevated temperature and a higher water TDS. Secondly, thermal expansion of dissimilar metals could stretch the tubes. In general, at these moderate temperatures and TDS, the geothermal water can have the following adverse scaling and/or corrosion effects (Reference 9):

(a) Chloride Ion Impact, Cl^-

Chloride ions form complex ions which increase the corrosiveness of the water. The chloride ions can cause a breakdown in protective oxide films. The combination of high chloride and acidity can cause corrosion pits.

(b) Carbon Dioxide, CO_2, Bicarbonate, HCO_3^-, Carbonate, $CO_3^=$

These ions and CO_2 are in an equilibrium which is strongly dependent on temperature. CO_2 causes corrosion of most structural metals. Of greater importance is the strong influence that carbon dioxide has on the solubility of calcium carbonate. Calcium carbonate solubility increases with the concentration of carbon dioxide. This has two effects. The absence of a protective calcium carbonate scale may result in increased corrosion. However, the absence of this scale improves heat transfer and pumping efficiencies. Where possible, calcium carbonate scales should be avoided.

(c) Dissolved Oxygen, O_2

The impact of dissolved oxygen is greater than that of CO_2. The solubility of oxygen in water decreases with increasing equilibrium temperature. Therefore, the O_2 content in the supply tank will be low, less than 7.0 ppm. Dissolved O_2 attacks carbon steel, oxidizing the iron.

(d) Sulfide Ion, $S^{=}$

The sulfide ion is found in geothermal water as Hydrogen Sulfide, H_2S. However, at Susanville, very little (if any) sulfide is present. Iron, copper, and nickel tend to react with dissolved sulfides in geothermal fluids to form sulfide scales, though iron is less reactive than copper or nickel. Alloys containing both copper and nickel are particularly susceptible to attack by dissolved sulfides.

(e) Calcium, Ca^{++}

Corrosion of most structural materials is not influenced by the presence of dissolved calcium. Calcium carbonate scales, on the other hand, tend to reduce corrosion rates by forming a barrier between the substrate metal and the geothermal fluid, but are undesirable from a heat transfer standpoint.

(f) Magnesium, Mg^{++}

The formation of magnesium silicates tends to protect the metal from corrosion by forming a barrier between the metal and the geothermal fluid. The magnesium silicates scales are difficult to remove from heating coils, however, and should be avoided where possible.

(g) Sodium, Na^{+}, and Potassium, K^{+}

Except for their effects on the electrical conductivity of the geothermal fluid, these alkali metal ions do not contribute to either corrosion or scaling.

(h) Silica, $SiO_2^{=}$

Silica in solution tends to retard corrosion and the scales form protective barriers. However, the scales decrease heat transfer and should be avoided.

Erosion can be caused by the suspended solids in the water. The main supply tank should settle out most of these solids in the Susanville system.

The heating coils in the Susanville public building system should be carefully checked to see if unprotected unions between galvanized iron and copper have been used. If present, they should be replaced with protected unions, and coils with iron headers should be replaced with heating coils which are all aluminum.

5. Environmental Considerations

The environmental effects are primarily associated with the resource development - the drilling, extraction, and disposal of the geothermal water (discussed in Section A-2). In addition, care has been taken to route the pipelines so as to have minimal impact during construction on normal City traffic on the major streets. In general, the pipeline will be located in easements along streets without sidewalks. Only in a two block area around Main and Lassen Streets will the line have to be located in the main pavement area.

The Park of Commerce will be located in an existing agricultural/ industrial zone of the city, an area well suited for growth. Greenhousing already exists here. The integrated meat processing plant will be a totally contained and controlled industry so that the usual odor problems associated with livestock production and processing will be avoided.

6. Impact of Resource Temperature on Design

The resource temperature has a major impact on the design. At temperatures down to 165°F, two options are possible that are not available at lower temperatures. First, the building heating water loop can be economically isolated from the geothermal by the use of plate heat exchanges. Second, the geothermal water can be used to heat the service hot water. Service hot water is usually specified as heated to 140°F (Reference 3). About 10% of the energy consumption of the public buildings is for service hot water.

The cost of the geothermal system is strongly dependent on the geothermal flow rate. The lower the temperature, the higher the flow rate required. Higher flow means more wells, larger pipes, larger tanks, larger pumps in general, larger and more costly equipment. Flow rate is directly dependent on the "allowable" temperature drop in the geothermal wherever it is used. Therefore, in a concurrent plate heat exchanger, the required geothermal flow rate at a given heat load is determined from the (1) return hot water temperature from building plus a 10°F approach, and (2) the inlet geothermal temperature. Since the air side controls in building heating coils, the return hot water temperature will stay about constant for any given building. Therefore, geothermal flow rate will increase rapidly with decreasing geothermal temperature.

Most large service water heaters for public buildings in Susanville are of the indirect type. Steam or hot water is used to heat the service hot water by means of an external or internal heat exchanger. The geothermal flow is directly proportional to the difference between the geothermal temperature and the return water temperature of 110°F plus 10°F, or 120°F for an external counter flow heat exchanger. For the internal type, the flow rate is proportional to the difference between the geothermal temperature and the service hot water temperature plus 10°F, or 150°F.

The heat load that can be obtained from a building terminal heating unit, such as a heating coil, decreases rapidly with the hot water temperature entering the coil but is much less sensitive to the hot water flow rate (Figure C-4). With 165°F water, 70 to 80% of the heat load could be obtained from the coils depending on the entering air temperature (EAT). At 150°F, this drops to 50 to 70%. At 140°F, it is 40 to 65%. Using 50% as a practical limit, geothermal water at 150°F would be used directly in the coils instead of heat exchanging with the hot water loop.

The air side thermal resistance of the heating coils controls the rate of heat transfer that can be obtained with a fixed size coil. The air flow is also normally operated at a constant flow rate in a given system. Therefore, beyond a certain water flow rate, the heat output from a coil is insensitive to an increase flow. To demonstrate this effect, the heat output versus water side

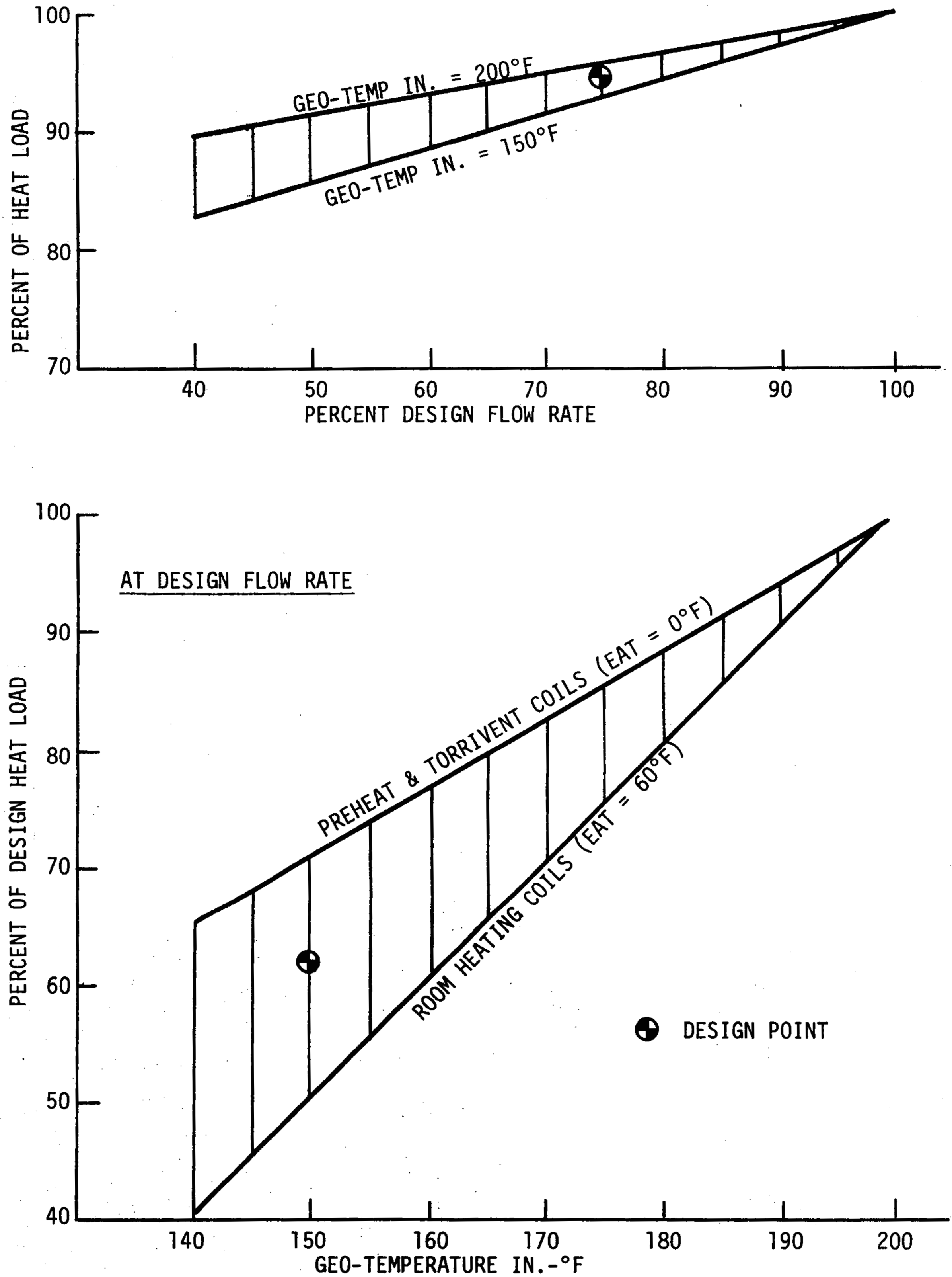


Figure C-4. Impact of Geothermal Temperature and Flow Rate on Heating Coil Output flow rate was calculated for an "averaged" fan coil for the high school (Figure C-5). This "averaged" coil represents the overall BTU per hour per °F that can be obtained for all the coils in the high school. Above about 300 to 400 gpm, increasing the water side flow has little effect on total heat output.

Taking into account these factors which are sensitive to geothermal temperature, the Public Building System design flow rates versus temperature were calculated (Table C-7).

Table C-7
Parametric Public Building System Design

Design Parameter	Geothermal Temperature 150°F	165°F	185°F	225°F
Peak Flow Rate, GPM	1,044	1,780	1,080	600
Maximum System Pressure, psig	110	115	108	105
Minimum Building Supply Pressure, psig	60	65.8	60.5	50.8
Minimum Building Supply Temperature, "F	146	161	180	218
Downhole Pump Motor, HP	175	292	175	92

These flows were used to size and cost the system parametrically. The drop in system flow rate at the 150°F design point reflects two major changes in the system design. As stated before, at 150°F, the geothermal water is used directly in the building terminal heating units and it is not used to heat the service hot water. Therefore, a lower percentage of the total heat load is provided by the 150°F water.

The Park of Commerce design was only investigated at the 150°F design point, the most probable geothermal production temperature.

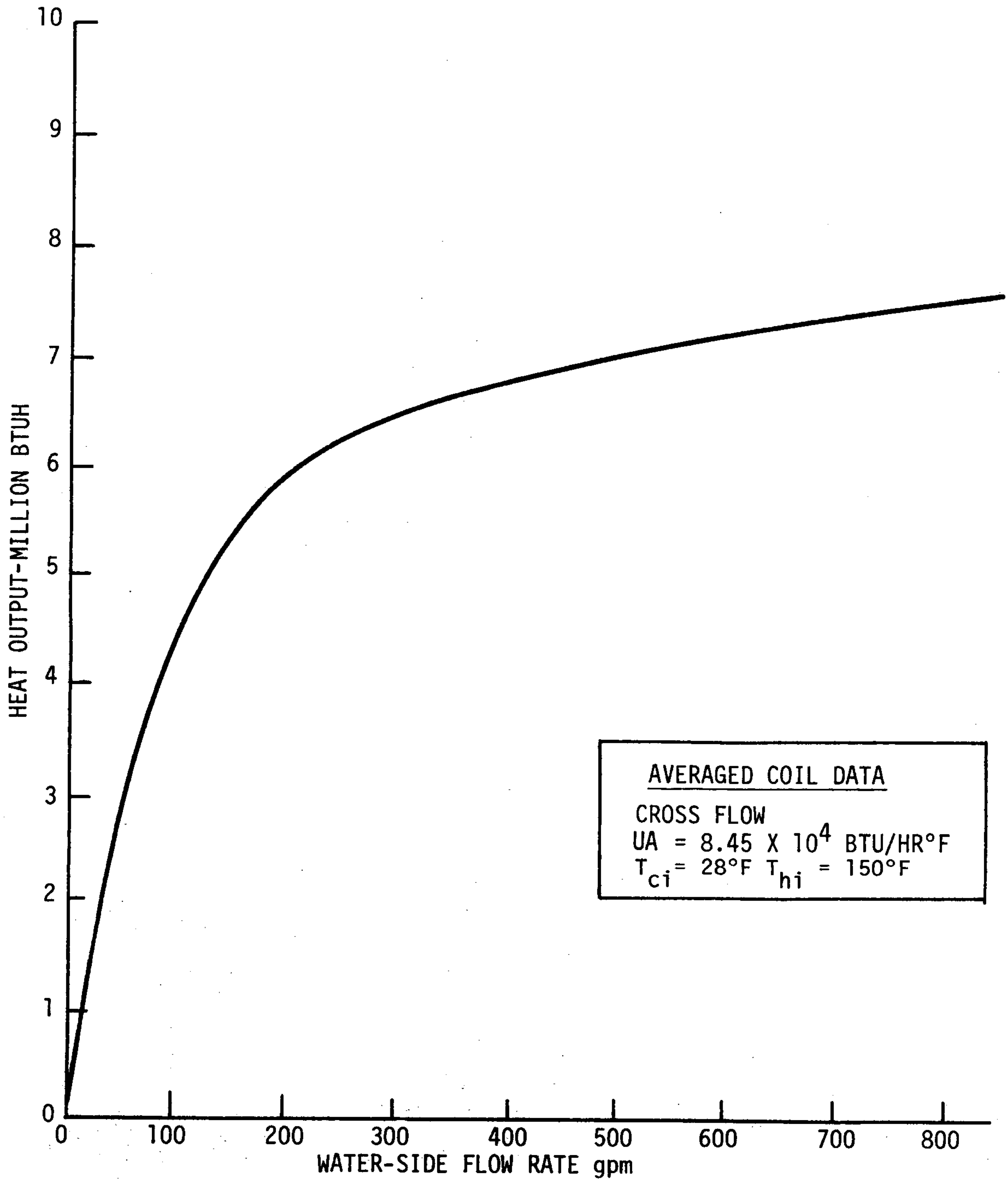


Figure C-5. Heat Output for Lassen Union High School Averaged Fan Coils

7. Use of Heat Pump to Replace Boilers

A heat pump is basically an electrically powered Rankine cycle machine which can, under certain conditions, compete with fossil-fueled hot water heaters (boilers). The competition is an economic one. The higher initial (capital) cost of the heat pump is paid back in a short time by the lower annual operating cost of the heat pump, provided there is a cheap supply of low to moderate temperature water. The water is the source of heat to the evaporator which, when added to by the compressor work, produces the required heat load in the condenser.

Hot water heaters (boilers) and heat pumps were compared at a 6 million BTUH heat load on the basis of the average annual cost. The annual cost is the sum of the annual operating cost plus the capital recovery cost for the equipment over its life. The assumption is that the equipment with the lowest annual cost is best.

The selection between alternatives is dependent on (1) the annual operating hours for the equipment, (2) the performance of the heat pump - COP, and (3) the value of capital - ROR (Figures C-6 and C-7). For public projects with low interest rates, the heat pump would be selected in most cases with 150°F temperature source and 185°F output to the load. For higher values of capital (30%), the selection is more sensitive to projected utilization and heat pump performance.

8. Approaches to Integrating the Heat Pump Into the Building System

Initial studies of the geothermal reservoir at Susanville estimated a possible temperature range from 150°F to 240°F, with the lower temperature being more likely to occur. Therefore, it was decided to investigate integrating the heat pump into the geothermal heating district using two different resource temperature ranges, moderate (185°F) and low (150°F).

The reasons for using the heat pump were to (1) try to decrease the overall flow rate, thus saving the associated capital costs of more wells, reduce pipe, tank, and pump size and cost, and (2) to reduce the dependence on fossil fuel.

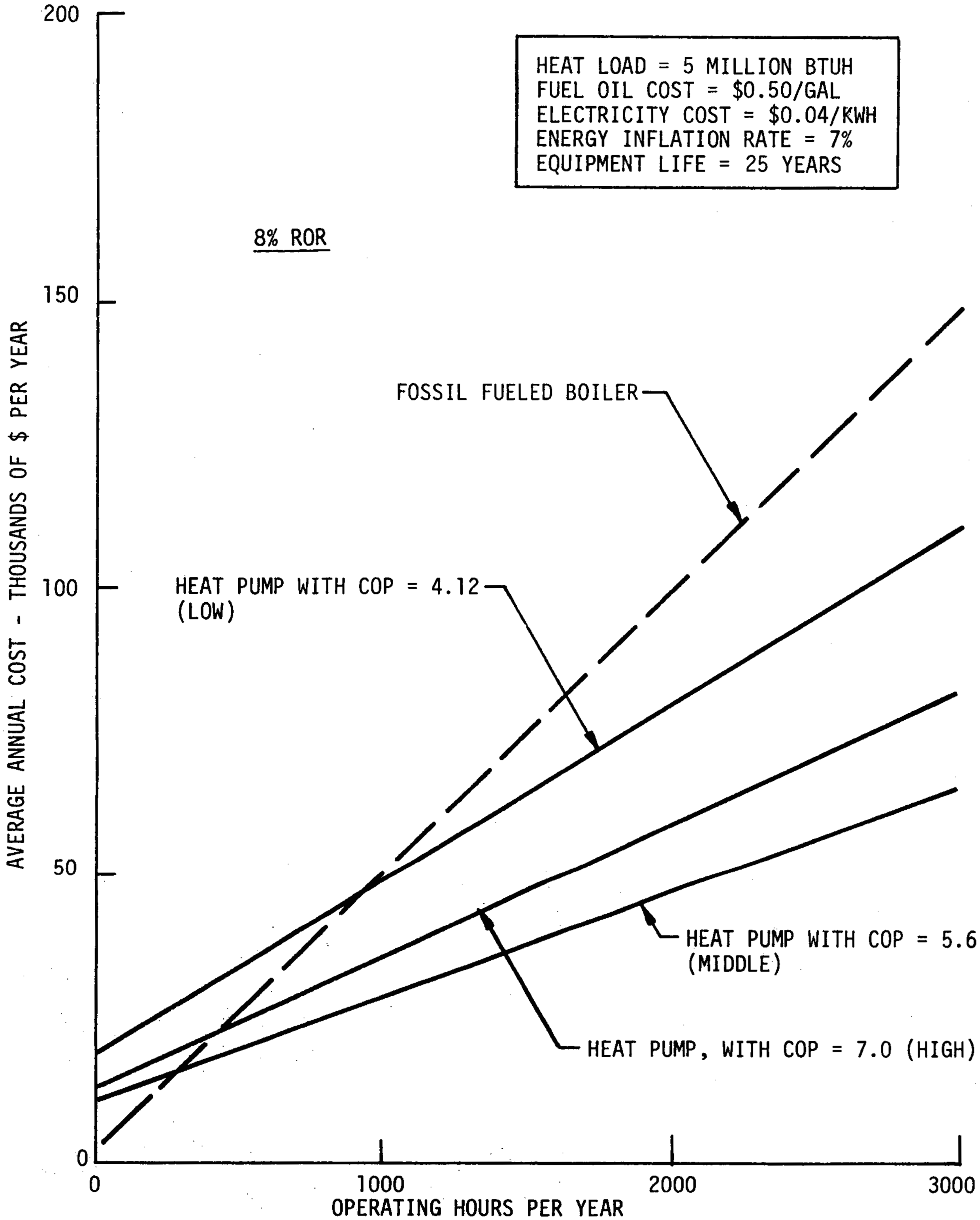


Figure C-6. Comparison of Annual Cost of Fossil Fueled Boiler and Heat Pump for 8% Rate of Return

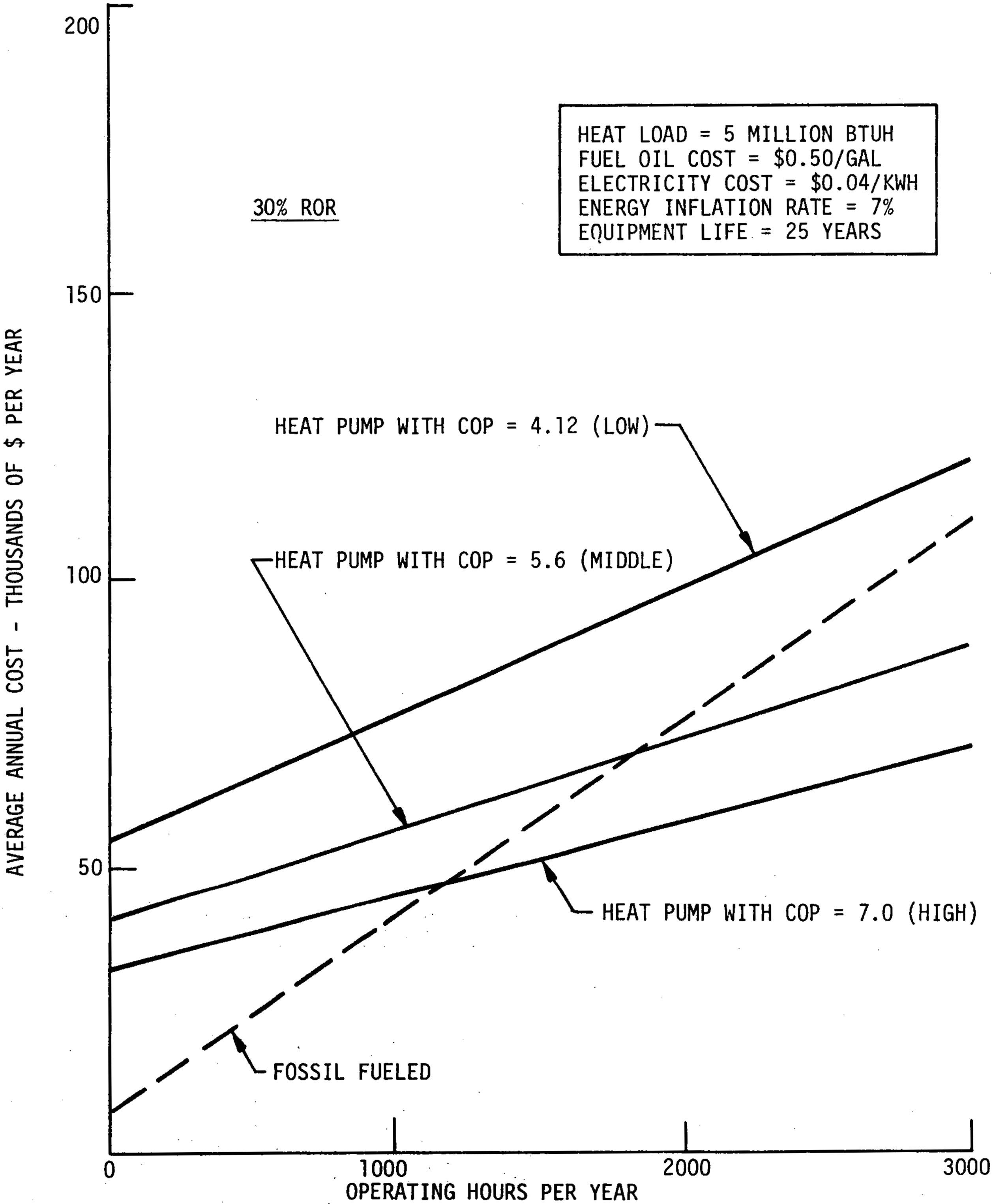


Figure C-7. Comparison at Annual Cost at Fossil Fueled Boilers and Heat Pumps for 30% Rate of Return

At 185°F, the plate heat exchanger can be used to isolate the heating system from the geothermal water. A 35°F temperature drop is taken across the geothermal side of the plate heat exchanger. The 150°F water leaving the plate heat exchanger enters the heat pump evaporator. When the heat pump is turned on, the geothermal temperature is further lowered to 125°F. On the heating loop-side of the plate heat exchanger, the temperature of the heating loop-water is raised from 145°F to 165°F. The 165°F water enters the heat pump condensers where its temperature is raised further to 185°F. The 185°F water then enters the building heating system and emerges at a temperature of 145°F. In some cases, the geothermal water may be incompatible with the copper fan coils and the fossil fuel boilers. For buildings designed to be heated with geothermal water directly, and for buildings to be completely retrofitted with new fan coils, the 185°F could be used directly. For buildings in which oil-fired peaking was to be retained, the use of heat pumps to replace the boilers load was investigated. A schematic of such an arrangement is shown in Figure C-8.

For the 185°F temperature, geothermal could be used to displace such a large percentage of the yearly heat load that the use of the heat pump was not economical. The economics would favor putting in a larger plate heat exchanger and raising the heat looping outlet temperature to within a 5°F approach to the geothermal temperature (180°F) instead. The capital cost of the system and annual operating cost were found to favor a direct heating system, even when all buildings conversion costs were considered.

For a 150°F resource temperature, several alternative heat pump schemes were examined. First, a centrally located heat pump which would peak the entire public building system with 185°F water in colder weather was investigated. Figure C-9 is a schematic diagram of such a system. With this system, under conditions of relatively mild weather, 150°F water would bypass the central heat pump plant and would be used directly to heat the buildings.

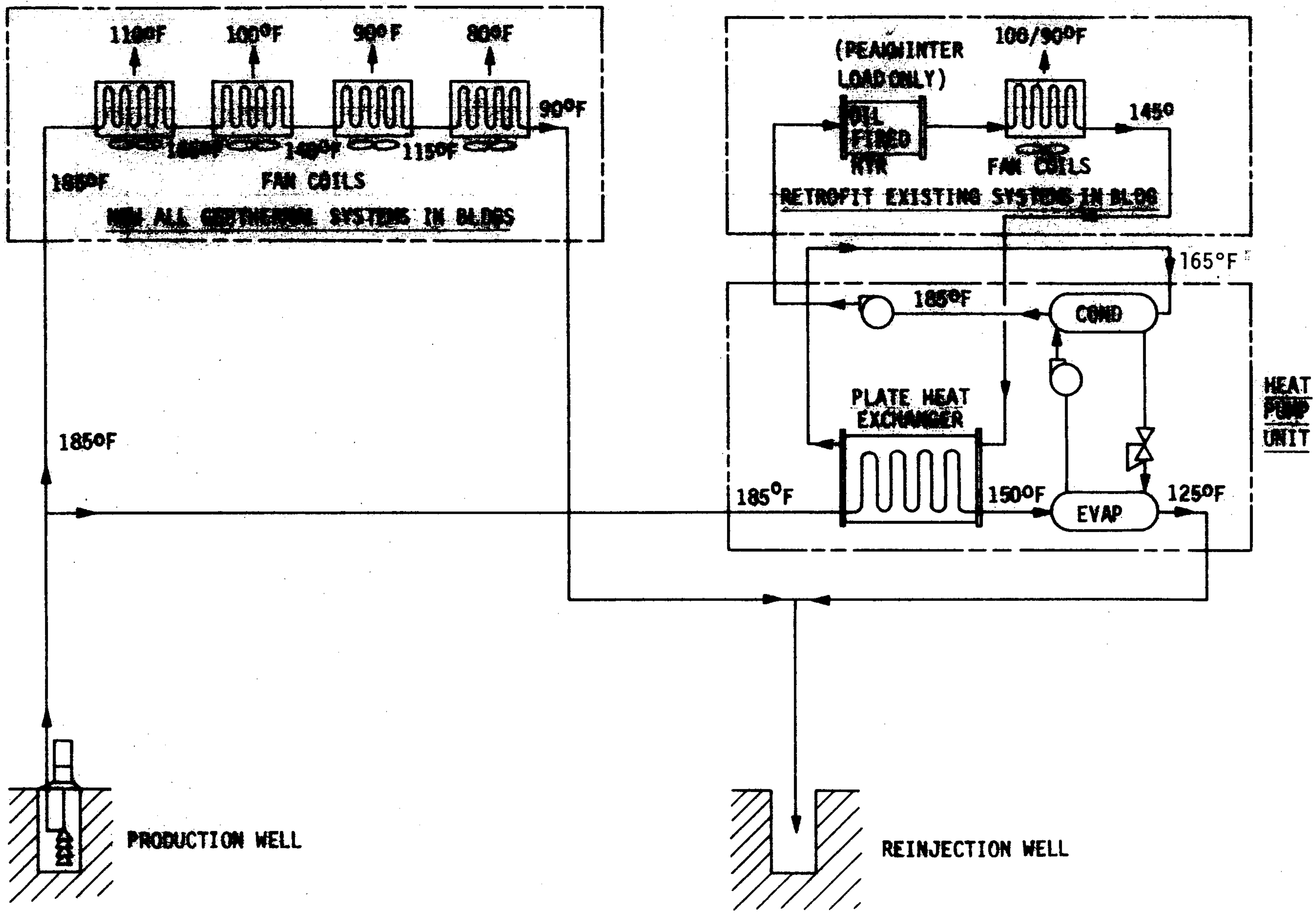


Figure C-8. Integration of Heat Pump Into a Building with 185°F Geothermal Water

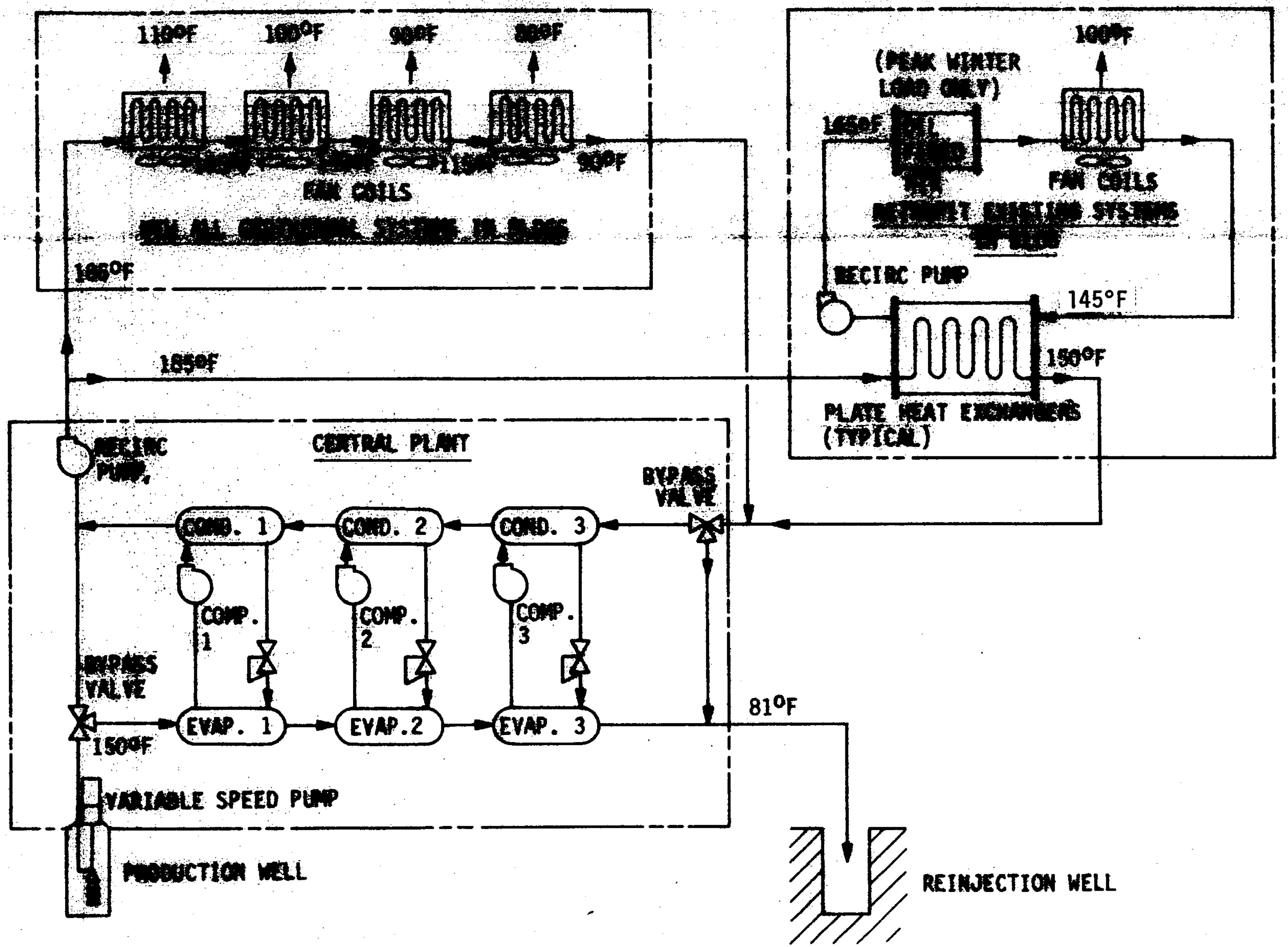


Figure C-9. Central Heat Pump Plant for 150°F Geothermal Water

The heat pumps would be off. At some predetermined outside temperature, the 150°F geothermal water would bypass the Public Building Energy system and be sent directly through the heat pump evaporator(s).

Heat pumps in series were found to have a higher overall coefficient of performance (COPH) than a single, larger heat pump. Therefore, for this central plant, a minimum of three heat pump modules would be installed in series. These heat pumps could be operated sequentially. First, a single heat pump would be operated, with progressively more heat pumps being turned on as the heating demand increased. The water being circulated in the public building energy system would then consist of whatever geothermal water was in the piping system when the bypass valves were switched. This water would be about 140°F after mixing of the discharges from all the buildings. It would enter the heat pump condenser(s) and have the temperature amplified. With all three heat pumps operating, the temperature of the water out of the condenser would be 185°F.

This heat pump central plant would have to be sized for the peak hourly heat load in order to displace all the fossil fuel in the system. This would require three 6,500,000 BTUH machines in series, at an installed cost of around $390,000. Insulated return lines would have to be considered for this system, since it is a recirculation system. This sytem has good potential when applied to a compact project where the reservoir and the buildings are located very close to each other. For the Susanville Public Building Energy System, no economic advantage could be shown.

For the 150°F resource temperature, initial system economic studies favored a centrally located heat pump for a large heat user with high building conversion costs. Lassen Union High School fits this description.

At Lassen Union High School, as an example, three approaches were studied for the integration of the heat pump into the system. Option I (Figure C-10) has the heat pump in parallel with the loads. The heat pump

OPTION I

Q_{TOTAL} = 6,540,000 BTUH

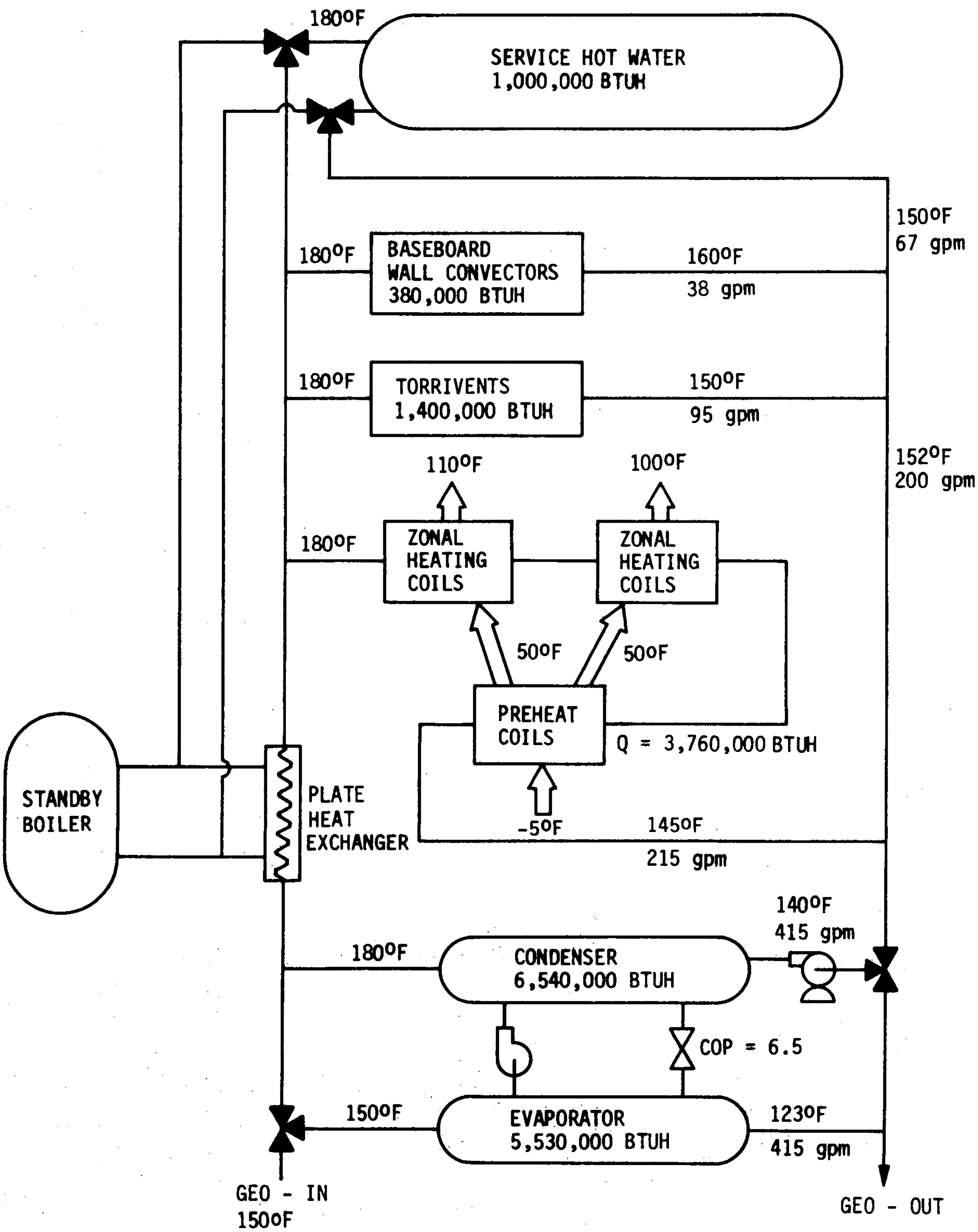


Figure C-10. Lassen Union High School Geothermal Heat Pump System - Option I would be sized to handle the total high school load. The geothermal water would flow directly through the system, providing about 50% of the design heat load (BTUH). On colder days, the geothermal flow would be diverted to the evaporator and the building water would be recirculated through the condenser. The heat pump could be throttled to provide variable output from 50% to 100% of design. The advantages of operating at part load are that less geothermal flow is required in the evaporator and the heat pump uses less power (Section C-10). No new heating coils are required with this option. The service hot water can be supplied by the boiler or the heat pump when it is running.

Option II (Figure C-11) has the heat pump condenser and evaporator in series with the loads. When the heat pump is first turned on with this arrangement, the inlet temperature to the evaporator would be 130°F, as opposed to 150°F for Option I. Therefore, the evaporator leaving temperature and refrigerant evaporator temperature would be lower than for Option I, at part load. This produces a lower COP and, therefore, more electric power is needed to produce the output load (Appendix C). This arrangement has the disadvantage of requiring more electrical power to provide the total augmented energy requirements over the heating season.

Since this is a flow-through system, recirculation pumping power is not needed except when using the standby boiler. Therefore, this arrangement has the advantage of normally not requiring electrical power for recirculation. The service hot water energy would be provided by the steam boiler when the heat pump is not operating.

When the heat pump is operating at full load, the performance will be about the same as for Option I (COP = 6.5) because the discharge temperature from the terminal heating units will be close to 150°F, and the system flow rate will be the same. However, the heat pump would only operate at this deisgn point a few days out of the year.

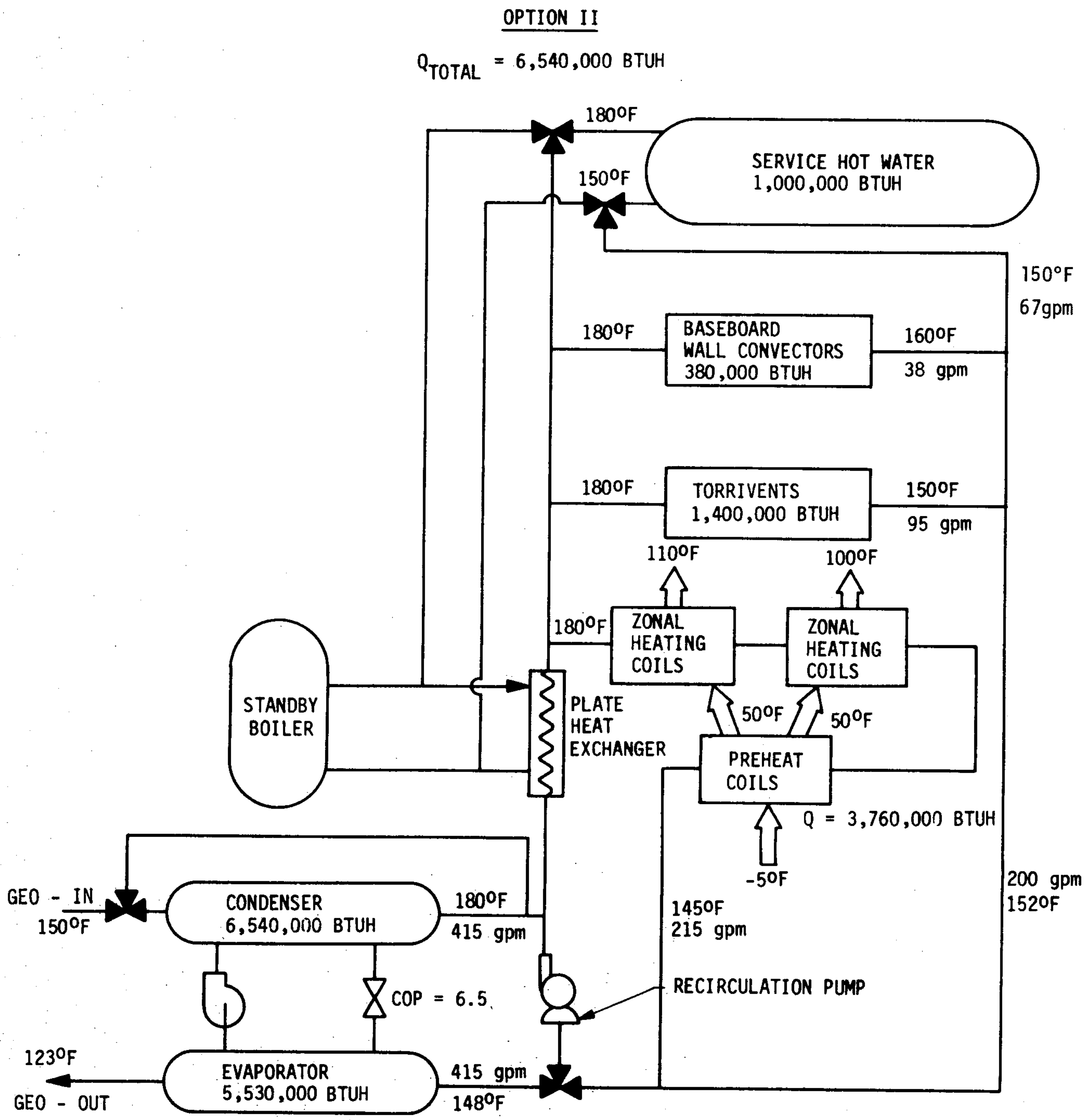


Figure C-11. Lassen Union High School Geothermal Heat Pump System - Option II

The third option (Figure C-12) would use the heat pump as a cascade to the heating energy obtained from the flow-through of the 150°F geothermal water. In this system, a geothermal flow of up to 245 gpm would be used directly in the existing building coils whenever heating is required. In addition, a smaller heat pump (4,000,000 BTUH) would be available for augmentation. This heat pump would have its own set of coils and an independent recirculation system. The added building heat required on colder days would be obtained from heat supplied by the heat pump to additional coil surface area at higher hot water inlet temperatures.

This heat pump could be operated from 20 to 100% of its design load (800,000 to 4,000,000 BTUH) using a variable geothermal flow rate. However, to obtain the same high performance at design (COP = 6.5), the overall geothermal flow would have to be higher than for Options I or II, 513 gpm versus 415 gpm. The heat pump would operate with a constant 150°F temperature input to the evaporator.

The disadvantages of this system are that new heating coils must be added to the buildings and recirculation lines must be added for these new coils from the condenser to and from each building. For a retrofit system, these disadvantages outweigh the operating cost advantage. For a new, single, large building, this sytem might be the preferred arrangement. The service hot water would be heated by boiler steam whenever the heat pump was off, or operating at too low a temperature.

For the retrofit of Lassen Union High School, Option I is the preferred system because it will have the lowest operating cost, it is the easiest to control, and it is the easiest and least costly to install. This arrangement was the one selected for the final design point presented in Section B.

Although Lassen Union High School was studied in the most detail, other buildings, the County Court House in particular, are amenable to installation of a heat pump.

9. <u>Maximizing Heat Pump Performance</u>

- Determination of Optimum Cycle

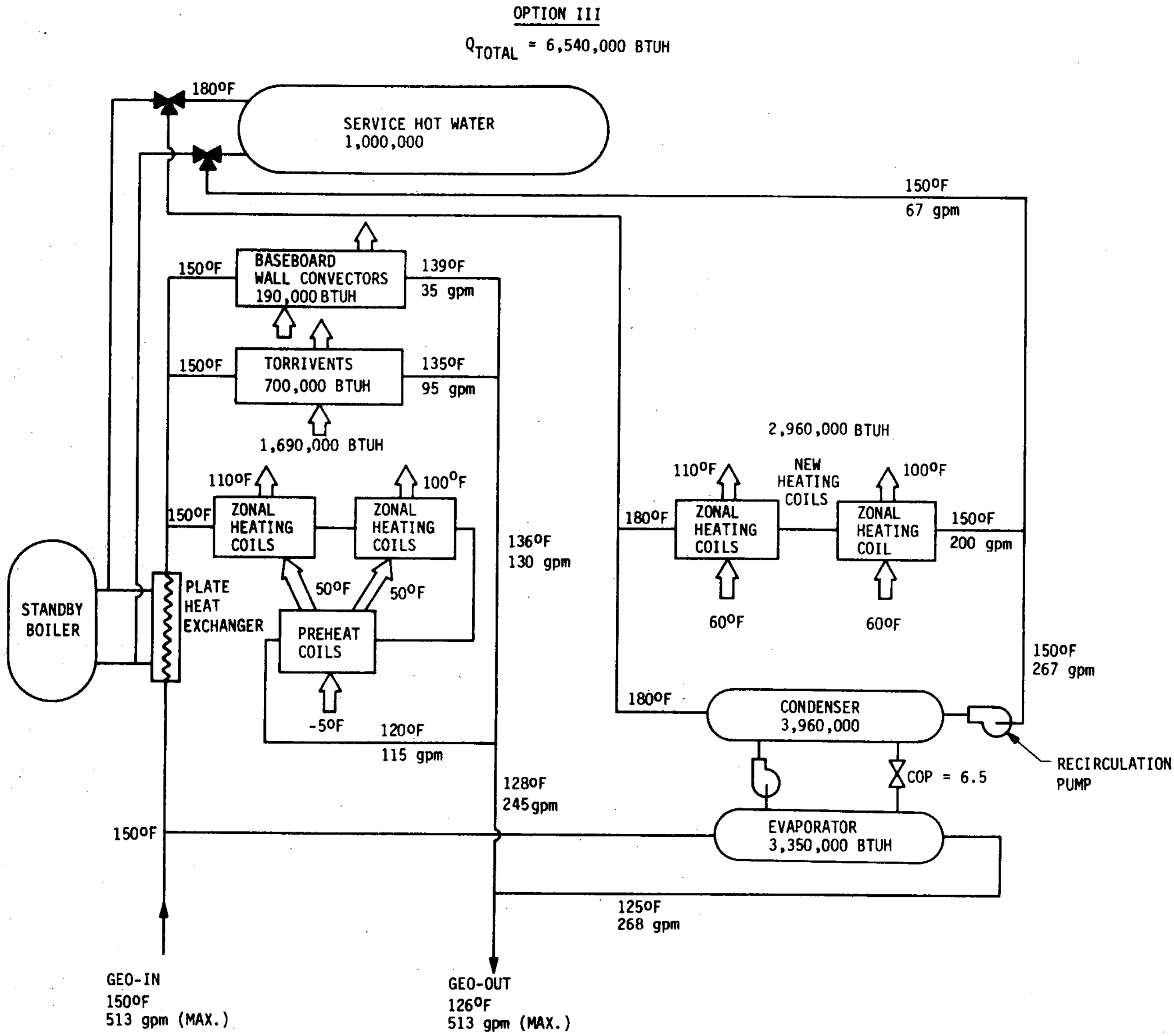


Figure C-12. Lassen Union High School Geothermal Heat Pump System - Option III

The Rankine cycle using the refrigerant R-114 is the basic cycle chosen for the heat pump. Vapor refrigerant leaving the evaporator is compressed and has its temperature and pressure increased. Upon leaving the compressor, the vapor is condensed and heat is extracted in a heat exchanger. This heat is what is provided to the load. Upon leaving the condenser, the now liquid refrigerant is expanded and has its temperature and pressure lowered, becoming a two-phase liquid and vapor mixture. This mixture is vaporized in the evaporator, removing heat from the geothermal fluid. The refrigerant is now ready to begin the cycle again, in the compressor. The heat removed in the condenser plus the heat added by compressing the refrigerant is the heat provided to the load. Appendix C provides a more detailed technical discussion of the basic heat pump cycle and its' operation.

The overall coefficient of performance is a measure of the heat pump performance. It is defined as the ratio of the heat extracted from the condenser to the electric power required to operate the machine. The maximum theoretical heat that can be transferred from the geothermal resource to the load is called the "Carnot coefficient of performance" and is defined as the ratio of the condenser temperature to the difference between the condenser and evaporator temperature. The actual COP is always less than the Carnot COP.

If the COP can be increased, less electricity is used and more heat can be transferred to the load. Subcooling the refrigerant out of the condenser adds additional heat to the load. Staging the machine reduces the losses associated with the fact that no work is recovered in the expansion process. Intercooling also helps reduce losses caused by no work recovery in the expansion process and helps superheat the vapor leaving the compressor, adding more heat to the load. Investigation of all three methods of increasing the COP shows that a single stage machine with intercooling and subcooling substantially increases the heat pump performance. Appendix C provides a more detailed discussion of the heat pump cycle optimization.

- 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 having 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 (Reference 10). Available energy, which is the maximum useful work transport associated with energy and the surroundings, is an equivalent measure regardless of the qualities 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 (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 surrounds, 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, when 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 resource to be evaluated, whereas first law efficiencies do not (Reference 11).

An analysis based on the above idea shows that the optimum evaporator leaving temperature is 125°F for a geothermal resource temperature of 150°F, when providing hot water at 185°F. Appendix C gives the detailed results of the analysis.

10. 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.

The following design point was specified for the manufacturers (1) R-114 as the refrigerant, (2) condenser heat lead of 500 tons (6 x 10^6 BTU/Hr), (3) condenser inlet temperature of 150°F, (4) condenser leaving temperature of 185°F, and (5) evaporator inlet temperature of 150°F. The evaporator leaving temperature was specified to be 125°F based on thermodynamic considerations. In addition, the manufacturers were requested to investigate using two or more heat pumps arranged serially.

Table C-8 lists the manufacturers contacted. These are the major U. S. heat pump manufacturers. No foreign heat pump manufacturers were contacted. At this time, foreign heat pump availability is unknown.

Trane Co., General Electric and Dunham-Bush responded negatively. Both Trane Co. and Dunham-Bush stated that they do not manufacture heat pumps in the 500 ton category in our temprature range. General Electric responded that they make only reciprocating machines which will not work with R-114.

Table C-9 lists those manufacturers who responded with the desired information. The Westinghouse Templifier has the highest Coefficient of Performance of the three listed, and the lowest budget cost. York's heat pump has the lowest COP and the highest budget cost. Carrier's heat pump has a COP similar to that of York's, but a significantly lower budget cost than that of York. However, Carrier's budget cost is still about a factor of 1.8 greater than that of Westinghouse.

Westinghouse and Carrier also provided some off-design performance data. The overall Coefficient of Performance versus condenser leaving water temperature for the Westinghouse Templifier is presented in Figure C-13. Even at 50% load, the overall COP is still 6.0. Also shown is the required compresser motor power for both Westinghouse and Carrier as a function of condenser leaving temperature. Both curves decrease at about the same rate, although the CArrier machine requires 22% more power at design and 40% more power at 50% load. The relationships of condenser leaving temperature to condenser output load and evaporator (geothermal) flow rate are presented in Figure C-14.

11. Integrated Geothermal Project - Public and Private

A unique aspect of the Susanville Geothermal Energy System is the simultaneous development of the heating system for the public buildings and a private Park of Commerce to increase the utilization of the geothermal water. The City of Susanville would develop and own the central geothermal utility plant which would provide 300°F steam, 200°F hot water, and 150°F hot water to the industrial and agricultural users under a pricing structure which would pay back the loan, cover all operating costs, and insure that the geothermal energy costs would always be significantly less than equivalent fossil energy costs. Also, the rate of inflation of geothermal energy costs would be controlled and kept much lower than the uncontrolled fossil energy costs.

The Park of Commerce was defined and then designed only for one resource temperature - 150°F. The overall integrated design has been discussed in Section B. The design studies that went into designing the central plant for the Park of Commerce are described in Appendix B. These studies include determination of the buildings' heating and cooling loads, determining the process heating and cooling loads and load distribution, designing the energy cascade for each industry to minimize the geothermal flow rate required, and sizing and costing an all-fossil-fueled central plant to compare with the geothermal plant.

C, 11, Integrated Geothermal Project - Public and Private (cont.)

U. S. Commercial Heat Pump Manufacturers

Table C-8

Commercial Heat Pump Manufacturers Contacted

Manufacturer	Date Contacted
1. Trane Company	9 May 1978
2. Carrier Corporation	10 May 1978
3. Dunham-Bush Corporation	10 May 1978
4. General Electric Corporation	10 May 1978
5. York Division, Borg-Warner Corporation	11 May 1978
6. Westinghouse Corporation	15 May 1978

Table C-9

Responses from Commercial Heat Pump Manufacturers

Manufacturer	Response
Westinghouse Corporation	Model TPE-079 Templifier System COP-6.1 Power Requirement - 286 KWI Evaporates Flow Rate - 400 gpm Condenser Flow Rate - 350 gpm Budget Cost - $86,000.
Carrier Corporation	Model 17FA Single Piece System COP-5.2 Power Requirement - 350 KWI Evaporates Flow Rate - 400 gpm Condenser Flow Rate - 350 gpm Budget Cost - $155,000.
York Division Borg-Warner Corporation	Model M225B System COP-5.1 Power Requirement - 380 KWI Evaporates Flow Rate - 400 gpm Condenser Flow Rate - 350 gpm Budget Cost - $200,000.

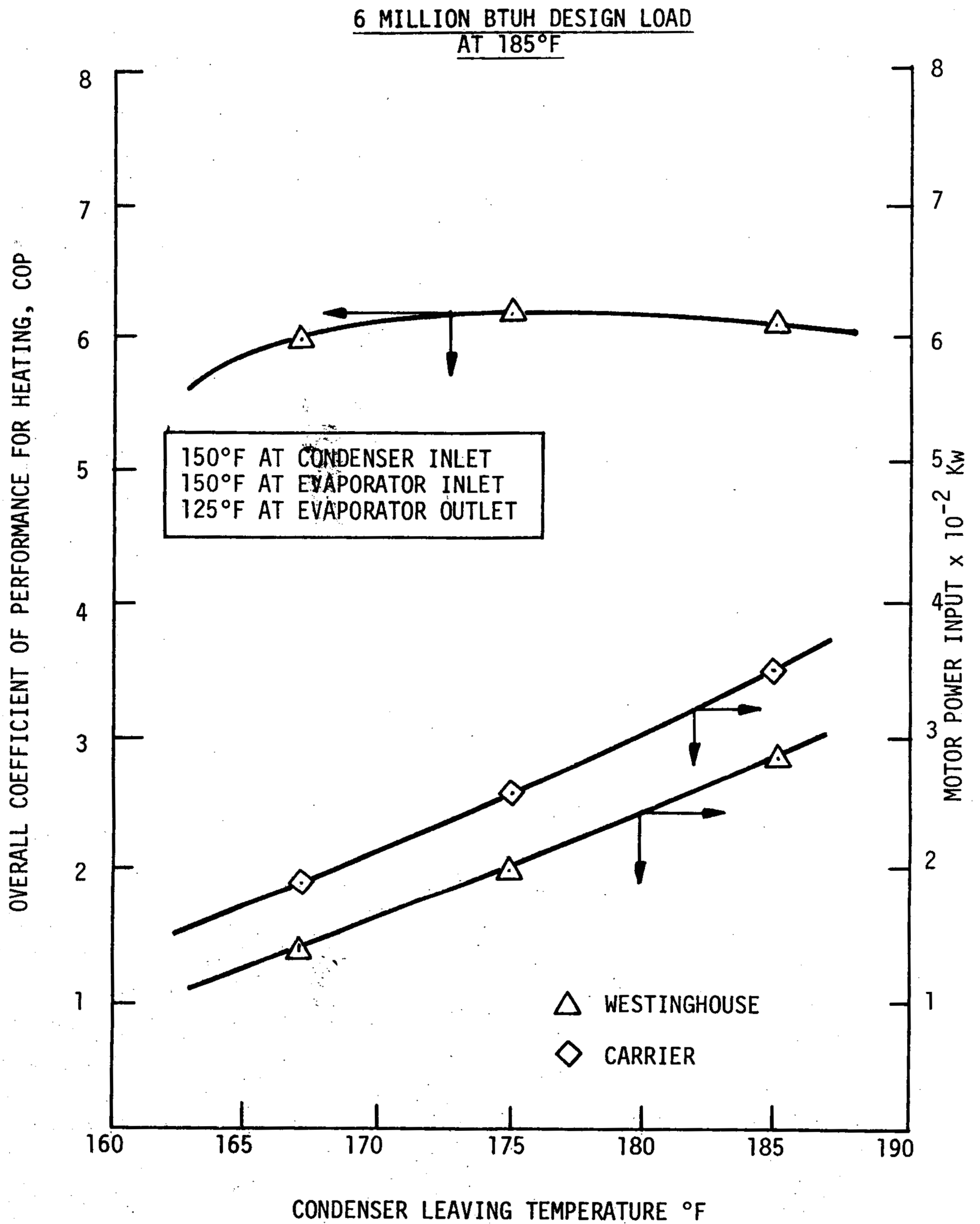


Figure C-13. Heat Pump Off Design Performance - COP and Power

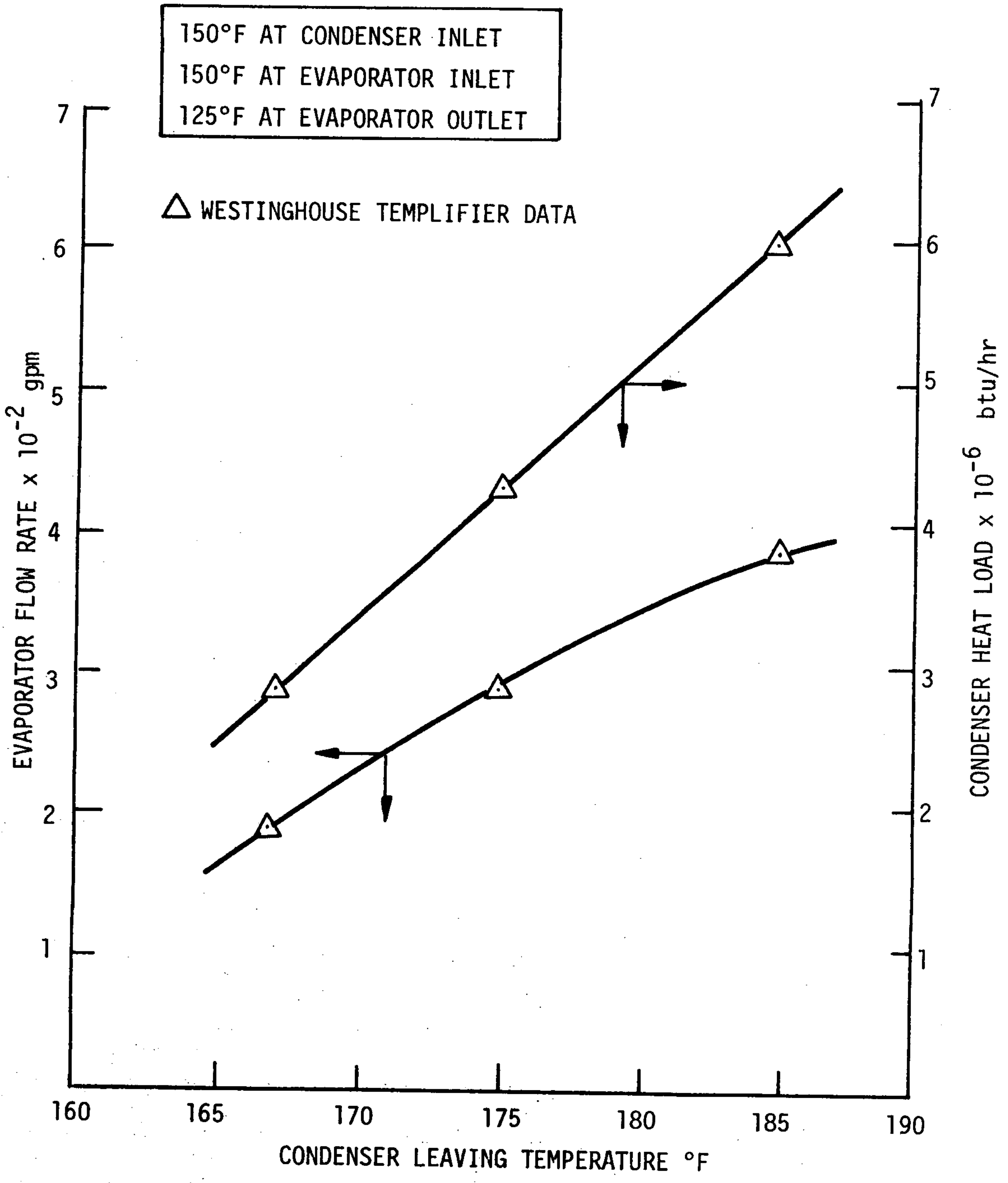


Figure C-14. Heat Pump Off-Design Performance - Evaporator Flow and Heat Load

D. SUSANVILLE SYSTEM ECONOMIC ANALYSIS

The parametric economic analysis was based on the comparison of the two basic alternatives for providing heating energy at Susanville: (1) continue to use the existing fuel oil and propane systems, or (2) develop a geothermal heating system with fossil or electric heat pump peaking. Initially, a third alternative was considered - that of a totally geothermal system to provide for the total heating load. However, analysis showed that this system was not as economical as an augmented system and therefore it was dropped from the comparison. To determine if there would be sufficient return to pay back the low interest loan, the rate of return on the added investment in the geothermal system was determined for the non-profit municipal entity that would own and operate the system. This interest rate is 8%.

Exact well costs, flows, temperatures, and building retrofit costs are unknown. Therefore, a parametric study was conducted to evaluate economic feasibility. Temperatures were varied from 150 to 225°F. Flow was varied from 350 to 700 gpm, and well cost from $50,000 to $175,000 per well. It was determined that $150,000 could be spent on building retrofit costs without adversely affecting favorable economics for the public building system alone.

Another important variable in the economic analysis is inflation. All operating costs - fuel, labor, replacement parts - are assumed to inflate at a constant rate over the twenty-five year life of the project for both the existing system and the geothermal system. The inflation rate is varied from 0 to 10% with 7% the predicted value.

This economic analysis is classified as a before-tax analysis (because it is for a non-profit municipal organization) and assumes that all the cost of the geothermal system would be paid back. In cases where a project receives government support on the development of the resource, and the investment that must be recovered is less, a more favorable rate of return can be anticipated.

The public building system alone will provide a rate of return of 8 to 10% over the parametric range with a 150°F resource. The addition of a heat pump at the high school has several beneficial effects, but improved economics is not one of them. With higher resource temperatures (185-225°F), the ROR for the public building system would increase to 12-16%. At these temperatures, a heat pump would not be used at the high school.

The impact of the utilization of the effluent from the public building system in the Park of Commerce with a 150°F resource is discussed in Section B.

1. Basis for Economic Analysis

There are four major uncertainties in the economic analysis of the Susanville Geothermal Energy 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); (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; (4) the cost to retrofit the public buildings, which is dependent on the remaining useful life of the building and the existing heating system.

Susanville's production wells will be a maximum of 1000 feet deep. The geothermal flow rate per well was assumed to be either in the range of 350-450 gpm, or 500-700 gpm for production wells, and double those flows for injection 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 injection wells. Building conversion costs are anticipated in the $150,000 to $415,000 range, depending on the geothermal temperature utilized and improvements made in existing buildings. 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 initial parametric economic analysis was based on a geo-heating system designed to provide 23.4 million BTU/Hr and 4.07×10^{10} BTU/Yr, based on the installed equipment. 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 revenue 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 costs is an educated guess using Klamath Falls experience. 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.

The same assumptions were used for the integration of the Park of Commerce into the overall system. However, this economic analysis was performed only for the 150°F resource temperature. In general, capital cost estimates of this type are accurate to ± 20%. The operating cost estimates should have about the same accuracy.

2. Alternatives for Susanville

The economic analysis used in this study is based on a comparison to two basic alternatives for providing the energy required for heating the public buildings and operating the Park of Commerce. These basic alternatives are (1) an all-fossil-fueled system, and (2) a geothermal system with some form of peaking augmentation - either fossil boilers, electric heat pumps, wood boilers, or some combination of the three.

The rate of return for the geothermal alternatives is therefore a function of the difference between the capital costs of the alternatives divided by the difference between the annual operating costs of the alternatives. Inflation is considered in calculating the rate of return. The rate of return presented is a "before tax" ROR because the owning institution is to operate on a non-profit basis. Items such as depreciation, investment tax credit, state, local, and federal taxes, are not involved in the determination of before tax rate of return.

3. Impact of Resource Temperature on Economics

For Susanville's public buildings, the alternative of replacing the existing fossil-fueled heating system with a geothermal heating system with fossil boiler peaking was evaluated over the temperature range of the study and as a function of well cost and fuel inflation rate. The initial results for a 700 gpm/well flow rate and 7% fuel inflation rate showed the system to meet the 8 to 10% ROR criteria for economic feasibility over a broad range (Figures D-1 and D-2). The impact of dropping the flow rate per production well to 350 gpm is to drop the ROR by 1.5 to 2.0% depending on the design point. For example, Table D-1 presents the impact at 150°F with a $175,000 cost per well.

Table D-1
Impact of Well Flow Rate on Public Building ROR
Resource Temperature = 150°F
Well Cost = $175,000/Well

Energy Inflation Rate (%)	Rate of Return for Geothermal With Fossil Fuel Peaking	
	700 gpm/Well	350 gpm/Well
0	3.8	2.2
7	10.4	8.6
10	13.2	11.4

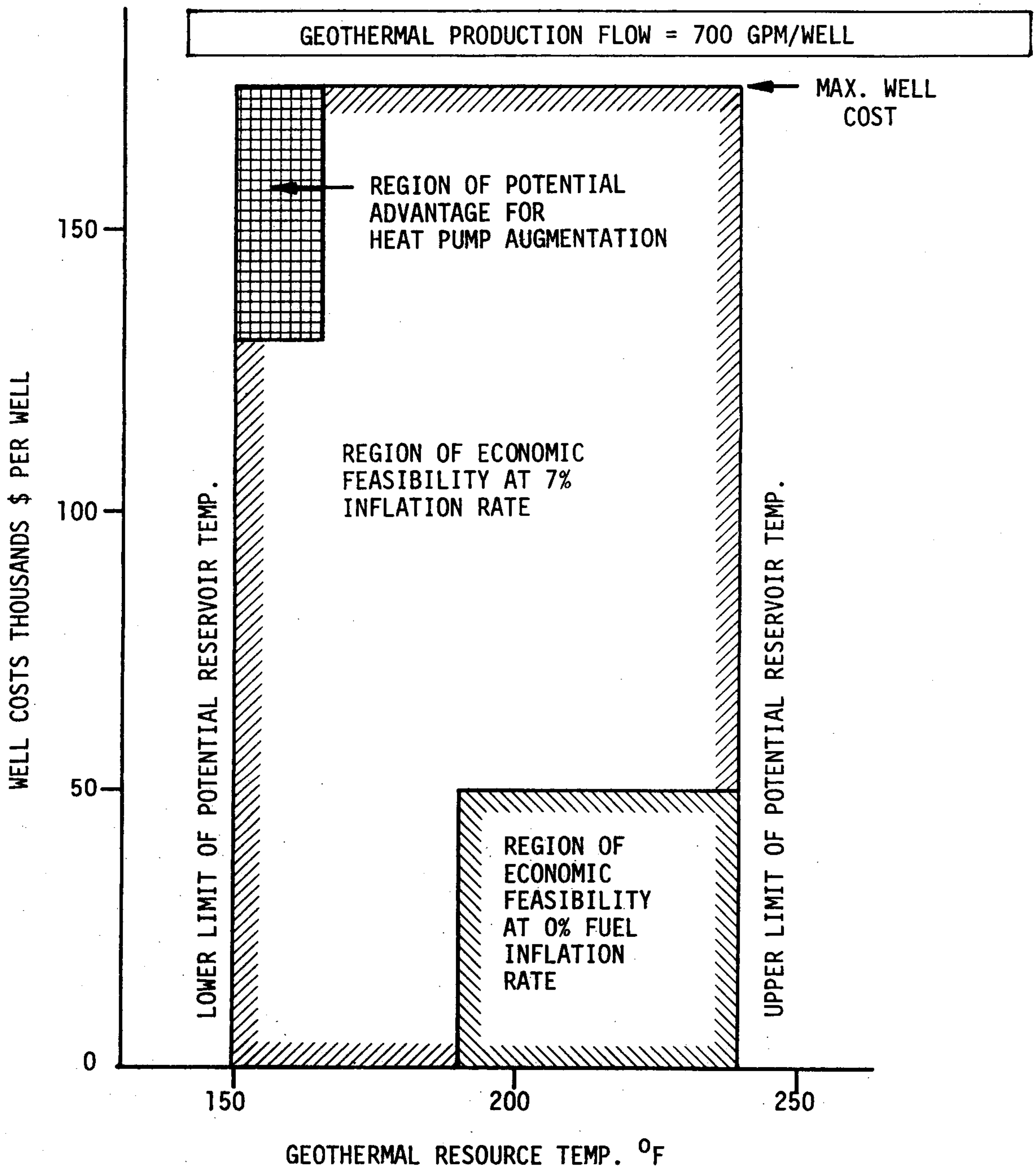


Figure D-1. Susanville Public Building System Conditions for Economic Feasibility at 10% Rate of Return

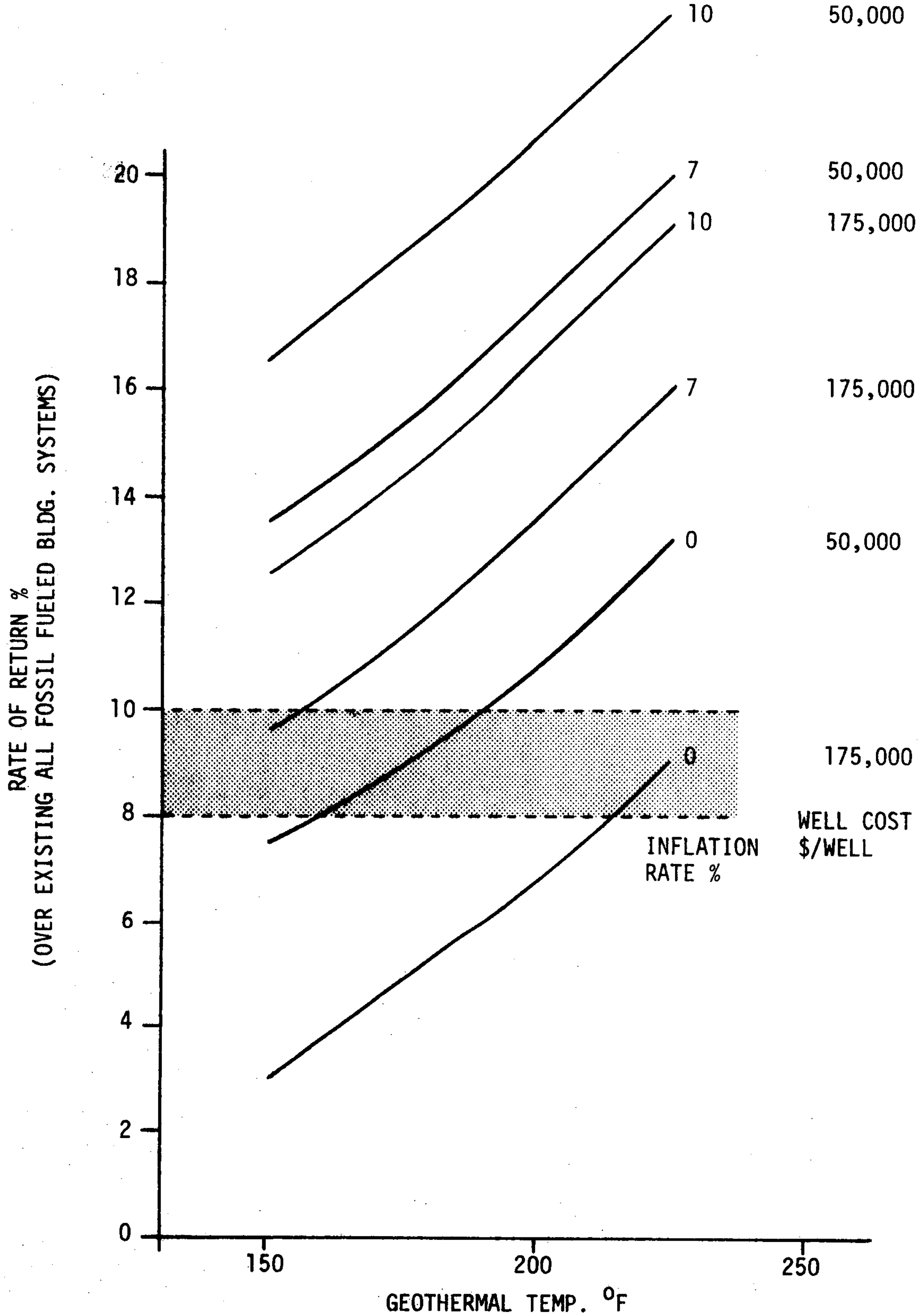


Figure D-2. Public Building Geothermal System with Fossil Fuel Peaking

4. Impact of Heat Pump Alternatives

For Susanville Public Buildings, no economic advantage could be shown for any of the alternatives considered (Section C.8.). However, in the Park of Commerce the heat pump can be shown to economically displace fossil fuel water heaters (Section C-7). The use of a heat pump in a retrofit case is difficult to economically justify if the existing boilers are in good working condition and do not need to be replaced. Such is the case at the Lassen Union High School even though the heat load is large enough to justify a heat pump.

For example, at the same design point used in the previous section (D.3), the fossil fuel system has no capital cost penalty. Therefore, the heat pump alternative shows a slight but definitely lower ROR because the lower annual operating cost does not compensate sufficiently for the higher initial capital cost (Table D-3).

Table D-2

Rate of Return
For Replacing the Existing All-Fossil Fuel System

Resource Temperature = 150°F
Well Cost = $175,000/Well

Energy Inflation Rate (%)	Geothermal With Fossil Fuel Peaking		Heat Pump at High School	
	700 gpm/Well	350 gpm/Well	700 gpm/Well	350 gpm/Well
0	3.8	2.2	2.8	1.4
7	10.4	8.6	9.2	7.8
10	13.2	11.4	12.0	10.4

However, the ROR is still within the acceptable range and the heat pump option can be selected for reasons other than economic ones. Such reasons include decreased dependency on fossil fuel and greater geothermal system operating range for expansion at the same geothermal flow or full load operation at lower geothermal flow.

5. Additional Options for Susanville

In addition to the use of heat pumps in the Park of Commerce to replace fossil-fueled boilers, wood-burning boilers were considered. The detailed economics of this alternative were not worked out due to the "softness" of available data but initial results looked favorable.

A new product called "Woodex" is now being marketed. It is currently being produced in Redding, California, across the mountains from Susanville. This fuel will produce about 8500 BTU/Lb and currently would cost $28 to $29 per ton delivered to Susanville. The energy cost would be $1.7 per million BTU, about 50% of the current fuel oil cost at Susanville.

Stoker type boilers used to burn the wood product are more expensive than the packaged oil-fired boilers. New fluidized bed boilers are under development which could cut these costs significantly. One such boiler, produced by Johnston Fluidized Bed Boilers of Ferryburn, Michigan, has recently entered the market.

6. Possible Economic Impacts of the National Energy Act (November 1978) On the Susanville Geothermal Energy System

Until the National Energy Act was passed in November 1978, the incentives for attracting private capital for exploration and product development for hydrothermal resources were much less than those for competing natural resource development. Even while other newer, more exotic energy forms (solar for example) were progressing and receiving the incentives needed, geothermal lagged behind.

The five Acts that make up the 1978 National Energy Act -- The Public Utility Regulatory Policies Act of 1978 (PL 95-617), the Energy Tax Act of 1978 (PL 95-618), the National Energy Conservation Policy Act (PL 95-619), the Power Plant and Industrial Fuel Use Act of 1978 (PL 95-620), and the Natural Gas Policy Act of 1978 (PL 95-621) -- go a long way toward fostering a climate in which significant progress can be made in the commercial development of geothermal energy. Incentives should stimulate early and widespread exploitation by a variety of users. The Energy Tax Act is the Act that most directly impacts on geothermal. It provides for depletion allowances, tax credits, and intangible drilling deductions. Its new definition of geothermal deposits is now broad enough to cover dry rocks. Indirectly, other sections of the National Energy Act could stimulate growth in geothermal. For example, the Natural Gas Policy Act, by establishing and implementing agricultural and industrial priorities for natural gas curtailment, focuses attention on the geothermal alternative.

The National Energy Act unfortunately did not adequately deal with direct heat use market sectors. Therefore, the impact of it on the proposed Susanville system is minimal. Also, since Susanville is treated as a municipality, the provisions in the Energy Tax Act do not impact the economic analysis discussed in this report. However, its relevance to Susanville will come during system expansion. At that time, the City will need to decide how best to handle the expansion. For example, it may cost less to expand into residential areas by having the residents form cooperatives. The City could allow resident cooperatives to tap into the system and use the water, but the residents would own the system from the City pipeline to their homes. This would expand financing options and also allow residential energy tax credits to be claimed by homeowners.

By the time Susanville is ready to examine alternatives for financing system expansion, the picture may have brightened considerably. Under the direction of Randall Stephens, Resource Applications, U.S. Department of Energy Washington Office, Geothermal Energy Omnibus Legislation is being proposed. The major purposes of the legislation are to streamline Federal leasing and permitting, to provide incentives and reduce disincentives for market sectors not adequately dealt with in prior legislation (especially direct heat use market sectors), and to clarify uncertainties in the National Energy Act. Of special interest to Susanville and other municipalities are:

D, 6, Possible Economic Impacts of the National Energy Act (November 1978) On the Susanville Geothermal Energy System (cont.)

- Proposed Amendments to PL 93-410 Loan Guarantee Program

  a. Authorize SBA, REA, HUD, and Farmers Home Administration to make geothermal loan guarantees.

  b. Authorize guarantees for 90% of project costs (rather than the current 75%) for publicly-owned bodies (municipalities and cooperatives) and for small business concerns.

- Proposed Amendments to National Energy Conservation Polity Act

  a. Include geothermal space heating in grants, secondary financing, and loan insurance programs.

  b. Include geothermal in programs for grants to hospitals, schools, government buildings, and public care facilities.

  c. Authorize increase in HUD and Farmers Home Administration loan limits for geothermal heating and cooling equipment.

E. APPLICATION PLANNING

The best procedure toward development of the Susanville Geothermal Energy System is to demonstrate the viability of the resource and concept by designing, constructing and testing the first module of an integrated system (Figure E-1). It would consist of two elements: (1) a field experiment for development of the Public Buildings Energy System, initially retrofitting 17 buildings for geothermal heating, and (2) a concurrent commercial/private development of a Park of Commerce, initially providing an augmented geothermal energy system for the first increment of the integrated meat production plant and five acres of greenhouse.

Funding for these elements would come from different sources. The field experiment module is the cornerstone of the system. Definition and development of the resource during the field experiment greatly reduces the unknowns and risks involved. Because of concern over uncertainties, it is felt that Federal involvement during this phase of development is warranted. The City of Susanville has proposed to the U. S. Department of Energy that they participate jointly with the City in the field experiment on a cost shared basis (DOE PON ET-78-N-03-2047). The City and the Department of Energy are currently negotiating a contract to this end. As soon as the risks are minimized and the resource proven adequate, private/commercial developers will be encouraged to begin implementation of the Park of Commerce, financed separately. Also, as soon as any part of the system is operational and revenue is generated, the problems of obtaining private financing for expansion are minimized considerably. Options for methods of financing are discussed in Section F.

Figure E-2 depicts the design, construction, and installation schedule recommended. If the field experiment is initiated in 1979, in less than three years after start date Susanville could have an integrated energy system servicing 17 public buildings, five acres of greenhouse, and a meat production facility. By the end of 1981, they could be successfully negotiating for private and public financing for system expansion, and the system could be generating revenue for payback, expansion, and other community projects. Given successful well drilling and indications that the system module installation is proceeding on schedule, this activity could begin even sooner.

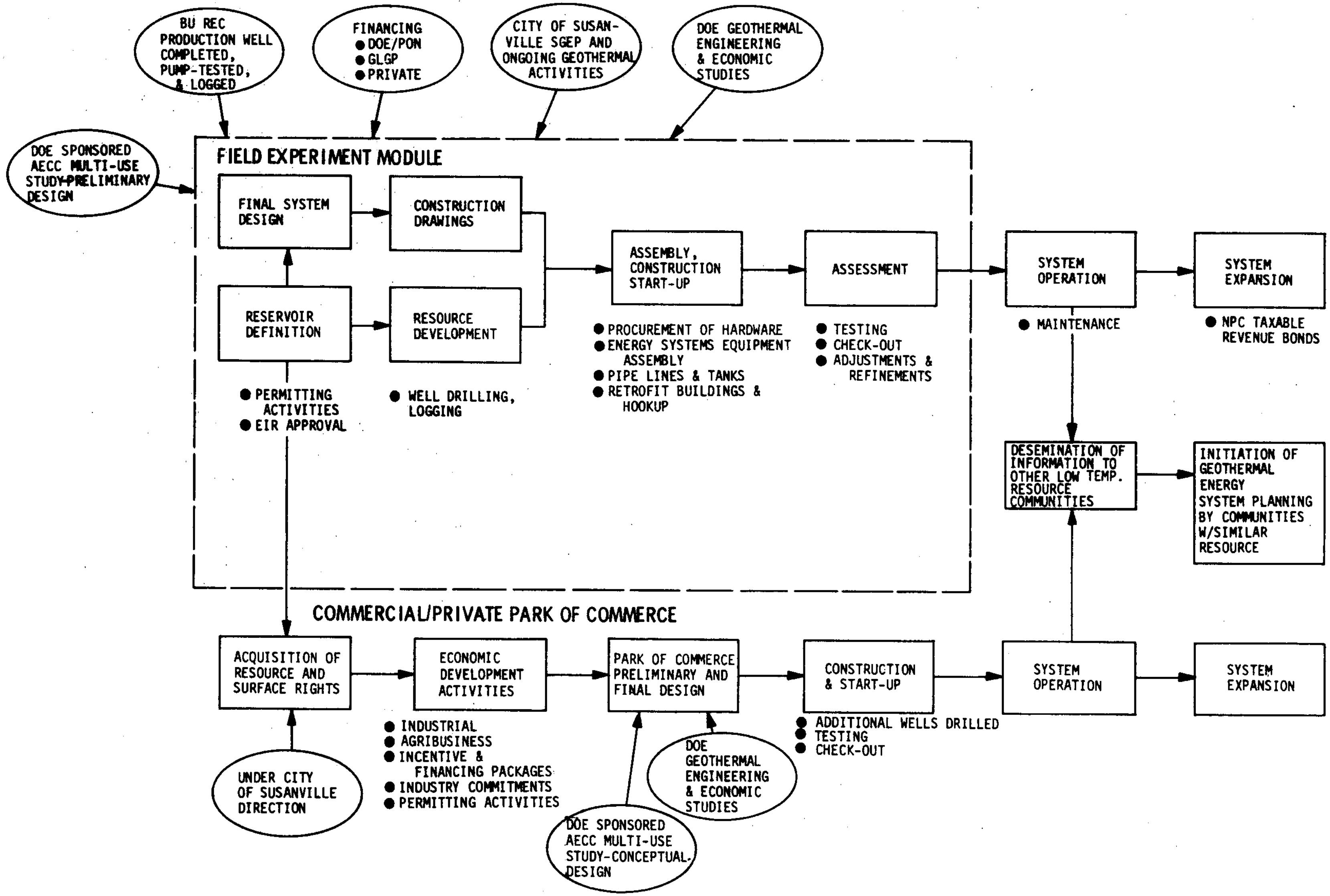
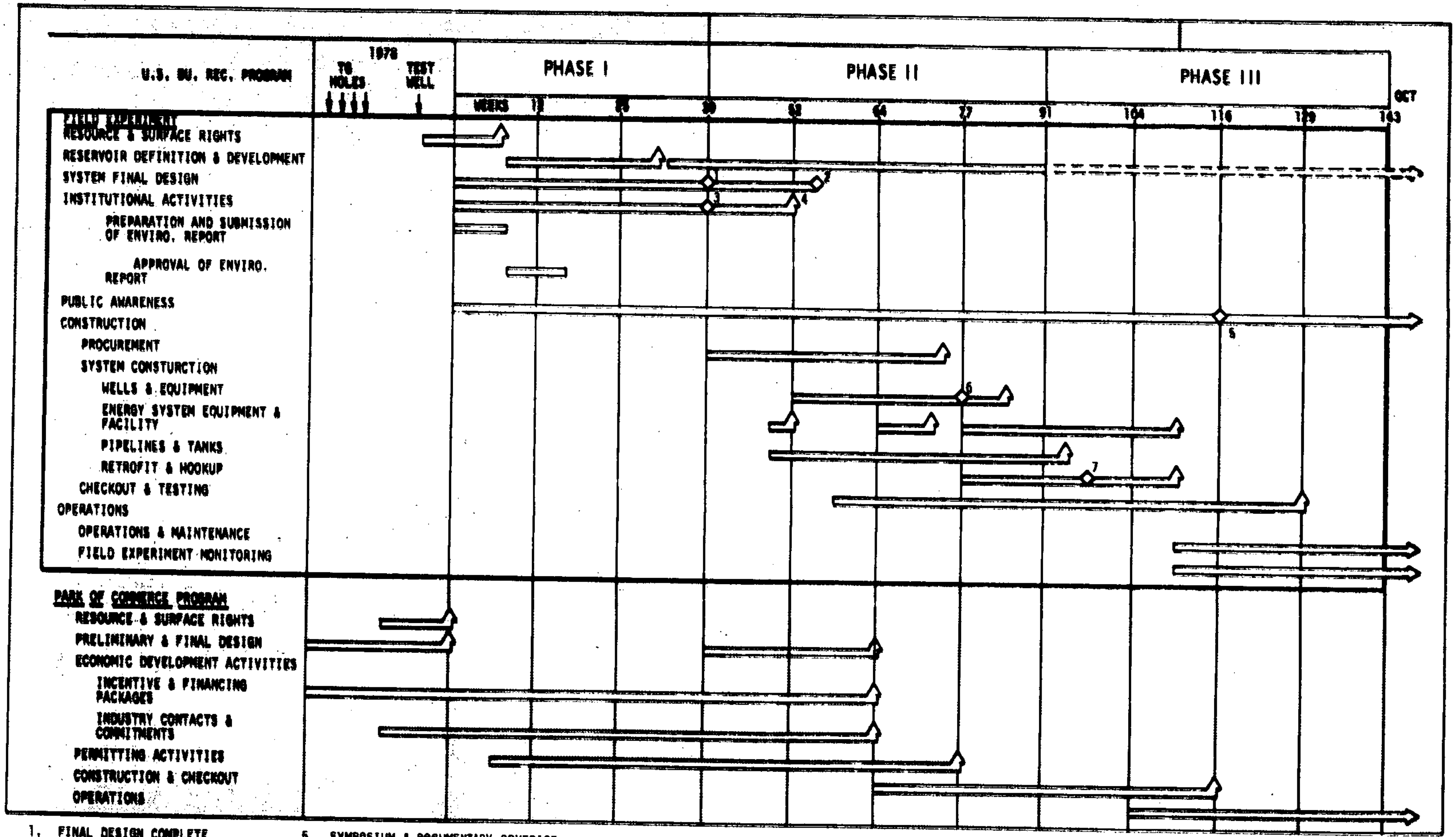


Figure E-1. Logic Flow Diagram-Susanville Geothermal Energy System Application/Implementation Plan



1. FINAL DESIGN COMPLETE
2. CONSTRUCTION DESIGNS COMPLETE
3,4. INTERIM & FINAL PERMITS
5. SYMPOSIUM & DOCUMENTARY COVERAGE
6. WELLS DRILLED & TESTED
7. INITIAL GEOTHERMAL FLUID FLOW THROUGH SYSTEM

Figure E-2. Design/Construction/Installation Schedule

F. U.S. BUREAU OF RECLAMATION DRILLING PROGRAM IN SUSANVILLE

In 1974 Public Law 94-156 was passed. Under this law, Congress can authorize the Bureau of Reclamation to engage in a comprehensive resource analysis for the explicit benefit of a community.

The City of Susanville requested that the U.S. Bureau of Reclamation (BuRec) aid in defining the resource in and around the City. Funds were made available by Congress and the work began in 1975. Since that time, numerous temperature gradient and test holes have been drilled searching for the hottest temperatures and the boundaries of the reservoir. The puzzle pieces are beginning to fit together and, at this writing, additional test holes are being drilled in order to fill in informational gaps and test the hypotheses already formulated from existing data. BuRec plans to finish these test holes in May. Lawrence Berkeley Laboratory (LBL) has been performing pump tests and monitoring wells in Susanville since early December and will assist the BuRec in interpreting the data. If more test holes are needed, it will become evident at this time. If not, a coherent hypothesis of the reservoir will be available about 1 June 1979.

It will be helpful to the reader to refer to the map on the page following this discussion (page 98). It is divided roughly into three geographic areas. These areas group existing wells, test holes, and temperature gradient holes into what are believed now to be related temperatures and sources. Circles represent approximate locations of current test hole drilling. The heavy lines represent what are believed to be fault blocks. They are at different elevations between the wells, from west to east. Fault blocks are rock masses bounded by fractures in rock along which adjacent rock surfaces are differentially displaced. The hypothesized fault blocks correlate well with what is known about geology in this region and follow the trend of fault patterns known to exist there. It is possible that these fault blocks are not impermeable and there may be some communication between these three areas.

There are three possible sources of Susanville's subsurface hot water. It could exist because underground water is circulating within a fault zone, or there could be a residual magma heat source under Susanville that is heating the water. But the most likely reason is now thought to be that somewhere to the north of Susanville is an aquifer that is flowing hot water into the Susanville area. The BuRec's new test holes, to the north, should support or refute this theory. If the holes indicate hotter temperatures than previous test holes, that would indicate that water might be flowing in from the north. If the water to the north seems cooler, it would indicate that there is closure and one of the other reasons for the hot water is probable.

The flow of hot water from the north into Susanville has very positive implications for a direct use system and its economics.

1. If the flow is constantly replenishing, depletion of the reservoir is not a problem and life of the system could exceed 30 years.

2. If the hot water is flowing in, conceivably the temperature of the resource could increase with pumping as stagnant water is removed.

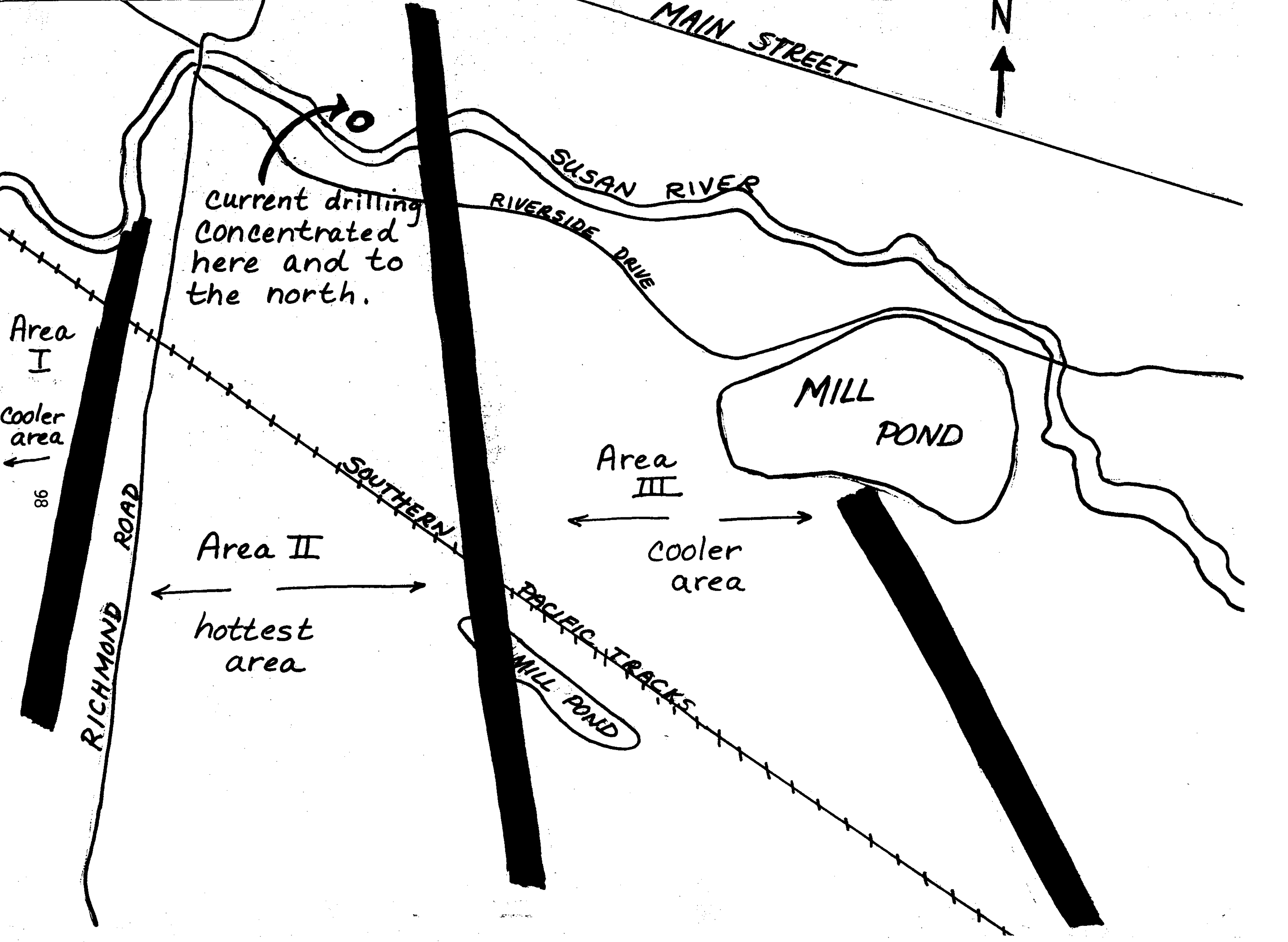
3. If the reservoir is constantly replenishing, subsidence would not be a problem. Indeed, injection of the fluid would not be necessary (or even desirable). The quality of the water is so good (500-600 parts per million dissolved solids) that it could be sold for irrigating the arid farmland surrounding Susanville.

4. If the hottest water is to the north, there are more possibilities for drilling on land already owned by the City. Pipelines to the public buildings included in the first module would be shorter, hence less costly.

Recent pump tests in the Susanville area point to better permeability than originally predicted. It may be possible to pump as much as 1000 gpm from one well without affecting other wells in the general area. The greater flow rates mean fewer wells needed for the system.

F, U.S. Bureau of Reclamation Drilling Program in Susanville (cont.)

Part of the intrigue and facination (and exasperation) with working in geothermal energy is trying to find out what, indeed, is under the ground where the human eye cannot venture. Susanville is on the brink of this disclosure. The test holes are, no doubt, approved and in progress. It is unlikely that these holes will not add much to our present knowledge. The drilling results will help to either delineate closure on the temperature contours already obtained (and on that basis LBL will be able to predict temperatures and flow rates that will be possible), or the drilling results will indicate hotter temperatures to the north and hot water flowing into Susanville. By 1 June 1979, we will know that answer.


MAIN STREET
N
10
SUSAN RIVER
RIVERSIDE DRIVE
Current drilling concentrated here and to the north.
Area I
Cooler area
RICHMOND ROAD
Area II
hottest area
SOUTHERN PACIFIC TRACKS
MILL POND
Area III
cooler area
MILL POND

G. INSTITUTIONAL CONSIDERATIONS BEARING ON ACCEPTANCE AND IMPLEMENTATION OF GEOTHERMAL ENERGY USE IN SUSANVILLE

An informal random survey of Susanville citizens and officials conducted in the summer of 1978 pointed to the following:

a. The community's attitude is positive - no problems anticipated from special interest groups or other citizen factions.

b. Local permitting is straight-forward and it is expected that Lassen County will handle permitting as expeditiously as it has in the past.

c. All rights of way for the first module of the proposed energy system are under the control of the City and County.

d. Previous environmental impact work indicates no problem or conflict with proposed energy system.

e. There are no known institutional impediments to implementation at this time.

1. Institutional Development

The successful development and use of geothermal energy for the inhabitants of a community is critically dependent upon the objectives and restrictions established by or found inherent in that community.

The City of Susanville initiated plans for geothermal development by establishing two principal objectives. These have remained unchanged since early 1974, and have been re-emphasized by City officials in recent conferences on this Project.

- TO DEVELOP new job opportunities in the private employment sectors.
- TO DEVELOP alternate sources of revenue in lieu of further increases in residential taxes.

At the same time, two restrictions were laid down.

- The development and utilization of the geothermal energy for the benefit of the community must be under the local control of the citizens and their elected officials.
- The relatively high local tax rate, narrow tax base (largely residential) and low assessed value of the City combine to preclude using the General Fund, (taxes) or General Obligation Bonds as a means of primary or secondary servicing of Project financing.

These objectives and restrictions clearly limit options for approaches to solutions to the community's problems and have required consideration of sources of financing outside of the community. Consequently, the prototype aspects of the Project led the City to explore financing through State and Federal agencies. Justification for Federal assistance required definition of how many "Susanvilles" could possibly benefit from a prototype project. A study of potential communities indicated the possibility of 160 "Susanvilles" in the thirteen Western States (discussed in Section E).

2. Candidate Structures

Options for institutional structures for implementation and operation were investigated. The options were constrained by the previously stated objectives and restrictions, and were evaluated for effectiveness, degree of local control, legality, practicability of financing, and revenue generation and flow to the community.

The primary candidate institutional structures for implementation of the Susanville Geothermal Energy System are:

- City-County Energy Department for government grant or contract.

- Non-Profit Corporation - plus - Private Developer with City buy-out through lease-purchase agreement for acquisition of the private equity. This will permit use of geothermal loan guarantee program - plus - commercial/revenue bond financing for the long term.
- Community controlled municipal utility district when conventional utility operations, including expansion without the GLGP, are warranted.

These options could be separate or used in a series as the system developes.

3. Extensive Search for Financing

The City has been fortunate to be able to depend upon the BuRec to continue to perform the high risk resource exploration under PL 94-156. However, as indicated before, the financing of the implementation of the energy system has been difficult to define and obtain. The City and its industry associates have conducted an extensive search for this project financing.

Options still under consideration include:

- A private developer agreement with the City for commercial development of the Park of Commerce, once the resource is proven.
- Bank financing plus long-term financing through revenue bonds plus geothermal loan guarantee program for the major elements of the development.
- Technical Assistance funding from the California Department of Housing and Community Development and U.S. Economic Development Agency.
- Municipal Facilities Grant for a portion of the Park of Commerce from the Farmers Home Administration and possibly similar additional support from the Economic Development Agency.

- Resource acquisition support from California Energy Commission.
- A cost-shared development of an energy system module with the U.S. Department of Energy.

A major development in this area has been the agreement between the City and the Carson Development Co. of Sacramento for the development of the Park of Commerce. Carson has been assisting the City in resource rights acquisition and planning for the Park development. This development is contingent upon the definition of the Susanville Reservoir. This is a key element of the City's proposal for a PON project.

The GLGP, as currently structured, has imposed two additional restrictions on small communities who desire a degree of local control.

a. A municipality has had an effective interest differential on taxable borrowings -- this has recently been accounted for in the new amendment to the GLGP under P.L. 95-238.

b. Under the GLGP, any proceeds/profit earned by the lender must be taxable. The conventional non-taxable municipal or general obligation or revenue bond issued by a municipal government will not qualify for a guaranty. NOTE: The issue of taxability is decided by the IRS, and the taxes are paid by the lender. Financial institutions such as the Bank of America, UCB, and the Bank of Montreal believe that a city cannot directly issue G.O. or revenue bonds and qualify for a guaranty.

In response to this situation, the Dean Witter & Co. developed a unique nonprofit corporate (NPC) structure for the City of Burbank and adapted this structure for Susanville and other small cities in California. Dean Witter & Co. subsequently proposed to the City, offering financial advice and expressing interest in underwriting taxable revenue bonds for the City's project.

A reasonable sized energy system, financed using the GLGP, requires private investment participation in the 25% local equity. All financial entities have recommended that the City search for such private participation for this approach to funding the Project.

A government grant would obviate or reduce the need for such private participation and enable the City to retain a commensurate higher degree of local control within the community. Eventually, the government will pull out and private participation will be necessary, either through revenue bonds or another financing mechanism.

A non-profit corporation, specially structured, can qualify to issue taxable revenue bonds. Informal opinion from qualified bond counsel was obtained by Dean Witter & Co. on this matter. This NPC must not be deemed to be a department or other sub-entity of the City, the County, or a Joint Power Agency of both. This requires that the Board of Directors contain representation of, say, the electorate (local citizens) as well as from the City Council and the County Board of Supervisors. Through this special structure, cities could qualify for GLGP guaranties and still maintain significant local control.

Informal response from the Attorney General's office, the Legislative Counsel and the PUC staff indicated that the State Constitution and legal precedence authorizes a General Law city such as Susanville to furnish heat, light, and power to its inhabitants (and those in the vicinity). Local pricing control is retained in the community provided energy is not transmitted and sold inter- or intra-state to other communities.

4. City Geothermal Policy Revisions

Through discussions with citizens and reporting through the media, it has become obvious that the ever growing cost of home heating has become a crisis. Of note, single family residence heating bills have exceeded $300 per month. This crisis was brought before the CA PUC and County officials, and a "strike" was waged against the utility company by the community of Westwood, near Susanville.

In order to address this issue and its possible impact on future changes in priority of application for the energy system, the Planning Commission was requested to review the City's Geothermal Policy for possible amendment to address residential heating and priorities for pipeline routing. The Commission took the position that residential heating should be given emphasis but only when it is economically feasible. Pipelines are to be placed in the streets and alleys rather than under the sidewalks. These and other refinements were recommended by the Commission to the Council. A revised Policy was adopted by the Council in May 1978.

5. <u>City and County Regulatory Documentation</u>

The City's regulations for environmental review and for zoning, and the Overall Economic Development Plan for Lassen County have been obtained and are available for review. These annual reports contain elements describing the City's Geothermal Project. Such documentation, along with the required public participation, are formulated under EDA guidelines and are required in order to qualify for EDA grants.

In summary, the local permitting process will include the following elements:

- If the Project is, at least in part, financed through DOE PON or GLGP financing, the City Environmental Review Committee (ERC) will review the DOE environmental assessment for compliance with State and local requirements.
- If no Federal funding or guaranty is involved (highly improbable), the ERC must review the Project to determine if a Draft EIR is required. If required, and EIR will be prepared by the Project and submitted for review in accordance with the City's Procedures.
- The engineering and systems layout and retrofit plans will be reveiwed by the Planning Commission and approved by the Council.

- All pipeline routing is on City property (with a small portion that can alternately be routed over private property), hence permitting will occur through the City (and any private entities involved).
- The County will be responsible, through building permits, for regulating the hookup of the candidate County facilities.
- Beyond BuRec exploration activities, the County will be responsible for permitting of geothermal wells. Exploration activities, including temperature gradient holes but short of geothermal wells, have been approved in Wendel on the basis of a negative declaration. Production and injection wells must be approved with special attention to preclude or accommodate interference, if any, with existing water wells in the area.
- Geothermal production and injection wells must be permitted through the California Division of Oil and Gas under California Geothermal regulations. Review by other State agencies for non-electric applications is coordinated by the California Geothermal Resources Board.

H. TECHNOLOGY TRANSFER

The transferability of the technology of heat pumps as applied to low temperature hydrothermal resources has been assessed for twelve communities in the Western U.S. Based upon these representative communities, it has been estimated that such appreciation could be considered for about 70% of the hydrothermal sites in the U.S. (approximately 160 sites according to the National Geophysical and Solar Terrestrial Data Center).

The greatest degree of transferability of the heat pump technology will occur in communities that can plan for a reasonable degree of cascading. Current studies are consistently pointing to the desirability of cascading for greater load utilization factors and improved economics.

In addition to improved load utilization, a number of other factors are important in cascaded hydrothermal applications:

- Theoretically, the multiple users required for cascading can obtain low-cost financing through conventional economic/rural development sources when sponsored by a community.
- Competent business managers considering new locations for branch plants desire the labor base and services that only a community can offer.
- Maximum load utilization and an established base heating load are most readily available from the greater density of housing and commercial facilities in a community, especially when combined with an agri-business park.
- Geothermal resources can be inexpensively explored by a community under PL94-156. Requests should be made directly to the U.S. Bureau of Reclamation.

1. Candidate Sites

As a representative group, twelve candidate sites were selected for evaluation of transferability of the heat pump technology. The sites were selected on the basis of knowledge of sites currently under active consideration for geothermal developments. The Susanville project has been included as a baseline.

Two parametric criteria have been used to assess the potential application of the heat pump to each of the sites. The criteria are:

a. The heat pump can be applied for space heating to a site having a geothermal fluid temperature of 165°F, (74°C) or less.

b. The heat pump can be applied to a site for process energy that requires 230°F, (110°C) or less.

It should be noted that in multiple application sites, there may be an economic trade-off for heat pumping a cascaded fluid between certain applications in lieu of drilling additional wells. This requires a site-specific analysis. This would expand the number of potential sites.

The candidate sites are as follows:

- Boise, ID - A large building complex heating district*.
- Bridgeport, CA - A potential agri-business park and heat-district for State and local public facilities.
- Desert Hot Springs, CA - A potential agri-business park and heating district.
- Edgemont, SD - A heating district.
- Kelley Hot Springs, CA - A planned private agri-business park.
- Klamath Falls, OR - Heating districts and industrial park.
- Lakeport, CA - A potential agri-business park.
- Lakeview, OR - A planned private agri-business park.
- Mammoth Lakes, CA - A heating district.
- Mountain Home, ID - A potential agri-business park.

*"District" does not necessarily designate a "special district" in the local governmental sense.

- Northeast Oregon Geothermal Project - A master plan for geothermal developments in Union and Baker Counties, Oregon, (heating districts and agri-business parks).
- Susanville, CA - A municipal heating district and agri-business park, the baseline site.

Each site has been evaluated as to the degree of maturity in engineering and economic planning required to make an assessment of the application of the heat pump technology to the site. If a site has been evaluated under a PRDA, a PON application has been prepared, or another similar level of study effort has been conducted, then the site has been considered to be ready for assessing the application of the heat pump. The evaluation of readiness of the site for the heat pump was conducted independent of the assessments of application to space heating or to process energy.

Table H-1 lists the candidate sites and the published temperature or temperatures of geothermal fluids that flow (or are projected to flow) from the primary source or sources at each site. Using the aforementioned criteria, the suitability of heat pump application for space heating and for process energy is indicated by a "+" or "-" as appropriate. In reviewing Table H-1, it can be seen that about 70% of the sites can be considered for heat pump application and are ready for such assessment. Based on this, it can be generalized that heat pumps should be evaluated for a large percentage of hydrothermal sites in the U. S.

2. Potential Impediments

There are potential limitations in transferrability -- some of which are related to hydrothermal resource utilization in general. However, some of these general limitations directly affect the ability to define a firm market for the higher technology and capital intensity of a heat-pumped energy system. Some of the more important limitations are summarized as follows:

- Typical "geothermal" communities are small ($\sim$5000 population) with a corresponding limited assessed value and bonding capacity; they cannot risk general funds for speculative leasing prior to exploration and thereby are in a non-competitive position with "outside" private speculators. A community cannot directly utilize the Geothermal Loan Guaranty Program (GLGP). Such utilization by a community requires a special, undemonstrated institutional structure.
- There is a lack of pricing policy and precedent for direct utilization. This directly affects market definition for the heat pump.
- Pending clarification and definitive regulations for the 1978 National Energy Act, incentives for attracting private capital for exploration and product development for hydrothermal resources have been less than those for competing natural resource development. Hopefully, the National Energy Act will improve this situation.
- There is a disparity of definition of hydrothermal resources from state-to-state and a coincident disparity in tax laws at both the State and Federal levels.

Table H-1

Potential Technology Transfer Assessment

Candidate Sites	Approximate Geothermal Fluid Temperature °F	Heat Pump Application		Status of Project for Assessment
		Space Heat	Process Energy	
Boise, Idaho	165	-	+	+
Bridgeport, California	120-150	+	+	-
Desert Hot Springs, California	150-180	+	+	+
Edgemont, South Dakota	127	+	+	+
Kelley Hot Springs, California	240	-	-	+
Klamath Falls, Oregon	70-230	+	+	+
Lakeport, California	90-130	+	+	-
Mammoth Lakes, California	340	-	-	+
Mountain Home, Idaho	260-350	-	-	+
Northeast Oregon Geothermal Project, La Grande, O.	90-240	+	+	-
Susanville, California	150	+	+	+
		(67%)	(75%)	(67%)

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APPENDIX A

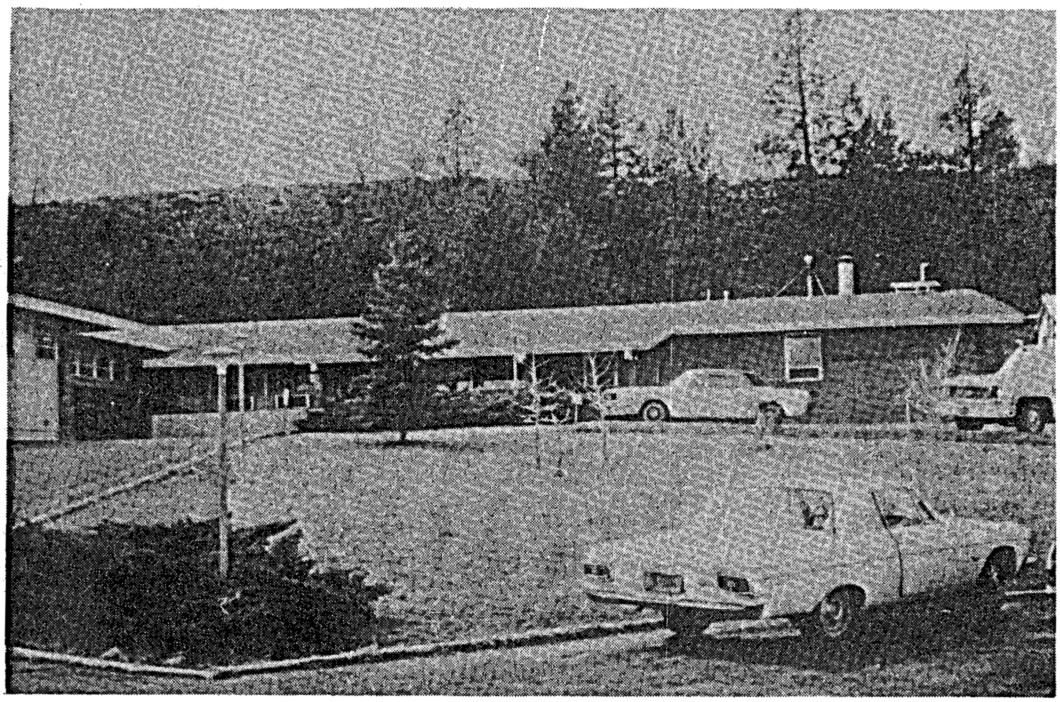
CANDIDATE PUBLIC BUILDINGS FOR
CONVERSION TO GEOTHERMAL

TABLE I

SUMMARY OF CANDIDATE PUBLIC BUILDING CONVERSIONS

	Square Feet	Total Heat Load 10^6 Btu-Hr	Geo Heat Load 10^6 Btu-Hr	Flow gpm	Conversion Process to Geothermal
Lassen Memorial Hosptial	16,000	2.03	1.22	102	Direct connection to existing hot water system (Fig. 1)
Hospital Warehouse	1,400	.12	.12	8	New hot water fan coils required (Fig. 1)
Hospital Annex	12,500	.95	.57	49	Replace existing radiators; hot air or finned convector option (Fig. 3)
County Health Center	5,000	.3	.2	15	Direct connection to existing hot water system (Fig. 1)
County Welfare	18,800	1.28	.83	32	Replace existing radiators; hot air or finned convector option (Fig. 3)
County Shop	8,400	.68	.68	68	Connect geo-water to existing hot water system (Fig. 4)
City Shop	4,100	.33	.33	16	New hot water fan coils required (Fig. 2)
Diamond View School	33,150	1.95	1.17	98	Direct connection to existing hot water system (Fig. 4)
City Hall	5,700	.52	.31	20	Extensive modification including replacing radiators were convectors (Fig. 5)
U.S. Post Office	5,700	.32	.19	16	Direct connection to existing hot water system (Fig. 1)
Masonic Temple	6,800	.36	.22	18	Direct connection to existing hot water system (Fig. 1)
U.S. Forest Service	18,100	.61	.40	23	Add hot water coils to existing hot air ducting (Fig. 6)
County Court House	22,000	1.26	.76	63	Replace evaporative coolers with heat pump (Fig. 7)
City & County Jail	7,050	1.24	.74	62	Add hot water coils to existing hot air ducting (Fig. 8)
Washington School	11,600	.50	.3	25	Connect geo-water to existing hot water system (Fig. 4)
Lassen Union High School		6.45	3.87	415	Heat pump (Fig. 9) or direct geo-water options (Fig. 10)
Lassen High School Office	3,200	.21	.21	14	Add hot water coils to existing hot air ducting (Fig. 6)

I-1.a & c Lassen Memorial Hospital and Emergency Addition



Design Conditions

Heat Load Hospital = 1,600,000 BTUH
Heat Load Addition = 426,000 BTUH
Total Heat Load = 2,026,000 BTUH
Cooling Load Total = 631,000 BTUH
Average Temp. Drop = 30°F
% Design Heat Load with Geothermal = 60%
Design Geothermal Flow Rate = 102 gpm

Building Description

This hospital was built in 1959 of frame and stucco construction. The emergency facility is an add-on. The building has about 16,000 square feet including the emergency rooms which are connected to the original building. There is a heating and cooling room which houses two boilers and a vapor compression chilled water system. The emergency addition has a separate closet containing the LPG boiler for this part of the building. This hospital has 28 beds plus six beds in the emergency addition.

Heating System

Heating is provided by a forced air hot water system. Hot water is heated up to 190°F in a Bryan 522-S hot water boiler. A Federal hot water boiler, FD350 is available for standby or peaking. Both boilers use C-2 fuel oil. Hot water for heating is provided to seven zones in the building (heating coils). Service hot water is produced in a hot water/service hot water heat exchanger in the equipment room. The heating system is designed for 200°F hot water to the coils.

Cooling System

Cooling is provided in the hospital from about May 1 to October 15. Otherwise the equipment is shutoff. About 50 tons of refrigeration is provided by an older reciprocating chilling water system (ACME Flow Cold: Model 515-0030-5700.) Cooling is provided to the emergency addition by three individual units, two Singer EA-10 and one Singer EA-12 having a total capacity of 2.6 tons.

Conversion to Geothermal

This building can be easily converted to geothermal by breaking directly into the circulating hot water loops in both equipment rooms. The standard control scheme, shown in Figure 1, can be used for the integration of the geothermal into the existing hot water system. No new coils would be needed unless material compatibility problems exist.

1.b. Hospital Complex Warehouse

Design Conditions

Heat Load = 120,000 BTUH
Average Temperature Drop = 30°F
% Design Heat Load with Geothermal = 100%
Design Geothermal Flow Rate = 8 gpm

Building Description

This warehouse is constructed of cement block. It has approximately 1400 square feet of floor space in two floors.

Heating System

The warehouse is currently heated by suspended propane to air heating units, one on each floor. The models are Bryant 100-341 and the Lennox GCS3 on the lower and upper floors respectively.

Cooling System

None

Conversion to Geothermal

This building would require two new ceiling mounted, hot water fan coils as shown in Figure 2. These coils would provide all the heating to the building.

I-1.d Hospital Annex (Old Hospital)

Design Conditions

Heating Load = 950,000 BTUH
Total Cooling Load = 55,000 BTUH
Average Temperature Drop = 30°F
% Design Heat Load with Geothermal = 60%
Design Geothermal Flow Rate = 49 gpm

Building Description

This building is an older building with 1 and 2 story frame and stucco construction. The hospital has 29 beds. The equipment room is located in a basement section. This room contains a single steam boiler used to provide steam to older steam radiators located throughout the building. The building has about 12,500 square feet of space.

Heating System

The basic system consists of a low pressure (9 psi, 235°F) steam boiler (National B47) and older steam radiators. Service hot water is produced by a steam/hot water heat exchanger located next to the boiler. The boiler operates on C-2 fuel oil.

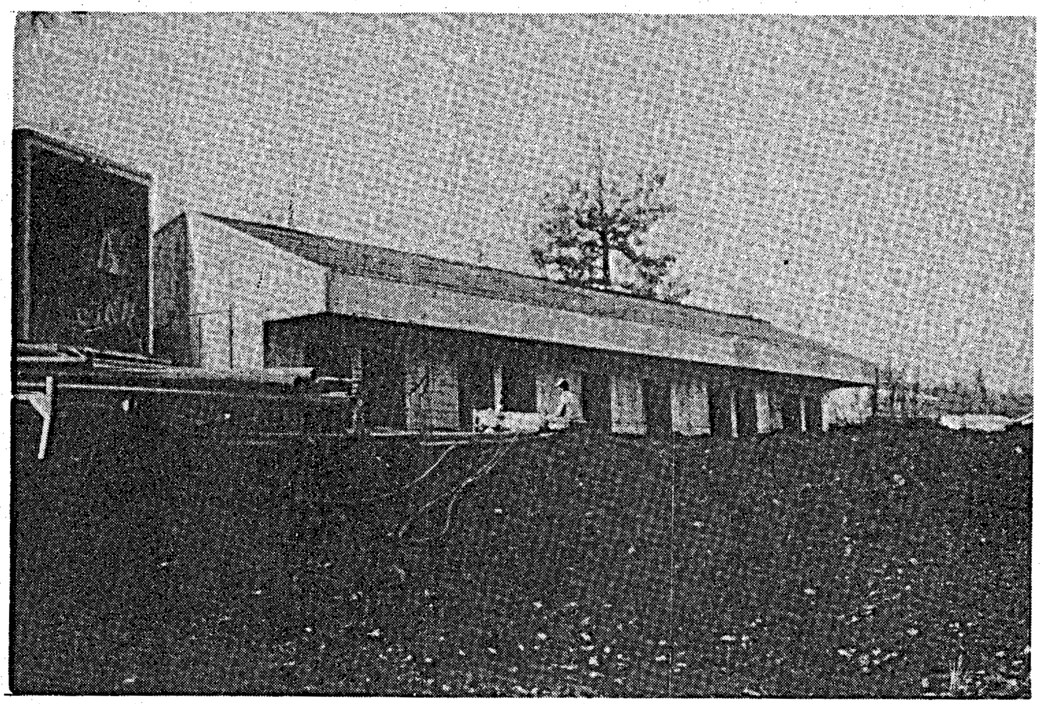
Cooling System

The 4.6 tons of cooling in the building is provided by a total of eight window units manufactured by Chrysler. These units would not be replaced.

Conversion to Geothermal

A totally new heating system should be considered for this building. Two candidate systems, shown in Figure 3, are forced air and new convectors. The forced air option would utilize the space afforded by the high ceilings to install ducts and would require installation of a new geo-water/air coil unit in the existing equipment room. The new convector option would conversely require installation of a steam/H_2O heat exchanger and replacement of all the old steam radiant heaters. The last option would most probably be the least expensive because of the lesser building renovation required. For both candidate systems, the existing boiler would be utilized as required for peaking.

I-1.e County Health Center



Design Conditions

Heat Load = 300,000 BTUH
Cooling Load = 228,000 BTUH
Average Temperature Drop = 30°F
% Design Heat Load with Geothermal = 65%
Design Geothermal Flow Rate = 15 gpm

Building Description

This building was built in 1978 for use as a day care center for the county. It is single story with frame and stucco construction. This building has about 5,040 square feet of space. It is located on a hillside above the current hospitals.

Heating System

The building is heated by a forced air hot water system. Hot water to the coils is heated in a oil fired hot water boiler (Jackson-Chruch SDF 30-172 FUMZ). C-2 fuel oil is used.

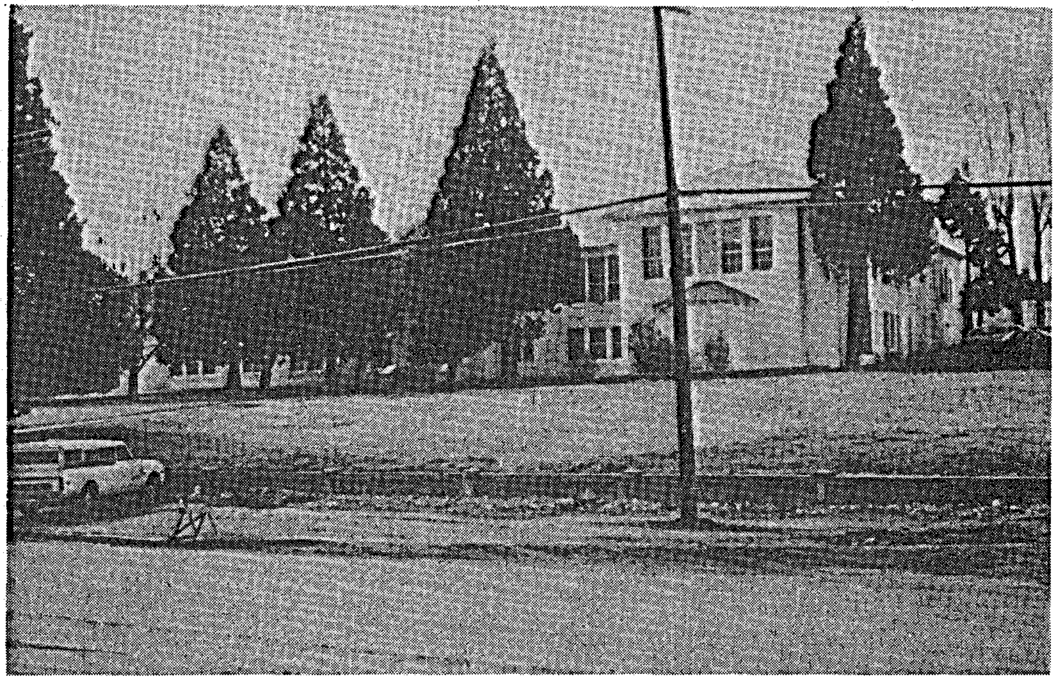
Cooling System

Cooling is provided by a 19 ton Carrier system (Model 06EV022). No attempt would be made to replace this new cooling system.

Conversion to Geothermal

This system can be converted to geothermal by breaking directly into the circulating hot water loop, as shown in Figure 1. No attempt would be made to replace the new A/C system. In the absence of material compatibility problems, the existing heating coils can be used. The new hot water boiler would be used for peaking. The control system could be the same as for the hospital.

I-2 County Welfare Building



Design Conditions

Heat Load = 1,280,000 BTUH
Average Temperature Drop = 60°F
% Design Load with Geothermal = 65%
Geothermal Flow Rate = 32 gpm

Building Description

The Roosevelt building is an older two story concrete building. It has approximately 18,800 square feet. The equipment room is in a basement. The current heating system is inadequate. Some areas of the building are too hot while others are too cold.

Heating System

Heat is provided in the system by an old low pressure steam system with old steam radiators, many of which are inoperative. The boiler is an old Kewanee steam boiler. It's model number is unknown. The boiler burns C-2 fuel oil.

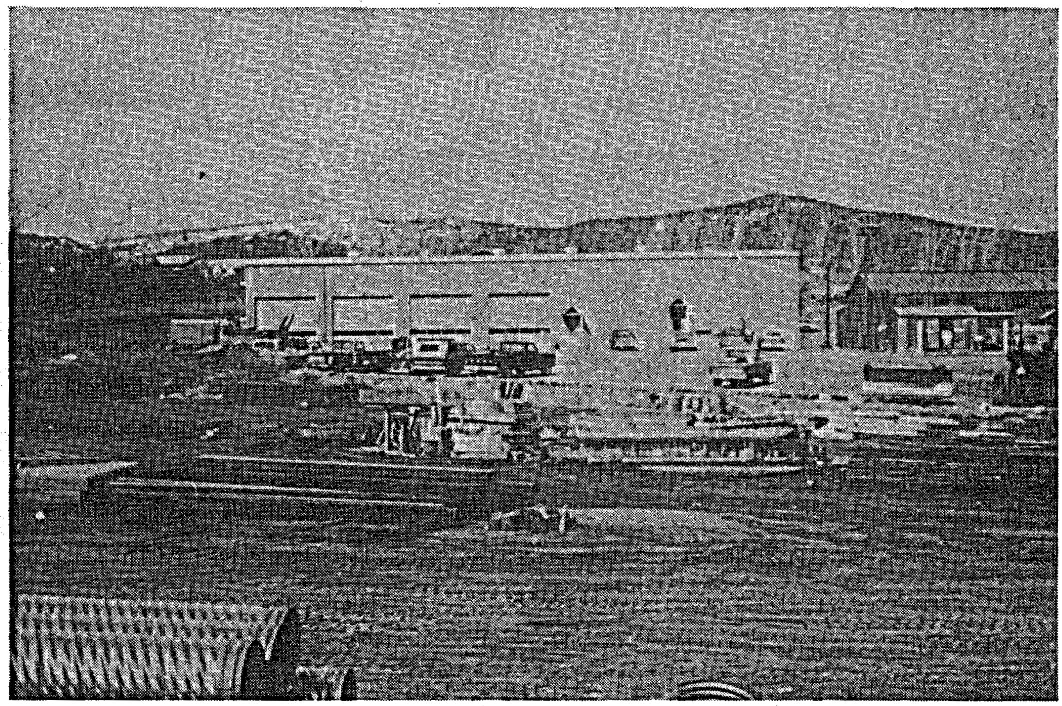
Cooling System

None

Conversion of Geothermal

A totally new heating system should be considered for this building. Two candidate systems, shown in Figure 3, are forced air and new convectors. The forced air option would utilize the space afforded by the high ceilings to install ducts and would require installation of a new geo-water/air coil unit in the existing equipment room. The new convector option would conversely require installation of a steam/H_2O heat exchanger and replacement of all the old steam radiant heaters. The last option would most probably be the least expensive because of the lesser building renovation required. For both candidate systems, the existing boiler would be utilized as required for peaking.

I-3 County Shop Complex



Design Conditions

Heat Load = 680,000 BTUH
Average Temperature Drop = 20°F
% Design Load with Geothermal = 100%
Geothermal Flow = 68 gpm

Buidling Description

This insulated steel frame building is used for maintenance on county vehicles. It has a few offices and storage rooms heated by fan coils. The main shop area, with large floor to ceiling metal garage doors, is heated by a radiant floor system. The building has approximately 8400 square feet. The current propane water heater is located in an equipment room at the rear of the building.

Heating System

This building heating system was designed for geothermal water. The system consists of a propane boiler feeding hot water via circulation pumps to the series of pipes embedded in the shop concrete floor and to the fan coils located in the offices and bathrooms. The shop thermostat is usually set at around 60°F. The system was designed to work with 150°F water, therefore all the heating can be done with geothermal.

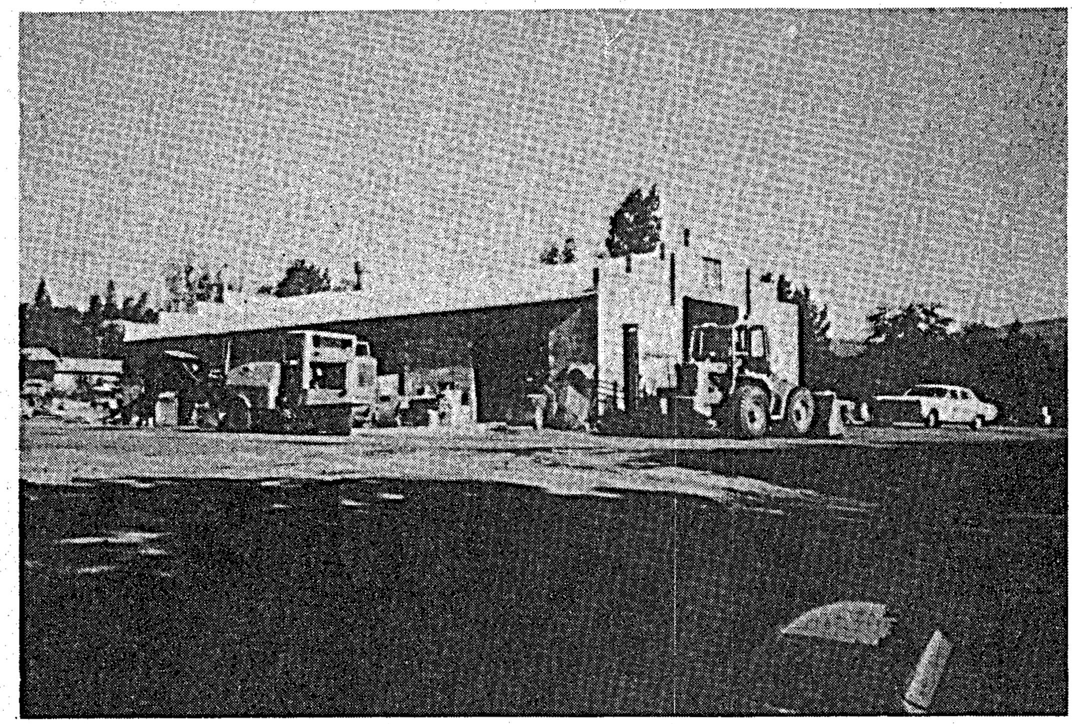
Cooling System

None

Converstion to Geothermal

Conversion can be accomplished by simply connecting to the existing system, as shown in Figure 4, with a minimum of new controls and plumbing.

I-4 City Shop



Design Conditions

Heat Load = 330,000 BTUH
Average Temperature Drop = 40°F
% Design Heat Load with Geothermal = 100%
Geothermal Flow Rate = 16 gpm

Building Description

This concrete block building is about one-half the size of the county shop but serves a similar purpose. The building is approximately 4100 square feet.

Heating System

It has a propane to air heating system. The units are ceiling mounted.

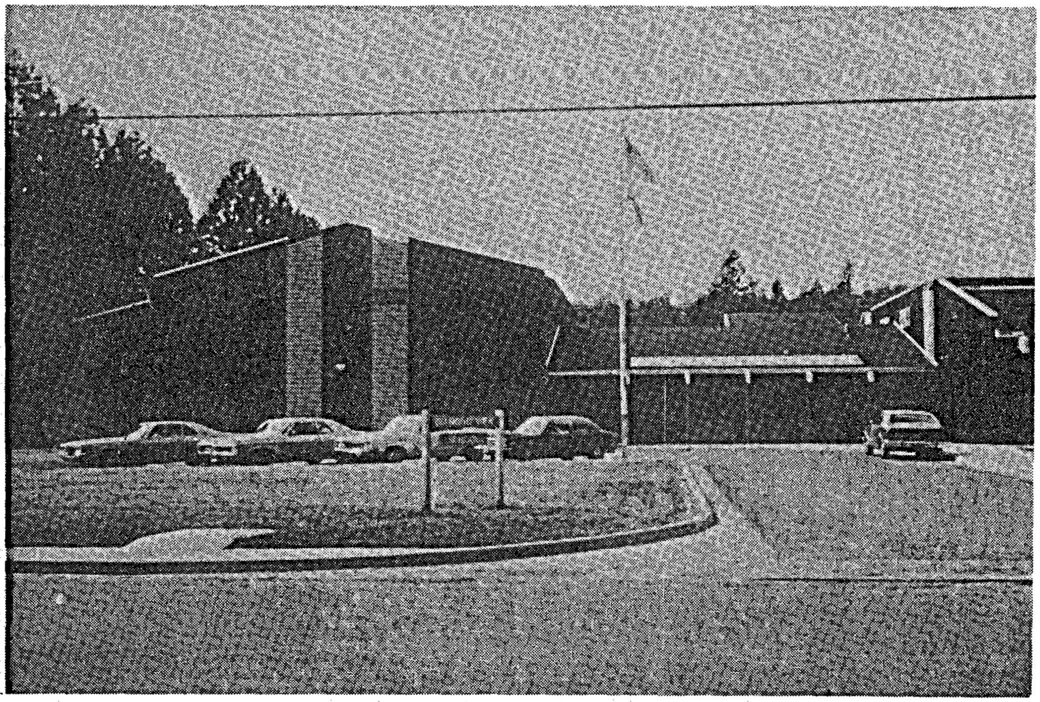
Cooling System

None

Conversion to Geothermal

This building can be heated by two ceiling mounted hot water fan coils, as shown in Figure 2, supplied in series with 150°F geothermal water. Controls could simply turn the system on or off in response to an indoor thermostat.

I-6 Diamond View School



Design Conditions

Total Heat Load = 1,950,000 BTUH
Average Temperature Drop = 30°F
% Design Heat Load with Geothermal = 60%
Geothermal Flow Rate = 98 gpm

Building Description

This large (33,150 square feet) elementary school is of modern frame construction and has large heated hallways and enclosed cluster areas. It has a modern zonal heating system with thermostats in each classroom. The equipment room is located in the front cluster of rooms in a corner of the Lassen Workroom.

Heating System

The building is heated with a forced air zonal hot water system. A Burnam Ray hot water boiler is fired by C-2 fuel oil. This boiler also provides heat for service hot water by means of a hot water to service water heat exchanger. The main boiler is shutoff from June through August and service hot water is supplied with a small electrical water heater. The heating system is designed for 185°F hot water to the heating coils.

Cooling System

None

Conversion to Geothermal

The location and size of the equipment room may create some problems in the conversion to geothermal. The existing equipment room is located off an inside hall in the northeast classroom cluster. This room is quite crowded with the existing system. Otherwise, the adaption to geothermal should be straight forward using the schematic of Figure 1.

II.A-1 City Hall and Annex

Design Conditions

Heat Load = 520,000 BTUH
Average Temperature Drop = 40°F
% Design Heat Load with Geothermal = 60%
Geothermal Flow Rate = 20 gpm

Building Description

This older concrete block building houses the city offices, the city council room, and the city police department. The building has approximately 5,700 square feet in two stories. The equipment room is located in the basement.

Heating System

The heating system in the building was originally designed for radiant steam heating. In 1950, it was converted to a hot water system with the installation of a US Radiator Co. (Model 25-7) hot water boiler. However, many of the steam radiators are still used as terminal heating units. About 9% of the total heating load is provided by electrical resistance heating in the police annex. The system is designed to operate with 180°F hot water.

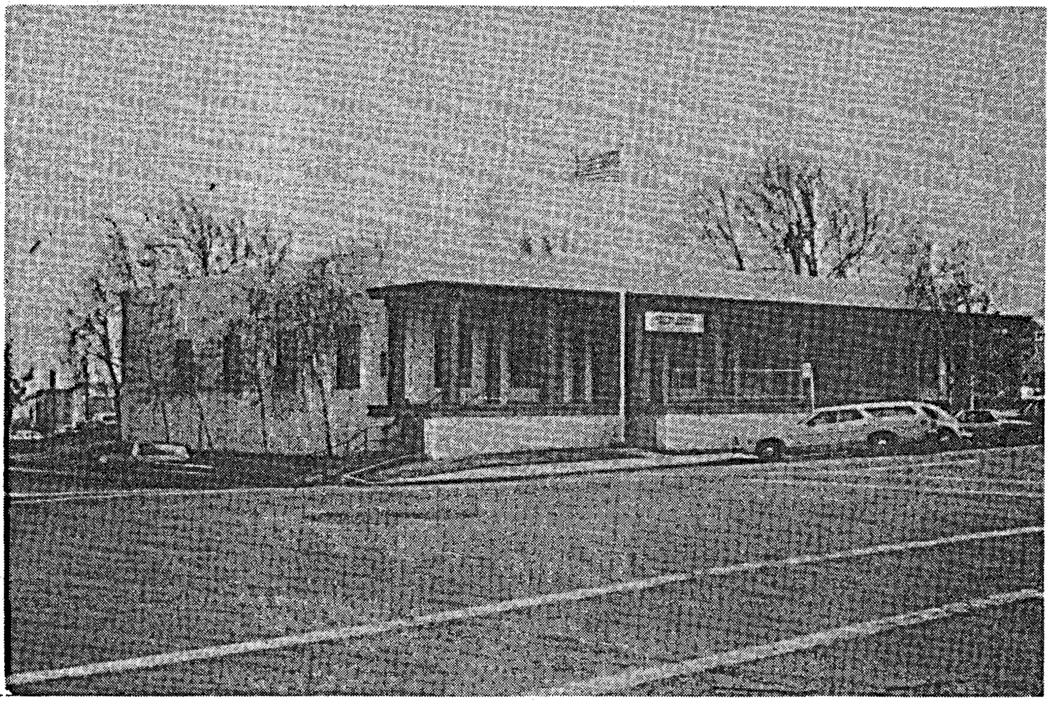
Cooling System

None

Conversion to Geothermal

The current heating system should be extensively modified, as shown in Figure 5. The hot water (steam) radiators should be replaced with convective baseboard units. The boiler arrangement should be improved by changing the location of the hot water circulation pump and expansion tank and by providing a duct for outside combustion air. After this modification, the geothermal system can be integrated in somewhat similar fashion to that used for the hospital.

II.A.2 U.S. Post Office



Design Conditions

Heat Load = 320,000 BTUH
Cooling Load = 240,000 BTUH
Average Temperature Drop = 30°F
% Design Heat Load with Geothermal = 60
Geothermal Flow Rate = 16 gpm

Building Description

This cement block building contains about 5,700 square feet in one story plus a basement. The equipment room is in the basement.

Heating System

The building is heated by a hot water boiler (Burnham BR-34HP-B5909) which burns C-2 fuel oil. Heating is by a combination of converters and hot water coils in an forced air system. The current boiler was installed in 1965. It burns C-2 fuel oil.

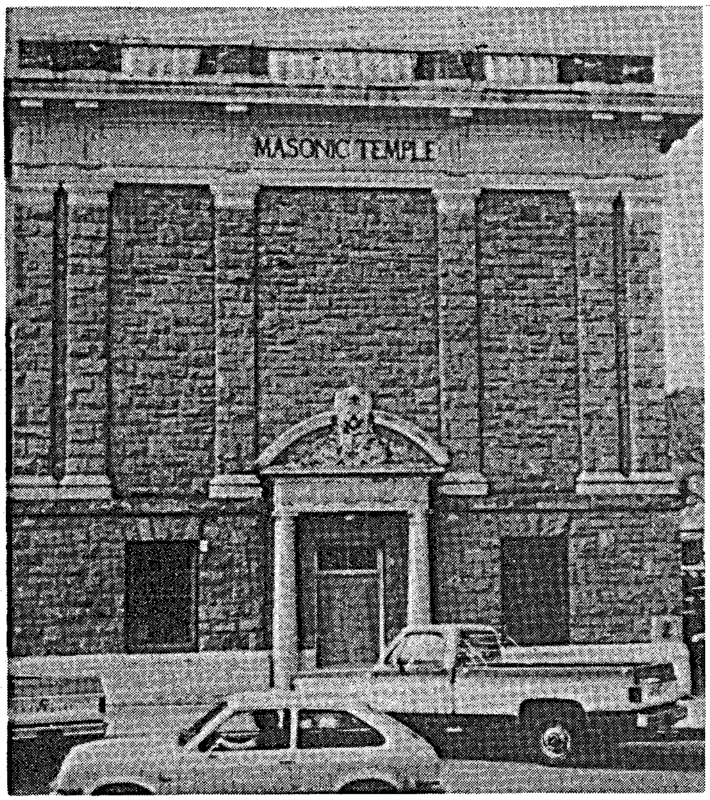
Cooling System

Approximately 20 tons of A/C is supplied by four Trane units (Types 167-17A,55,52). These units would not be replaced in the geothermal conversion.

Conversion to Geothermal

This hot water system can be converted to geothermal using the previously mentioned standard hot water system conversion approach. (Figure 1)

II.A.3 Masonic Temple and Sanitation District Office



Design Conditions

Heat Load = 360,000 BTUH

Average Temperature Drop = 30°F

% Design Heat Load with Geothermal = 60%

Geothermal Flow Rate = 18 gpm

Building Description

This older (1924) cement block and cut stone building is used as a meeting hall and houses the sanitation district offices. It has approximately 6800 square feet in two floors.

Heating System

The building is heated by a hot water boiler (Aire-Ray-ator, F-4207) which provides heat to a forced air system. This boiler burns C-2 fuel oil.

Cooling System

None

Conversion to Geothermal

This building can be adapted to geothermal by using the standard hot water system conversion approach, as shown in Figure 1. No major problems are expected.

II.A.4 U.S. Forest Service

Design Conditions

Heat Load = 610,000 BTUH

Average Temperature Drop = 40°F

% Design Heat Load Geothermal = 65%

Geothermal Flow Rate = 23 gpm

Building Description

This two story building is constructed of cement block on the first floor, which is partly used for parking, and is frame construction on the second floor, which houses the offices. The total occupied building space is about 18,100.

Heating System

This building is heated by four Mueller Climatrol heating and cooling modules. Heating is provided by a direct fired air heater. C-2 fuel oil is used. Two units each have an output capacity of 200,000 BTUH and 104,000 BTUH.

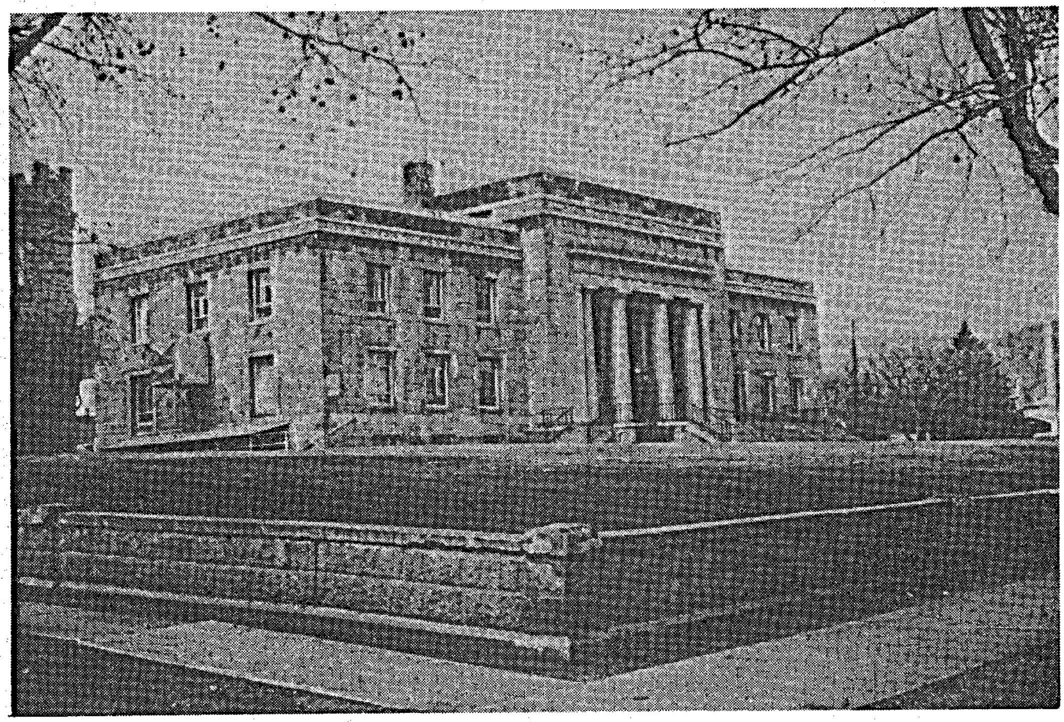
Cooling System

Cooling is provided by means of an evaporative coil in the Climatrol module. The compressors and condensers are external to the forced air unit.

Conversion to Geothermal

New hot water heating coils and controls would have to be added to the forced air ducting in this building. The equipment room is located downstairs at the end of the building and has ample room for these additions. The existing oil forced system would be integrated into the geothermal system and used for peaking and backup to the geothermal system.

II.A.7a County Courthouse



Design Conditions

Heat Load = 1,260,000 BTUH

Average Temperature Drop = 30°F

% Design Heat Load Geothermal = 60%

Geothermal Flow Rate = 63 gpm

Building Description

This old three and one-half story building was constructed of cement block in 1915. It has a floor space of approximately 22,000 square feet. The equipment room is in the basement. This room contains the old steam equipment which has been converted to a hot water system.

Heating System

This building is heated by hot water produced in an older National Steel Boiler, Model Number C-4275 which has been converted to burn C-2 fuel oil. The rooms are heated by hot water flowing through old steam radiators. This system is not a flow through system; the hot water in the radiators is not returned to the boiler after use. This system is currently providing adequate comfort for the building.

Cooling System

The top three stories of the building are cooled by forced air evaporative coolers mounted on the roof. There are two units rated at 12,500 cfm and 8500 cfm. The air cooled by evaporation is ducted to the various offices and court rooms.

Conversion to Geothermal

This flow through system could be converted to geothermal by direct connection to the existing system; however, return lines would have to be added to the existing radiators to route the geo-water back to the equipment room. The boiler could then be used as a peaking source by using a plate heat exchanger and a closed heating loop to protect the boiler if necessary.

However, since air ducting exists for cooling, it could also be utilized for heating by replacing the evaporative coolers with a heat pump. This is shown in Figure 7. The existing heating system could remain unchanged for peaking purposes.

II.A.7b City and County Jail

Design Conditions

Heat Load = 1,240,000 BTUH

Average Temperature Drop = 30°F

% Design Heat Load with Geothermal = 60%

Geothermal Flow Rate = 62 gpm

Building Description

This single story building houses the jail facilities for both the city and the county and is a modern structure built around 1968 of cement block. The building has about 7050 square feet of floor space.

Heating System

Heat is supplied to the building by a forced air hot water system. A Burnham hot water boiler burns C-2 fuel oil. This boiler runs all year including the summer to provide space heating and the rather large volume of service hot water for showers, and cleanup.

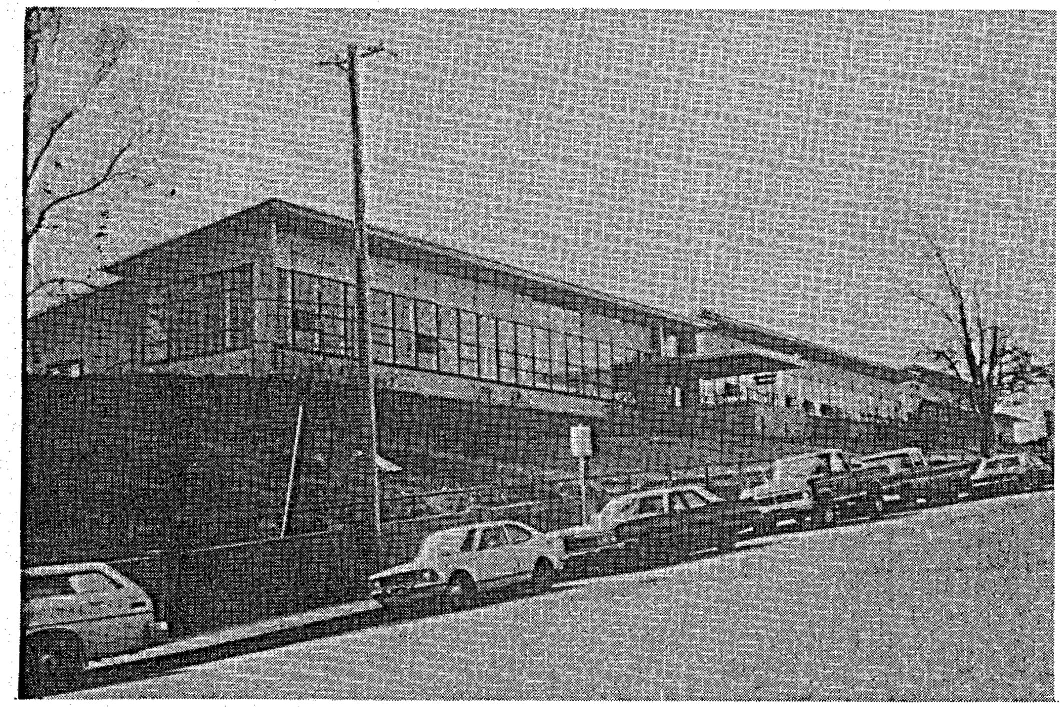
Cooling System

None

Conversion to Geothermal

This more modern hot water system can be easily converted to geothermal using methods similar to that proposed for conversion of the other forced air hot water systems. Similar to the Forest Service building, hot water coils would be added to the existing hot air ducts, this is shown in Figure 8.

II.A-8 Washington School



Design Conditions

Heat Load = 500,000 BTUH
Average Temperature Drop = 30°F
% Design Heat Load with Geothermal = 60%
Geothermal Flow Rate = 25 gpm

Building Description

This elementary school was built in 1948 of concrete and frame/stucco construction. The building contains about 11,600 square feet in one floor. The building is being phased out as a school and is being considered for use as public offices for the city or county.

Heating System

Heating is provided by recirculating hot water through copper radiant floor pipes. Temperature is controlled by the addition of ventilation air via a forced air fan system. The boiler operates at a relatively low temperature, 110°F in and 140°F out. An American Water Tube Boiler burns C-2 fuel oil to provide the hot water for the system.

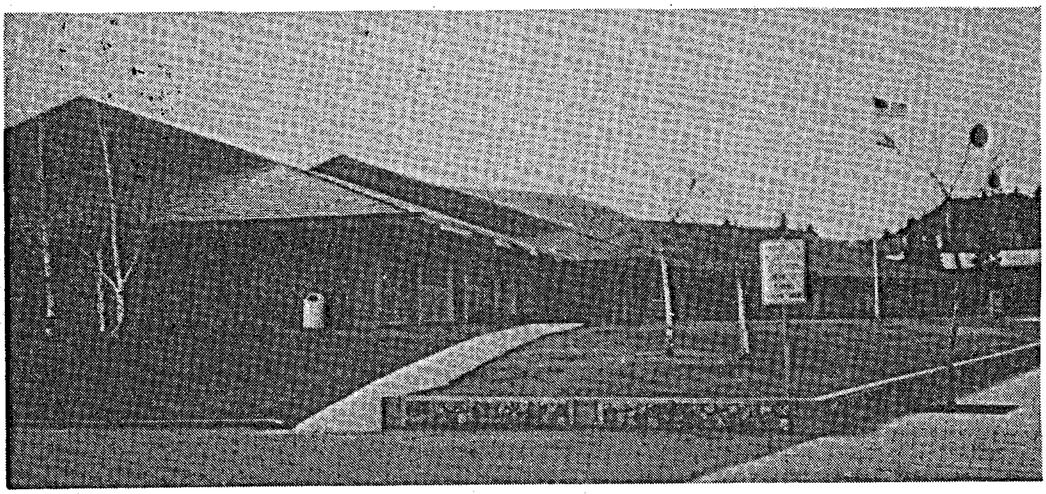
Cooling System

Cooling is provided during the summer by circulating city water through the radiant floor tube and the hot water coils in the forced air system.

Conversion to Geothermal

Geothermal water can be used directly in the radiant floor system as long as it is compatible with the copper pipes. The geothermal system would be a flow through system and could be peaked with the existing boiler as necessary, as shown in Figure 4.

II.B-1a Lassen Union High School



FRONT VIEW

REAR VIEW

<u>Design Conditions</u>

Heat Load = 6,540,000 BTUH

Average Temperature Drop = 32°F

% Design Heat Load with Geothermal = 50%

Geothermal Flow Rate = 415 gpm

Building Description

This large high school complex consists of seven major buildings. (Figure 11) These buildings are all single story frame and stucco construction. Unit 1 contains the administration offices and classrooms and is a large "V" shaped building facing onto Main Street. Behind this building is Unit 2 containing the music center, student center, and the library. To the left of this building is the Boy's Gym. The heating plant equipment room is in the Southwest corner of this building. Unit 3 is located right behind Unit 2 and is primarily a classroom building. To the left of Unit 3 is the Girl's Gym (Unit 4). To the right is the auto, agriculture, and wood shops (Unit 5). To the right of Unit 1 is a classroom building (Unit 6) which was the original high school building. This building has its own heating system. Next to Unit 6 is a greenhouse which could also be adapted to geothermal.

Heating System

Units 1 through 5 and the Boy's Gym are heated by the steam boilers located in the Boy's Gym. The boiler room contains two Kewanee Boilers, Type C, which burn P300 fuel oil (C-3). Additionally, the Boy's Gym and the Shop have direct fired space heaters which burn C-2 fuel oil. 15 psig steam produced on the boiler plant is piped to Units 1 through 5 where it is heat exchanged with a recirculating hot water loop. The hot water is used for space heating either in the heating coils in the forced air systems or with a small amount of modern convective baseboard heaters.

Service hot water for the boys and girls showers is heated by steam coils in large hot water tanks. (940 gallons in the boys gym.)

Cooling System

None

Conversion to Geothermal

Utilization of a heat pump was discussed in detail in Section B with schematic options shown on pages 68 and 70. In addition to a heat pump, candidate conversion systems could utilize the geo-water directly in the existing hot water system. Two such systems are shown in Figure 9; one utilizes the geo-water only circulated through the central equipment room while the other supplies geo-water to each building.

II.B-1b Lassen Union High School District Office

Design Conditions

Heat Load = 210,000 BTUH
Average Temperature Drop = 30°F
% Design Heat Load with Geothermal = 100%
Geothermal Flow Rate = 14 gpm

Building Description

The small frame building (3240 square feet) is located in the Southeast corner of the high school complex. It is a small office building which is poorly insulated.

Heating System

This modern building is heated by two unitary forced air direct fired heaters (Lennox G8). These heaters burn propane.

Cooling System

An evaporative cooler mounted on the roof is used to provide cooling in the forced air system.

Conversion to Geothermal

Hot water heating coils would be added to the forced air ducting in this system. The coils would be sized to handle the peak heat load to totally remove the dependence on propane for the building.

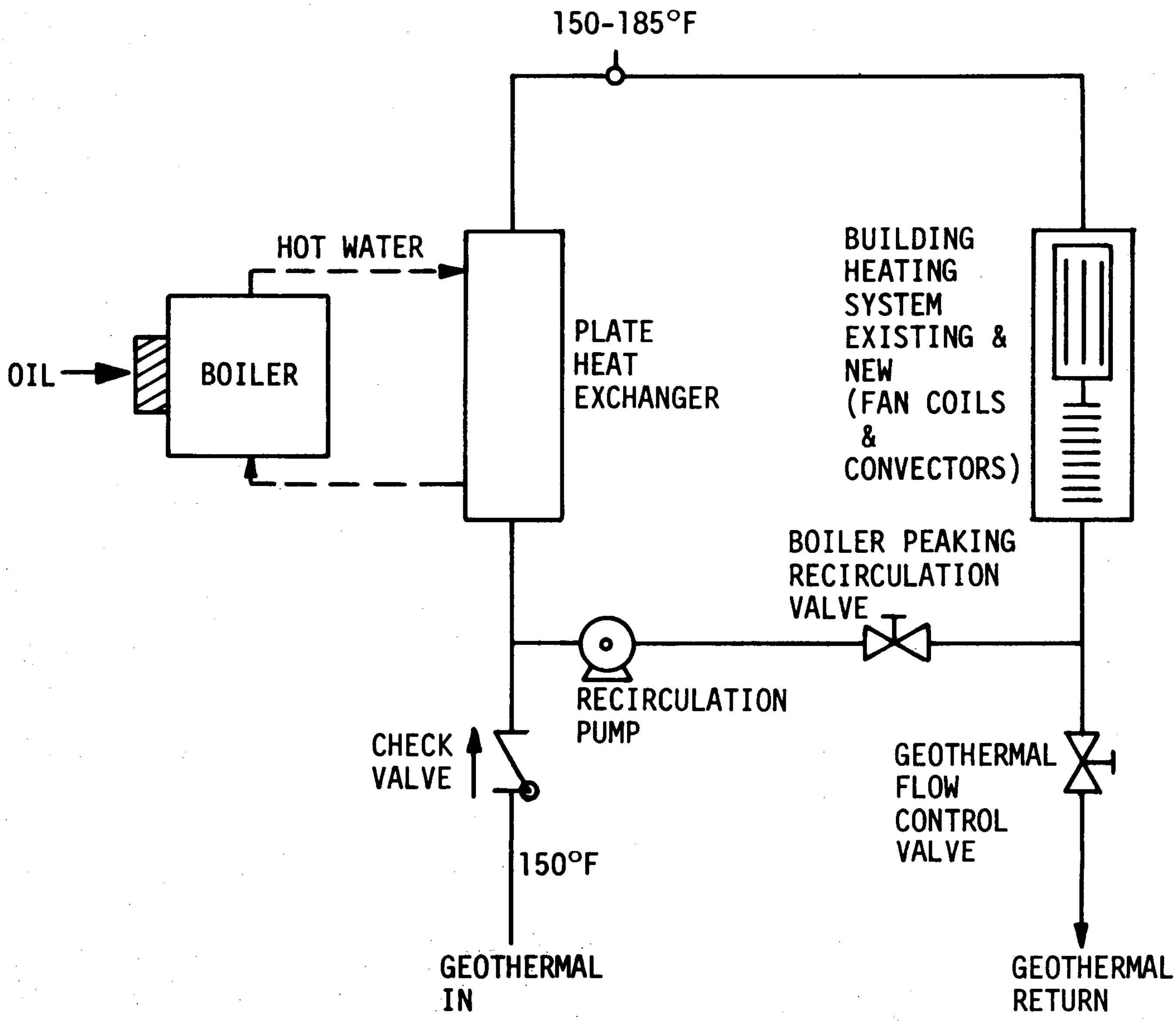
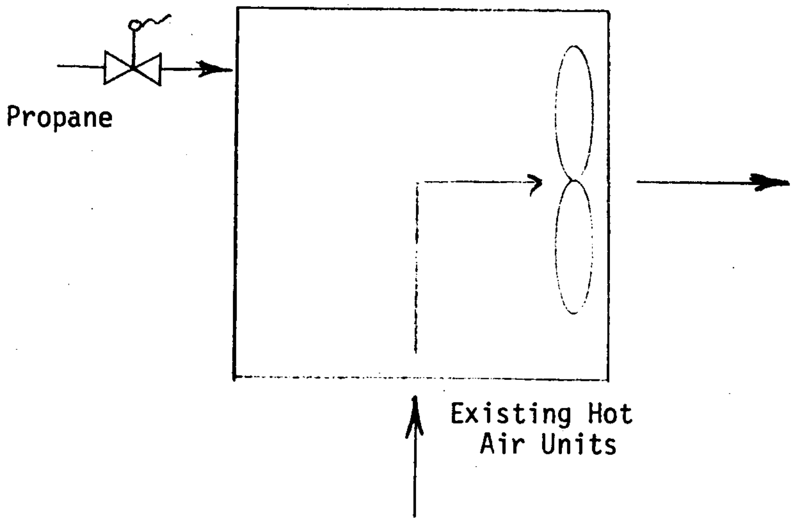


Figure 1. Candidate Approach for Adaptation of Hot Water Boiler Systems

FIGURE 2

Candidate Approach - Geo-Water
Coil-Fan Units

CURRENT



CANDIDATE MODIFICATION

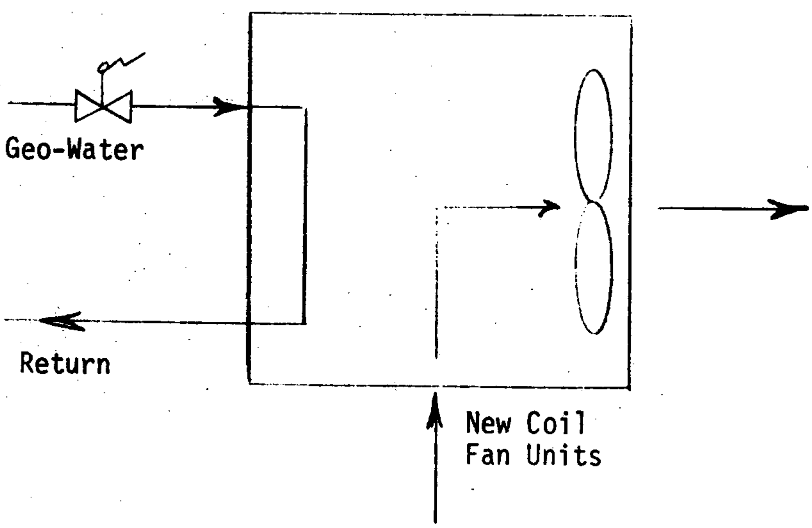


FIGURE 3

Candidate Approach - Hot Air
And Finned Convector Options

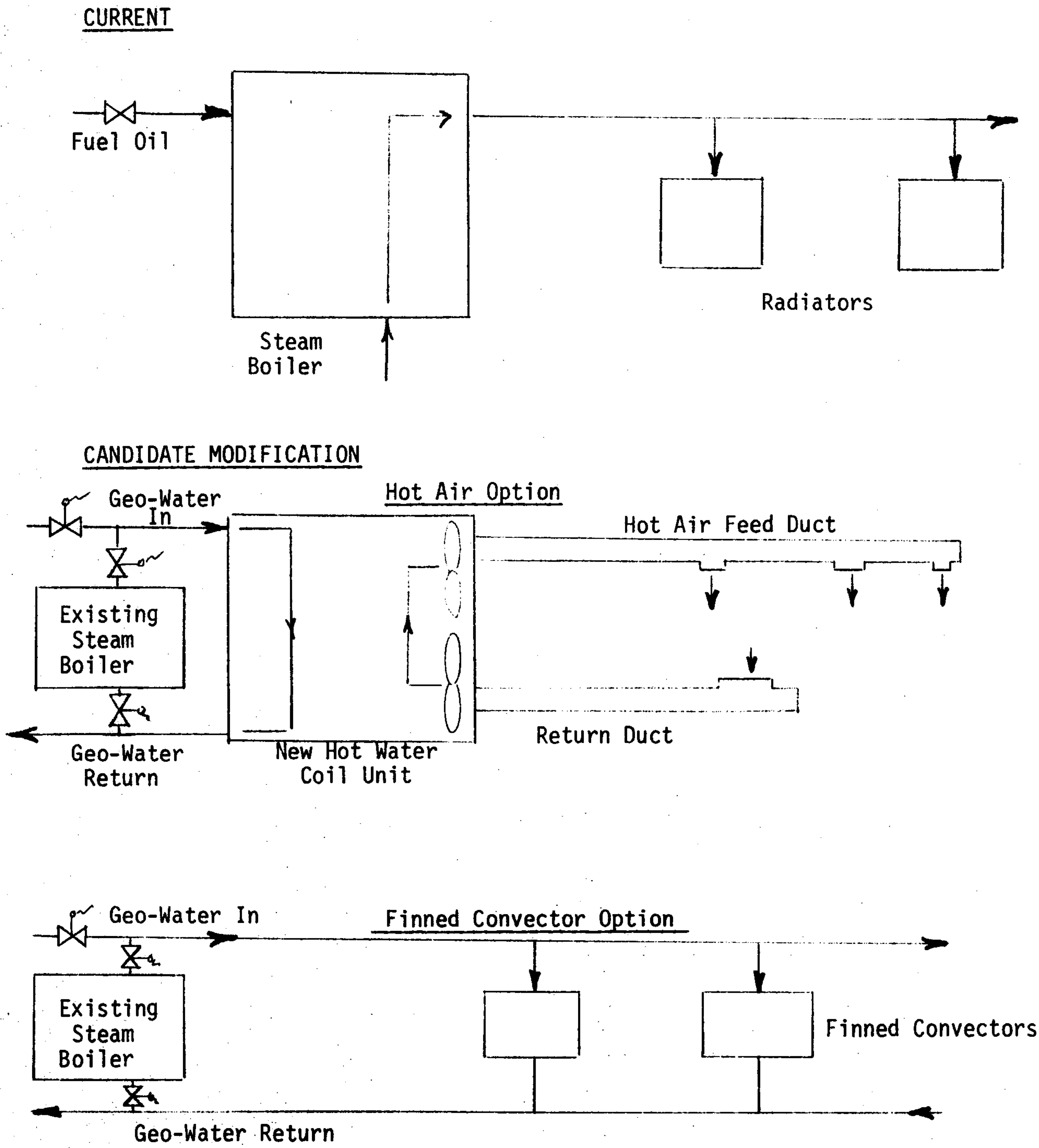
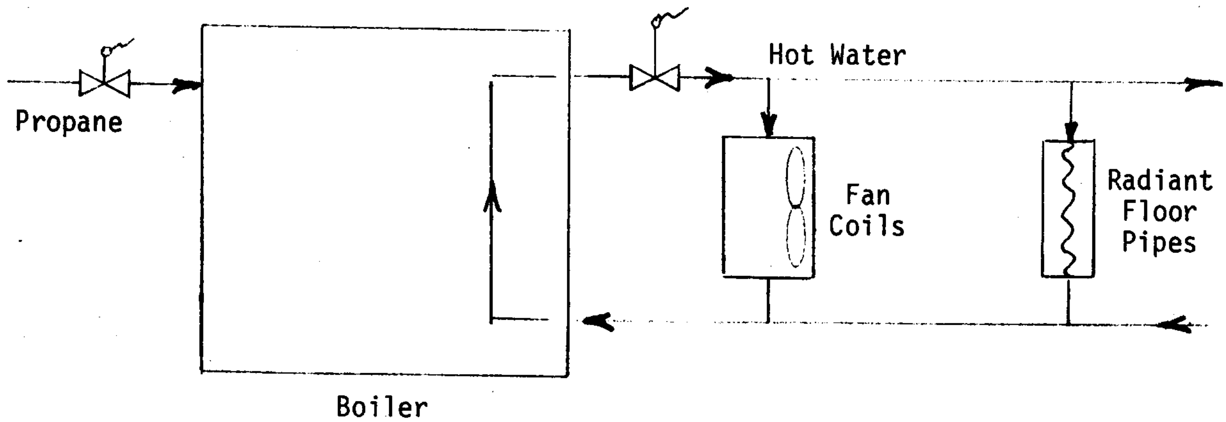


FIGURE 4

Candidate Approach - Geo-Water
Connection to Existing System

CURRENT



CANDIDATE MODIFICATION

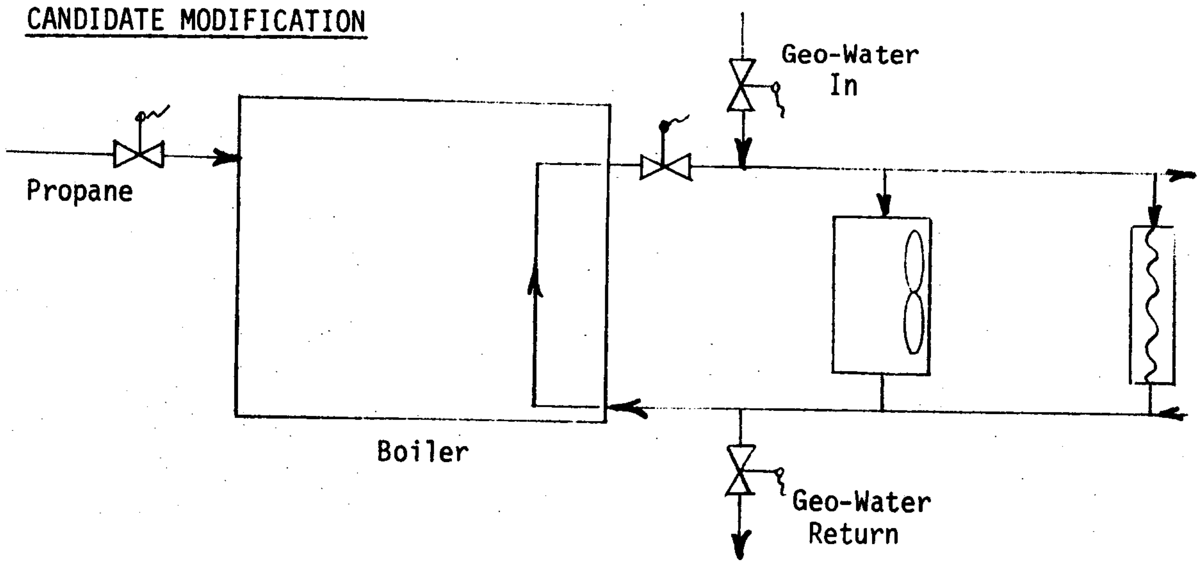


FIGURE 5

Candidate Approach - City Hall
Heating System Modification

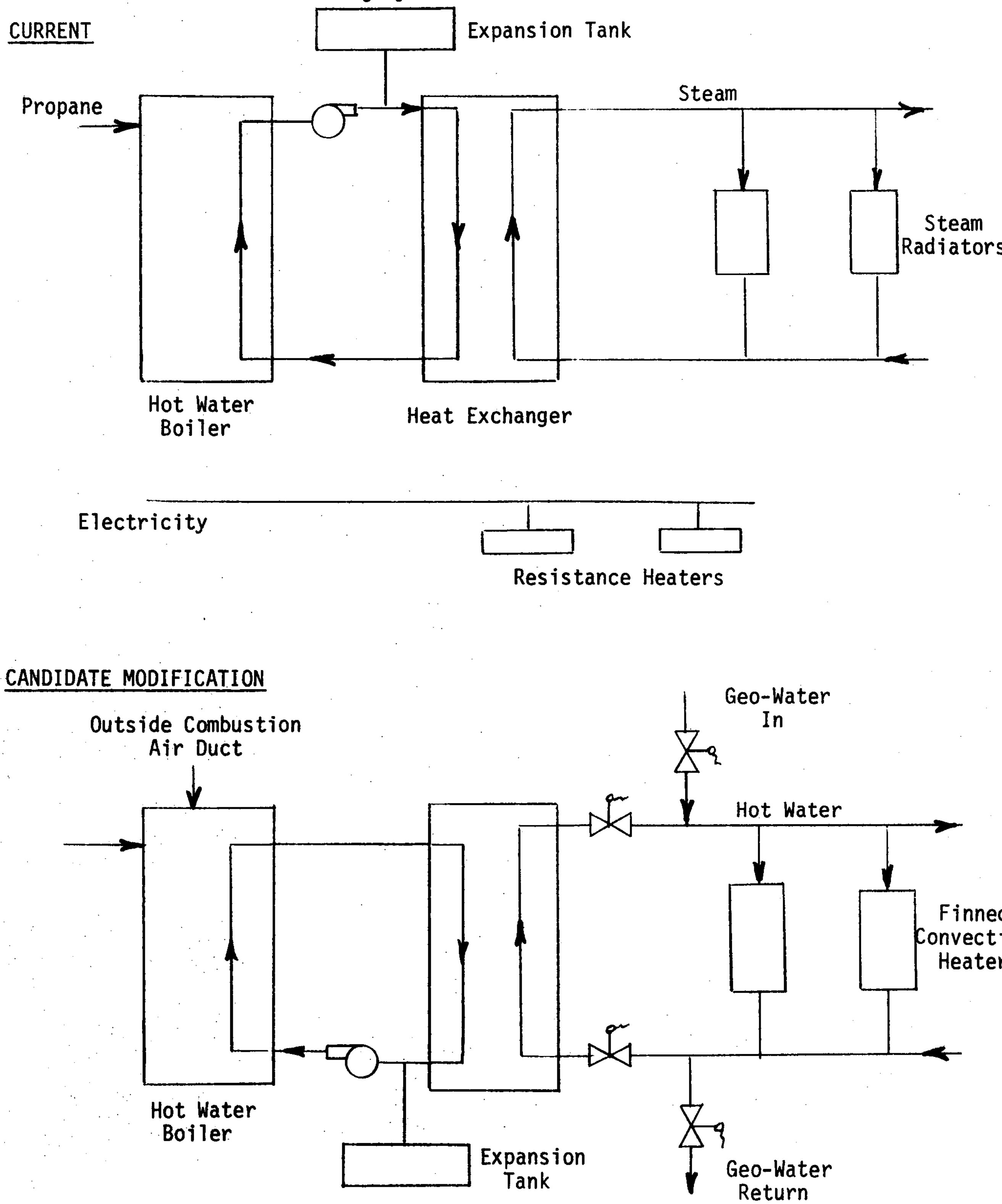
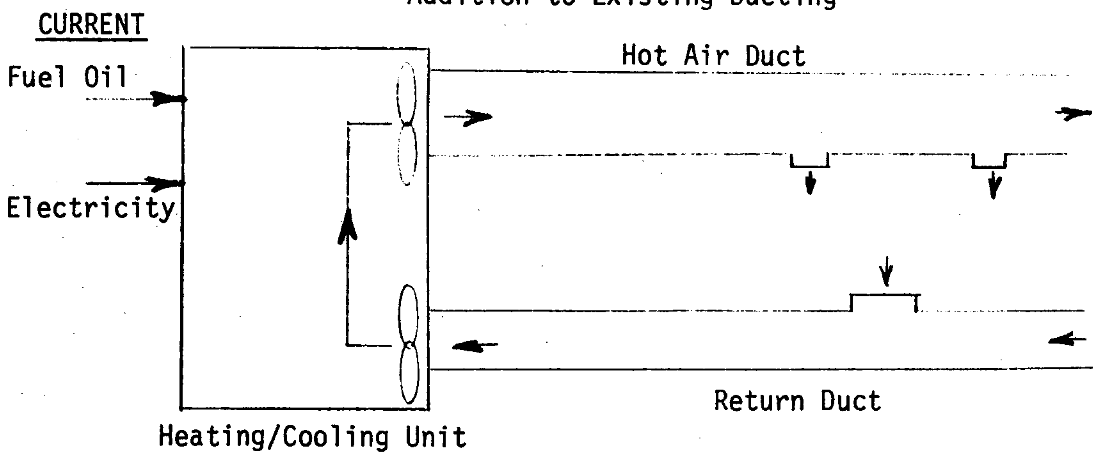


FIGURE 6

Candidate Approach - Hot Water Coil Addition to Existing Ducting



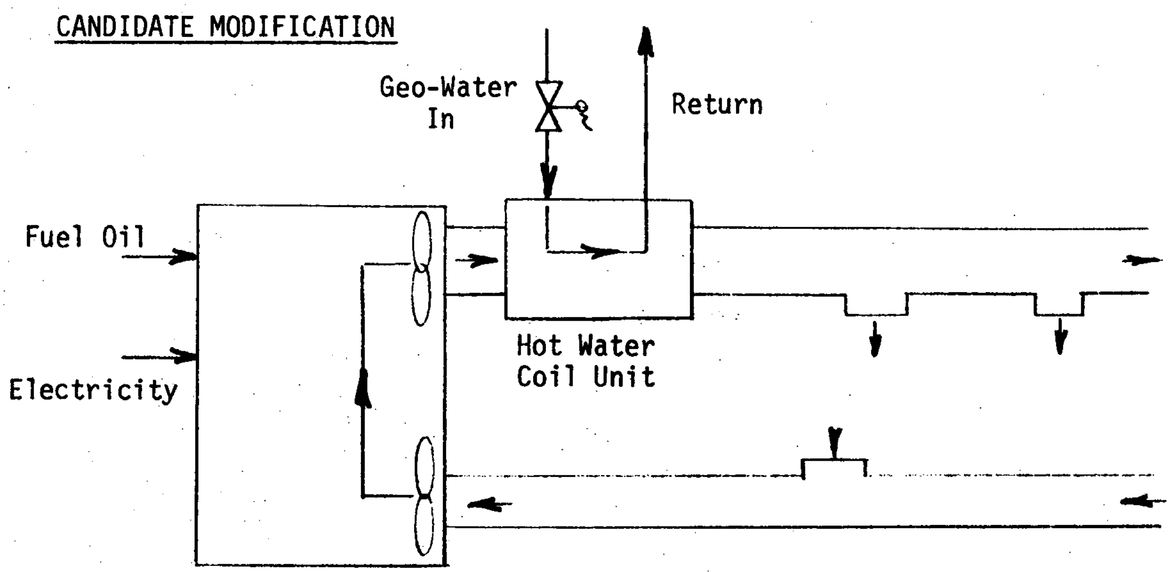
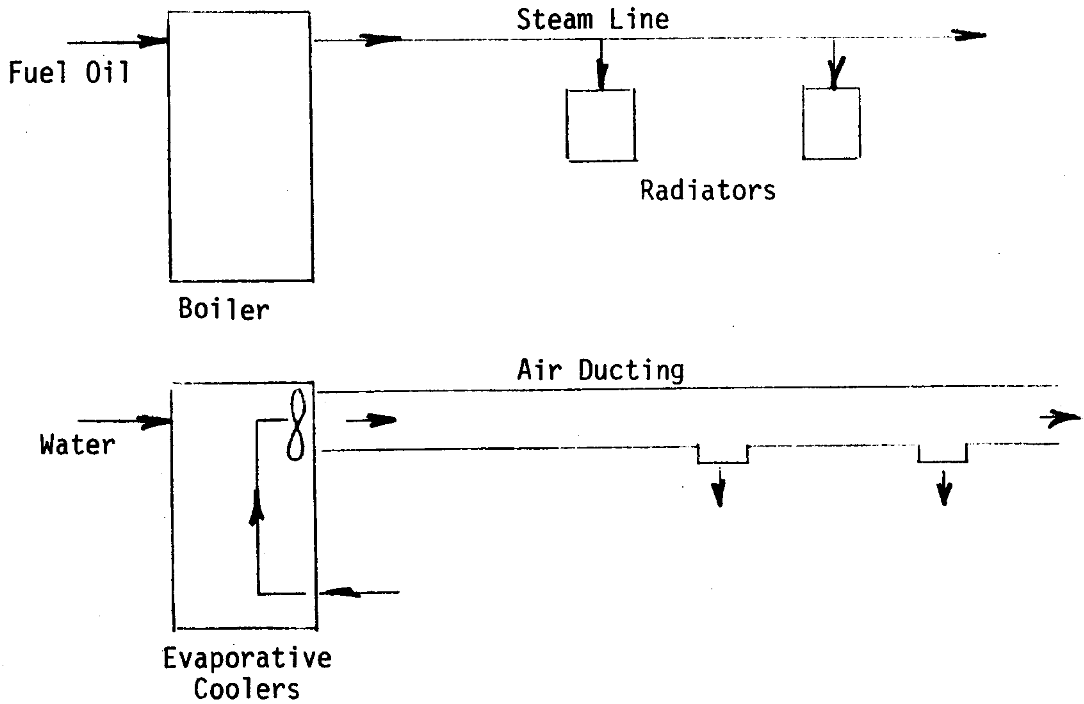


FIGURE 7

Candidate Approach - Heat Pump
Installation to County Court House

CURRENT



CANDIDATE MODIFICATION

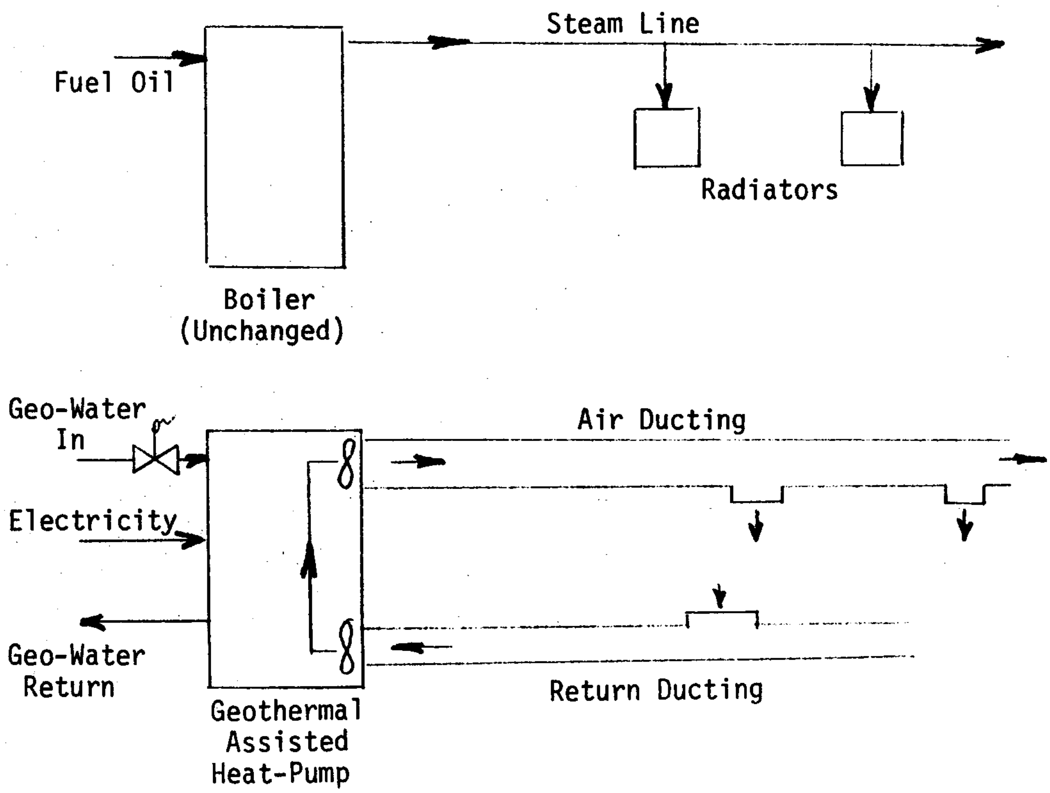
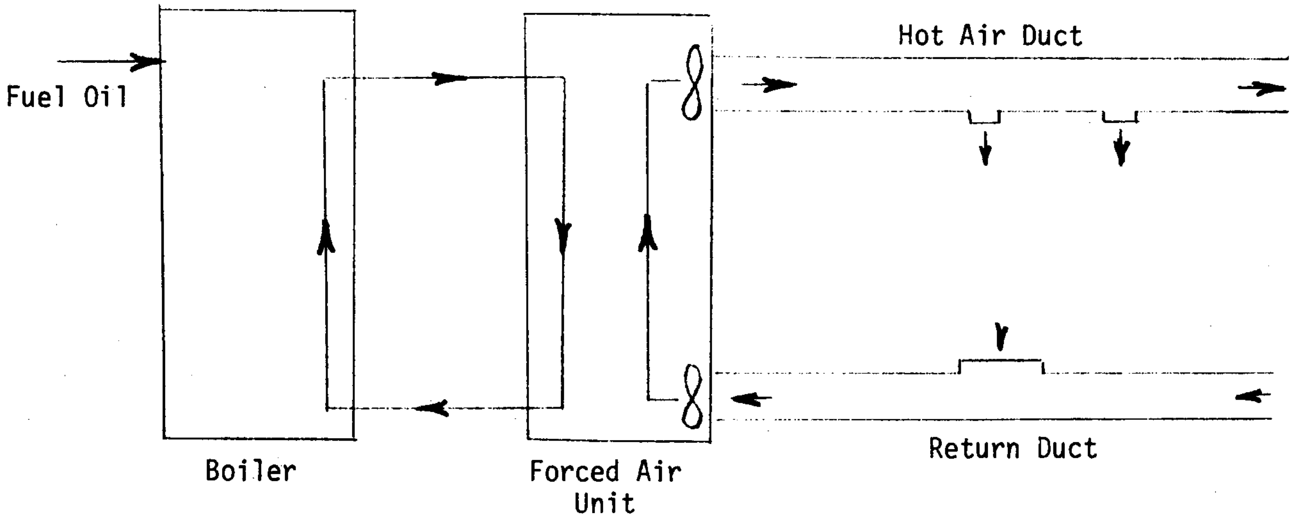


FIGURE 8

Candidate Approach - Geo-Water
Coil Addition to Air Duct

CURRENT



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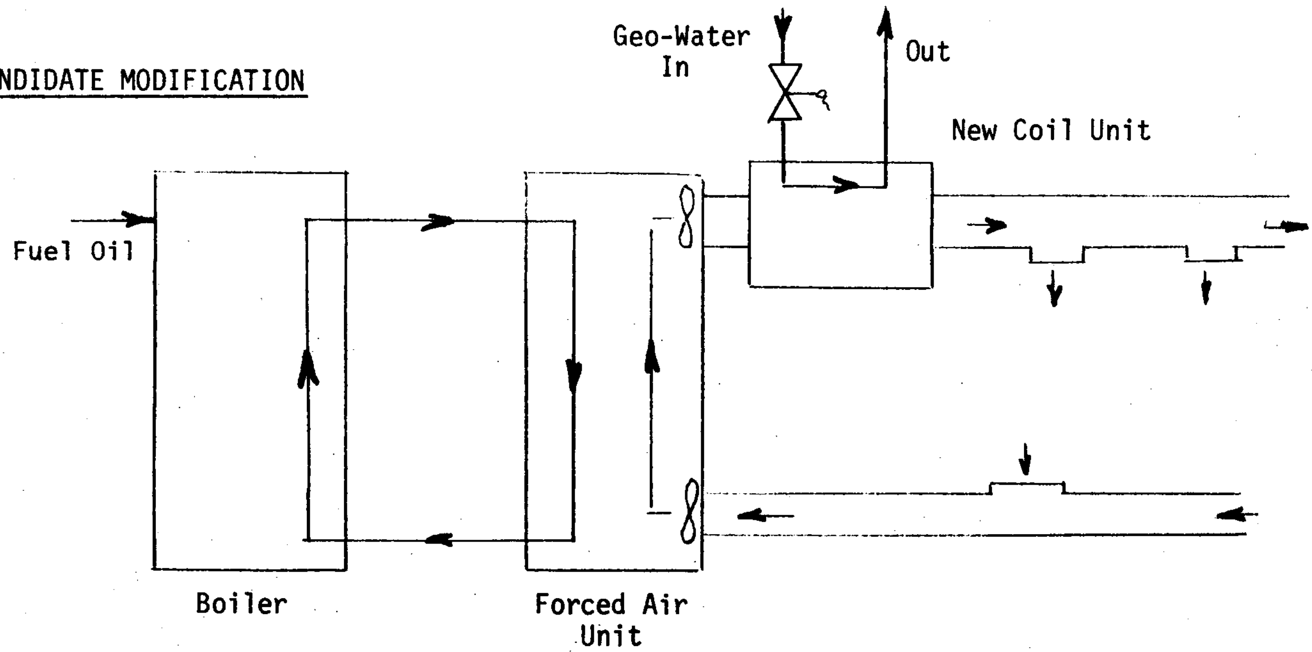


FIGURE 9

Candidate Approach - Lassen Union High School
Geothermal Heat Pump System

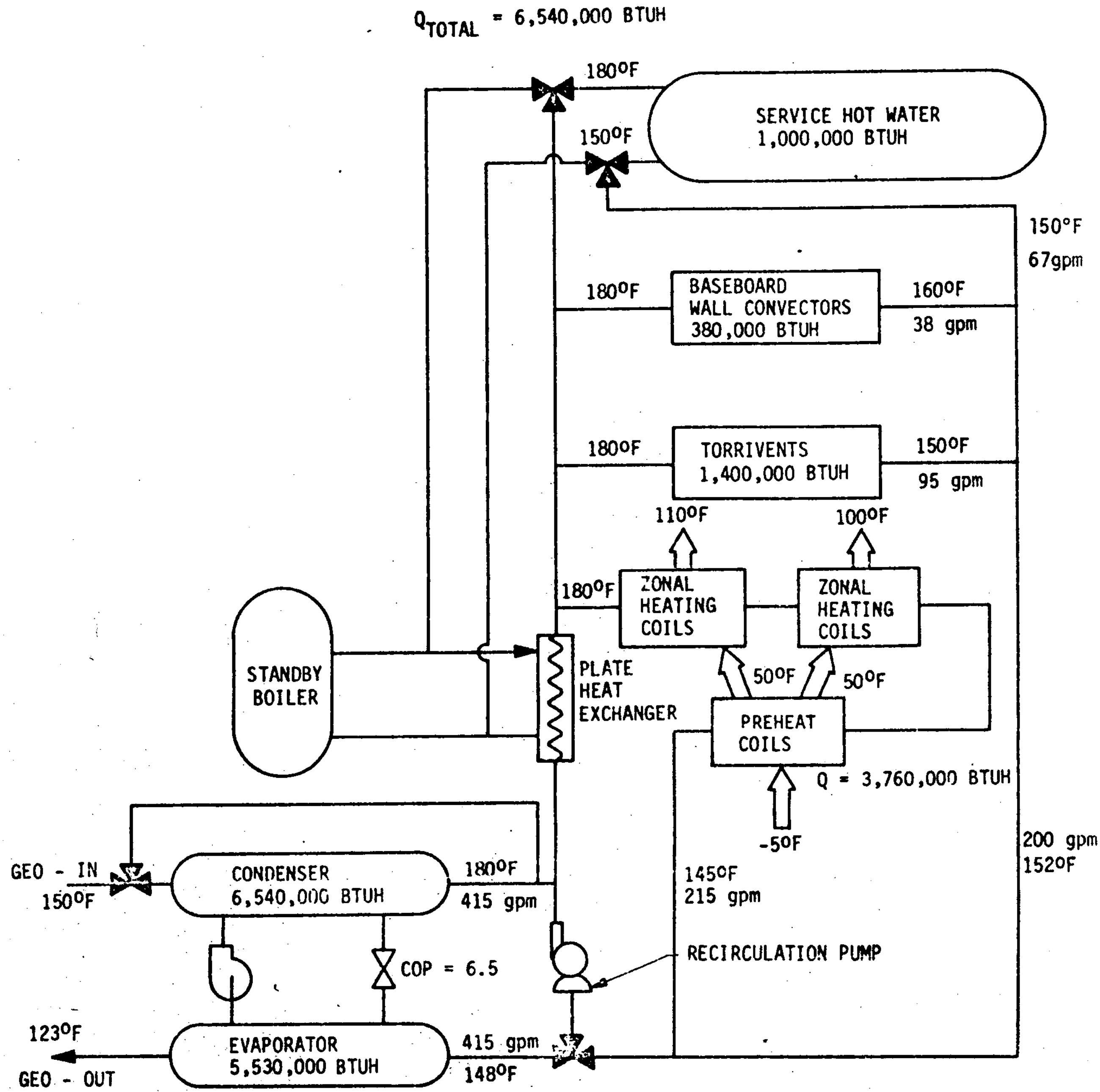
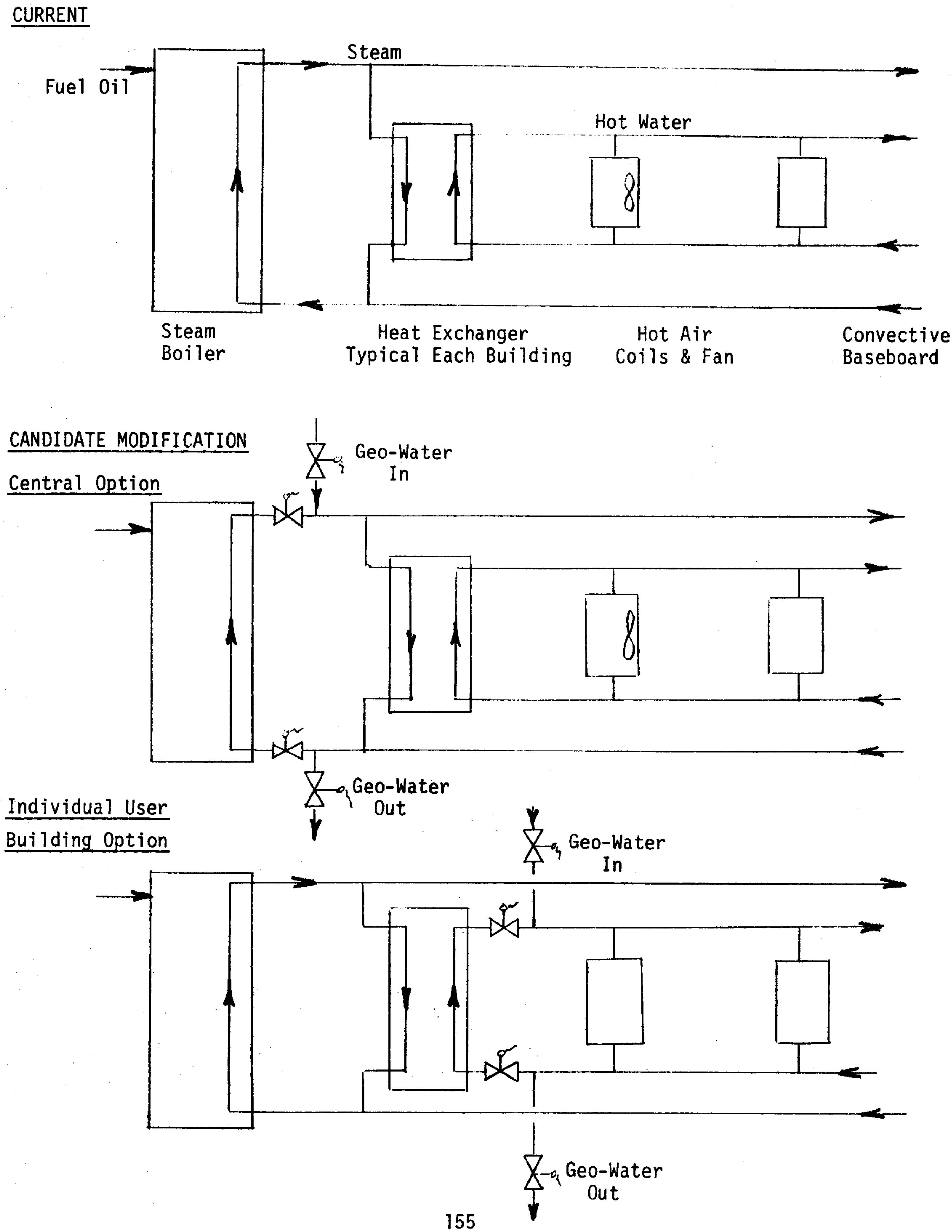


FIGURE 10

Candidate Approach - Direct Connection to Existing High School Hot Water System



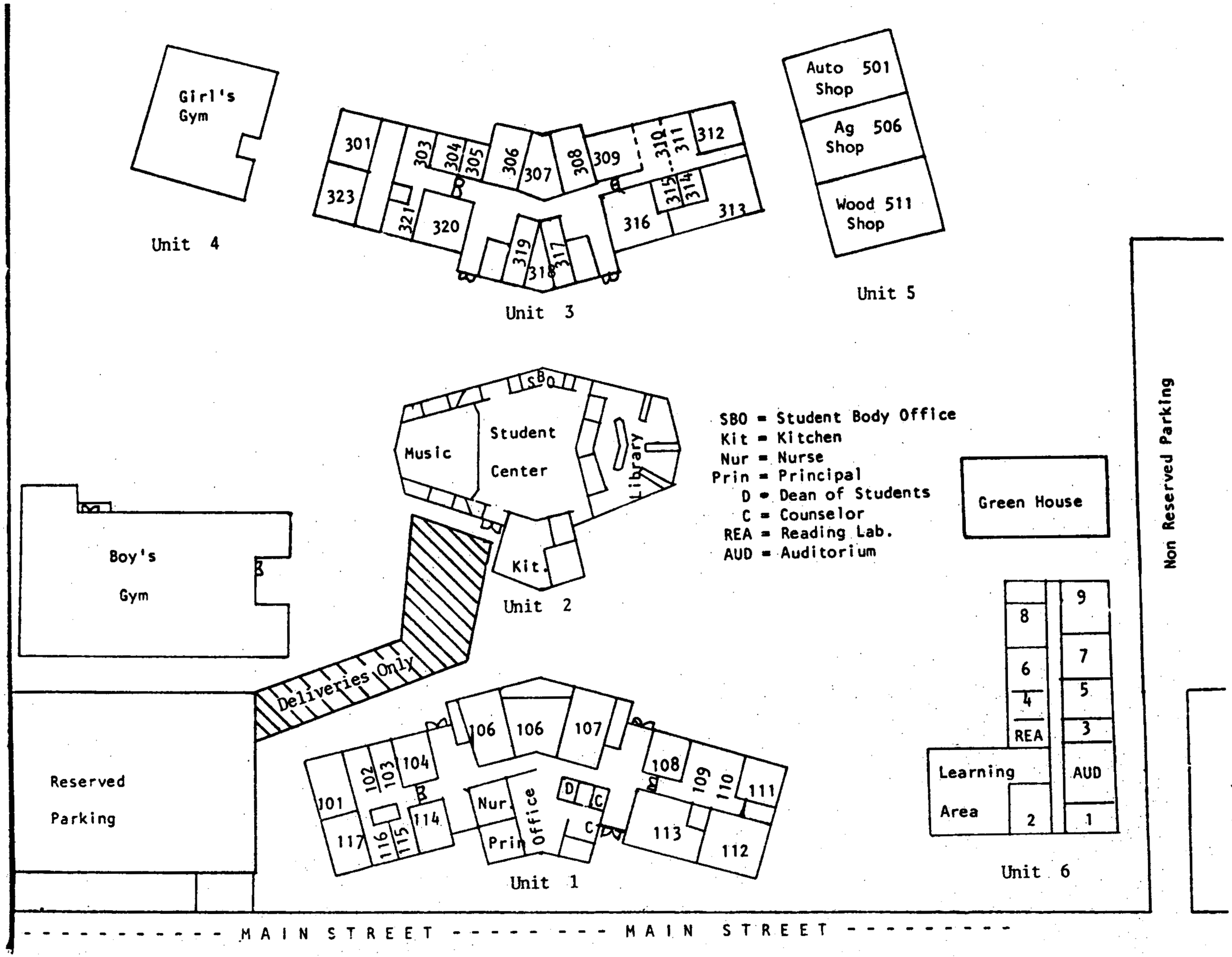


Figure 11. Lassen Union High School

APPENDIX B

PRELIMINARY PARK OF COMMERCE DESIGN

1.0 GENERAL DESCRIPTION

The Park of Commerce (P.O.C.) industries were selected after a survey by the Fred Longyear Company on companies which would be interested in relocating or starting new businesses in Susanville. Two businesses were selected. A greenhouse operation producing potted plants and a hog and rabbit feed and meat production facility producing meat products and animal by-products. A complete description and the energy requirements of these complexes is presented in Section II.A.5.

2.0 BUILDING HEATING AND COOLING LOADS

The industry survey defined the size and types of buildings and greenhouses which would be used in the P.O.C. Industry and ASHRAE data were used to calculate the heating and cooling loads for these structures. in Susanville.

The greenhouse heating loads were calculated using design data provided by the U.S. Department of Agriculture (Reference 12) in conjunction with Susanville weather data. The total heating load is a combination of conduction and infiltration heat losses. The same climatological data used in the design of the public building systems applies (Section II.A.3). The basic 1.25 acre module would have a design heat load of 4.0 million BTUH.

The heating and A/C loads for the meat production facility were calculated based on design data for insulated steel buildings. The six heated buildings would have a total design heat load between 2.0 and 4.0 million BTUH depending on the ventilation requirements, and the number of windows and doors. The larger value was selected for the system design.

3.0 PROCESS HEATING AND REFRIGERATION LOADS

The greenhouse industry's only process heating load is for soil sterilization. This load requires 180°F temperatures and was not included because it assed to be small relative to the other loads. It should be considered in more detail in the next design iteration. The process heat loads for the meat production facility were supplied by the potential developers. However, these numbers are preliminary also and would be refined in the next design phase. The refrigeration loads for the slaughter and break operations were also specified by the developer while the other loads were calculated from industry design data. These loads are presented in Table A-6 and A-7 in Section II.A.5.

4.0 ENERGY CASCADE

For the meat production industry, the total energy load was divided among the various processes using data collected by the industry (Reference 5), particularly for the slaughter and break operation. These data were used in the development of an energy cascade for the geothermal system to efficiently utilize the resource - maximizing the temperature drop and minimizing the flow (Figure 1).

The slaughter and break operation requires the highest temperatures, therefore it heads the list in the cascade. From this operation, the 178°F effluent is used for feed drying in a tunnel dryer, and space conditioning (heating) of the metal buildings. The effluent would leave this industry at an average of about 112°F.

The greenhouse heating system was also designed to maximize the utilization of the geothermal resource. The system was designed so that 60% of the design hourly heat load could be provided by 150°F geothermal water. The remaining load would be obtained by increasing the temperature

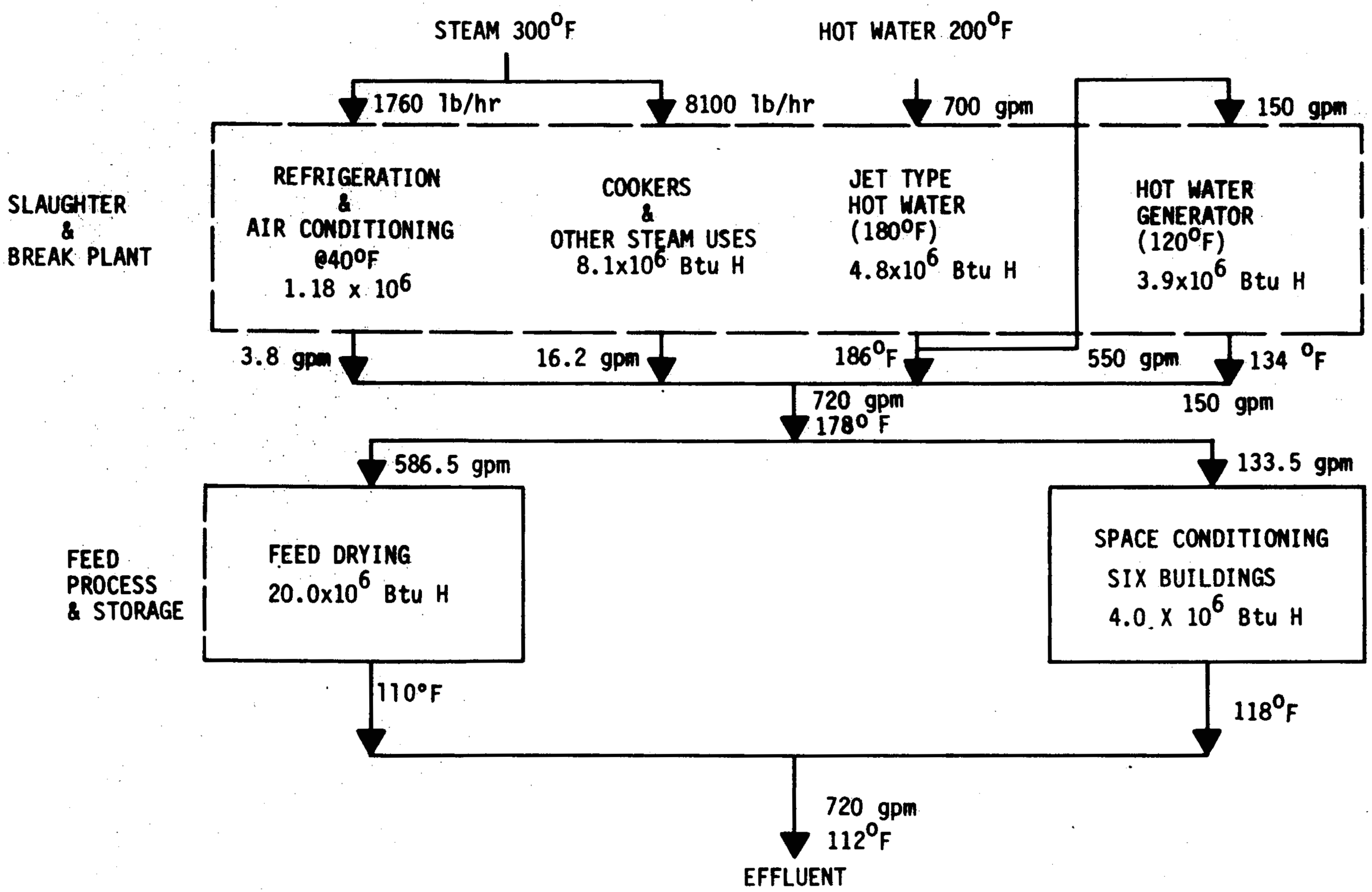


Figure 1. Integrated Meat Plant Energy Cascade

at the same flow to 190°F by peaking with either the electric heat pump or a fossil fueled hot water boiler. Each 1.25 acre greenhouse module is divided into seven (7) gable connected units, 24 feet wide and 325 feet long. These units would be serviced by a heating system installed in each end with the heat ducted by a central pipe down the middle. Commercial data was used to select two coils in series and eight PVC heating pipes located under the benches as the best approach for these greenhouses (Figure 2). There would be a total of 14 of these systems for each 1.25 acre module.

The 150°F geothermal water would heat the output air to about 76°F and have an effluent temperature of 95°F. The peaked hot water at 190°F would heat the output air to 85°F and leave at 98°F. A design flow rate of 6.25 gpm per heating system would be required. Five acres of greenhouses could be heated with 350 gpm.

5.0 CENTRAL PLANT DESIGN

Using the energy requirement and energy cascade data, the central utility plant for the P.O.C. was designed for the two basic alternatives. An all fossil fueled system was designed using oil fired boilers to provide the energy requirements (Figure 3). For energy conservation, this system was designed with recirculation. The size and cost of the major components in the system are presented in Table 1. The total installed cost for the major equipment is estimated from manufacturers data to be about $370,000.

The geothermal system was designed to use the effluent from the public buildings to maximize the utilization of the resource. The results of the conceptual design are shown in Section II.B.2., Figure B-4, in this system, the public building effluent is used as feed water to the boilers and to the heat pump servicing the greenhouse industry. The sizing and costing of the major equipment produced a total installed equipment cost, including one additional production well, of $750,000 (Table 2) or about twice that for the fossil fueled system.

However, a comparison of the annual operating cost of the two alternative central plants (Table 3) shows a cost saving of about $225,000 per year with the geothermal system without considering inflation. This cost savings is due to significant displacement of fossil fuel energy use - $415,000 down to $145,000 per year in going to the geothermal system. On a simple 1978 cost basis, this savings would payback the added investment in the geothermal central plant in less than two years.

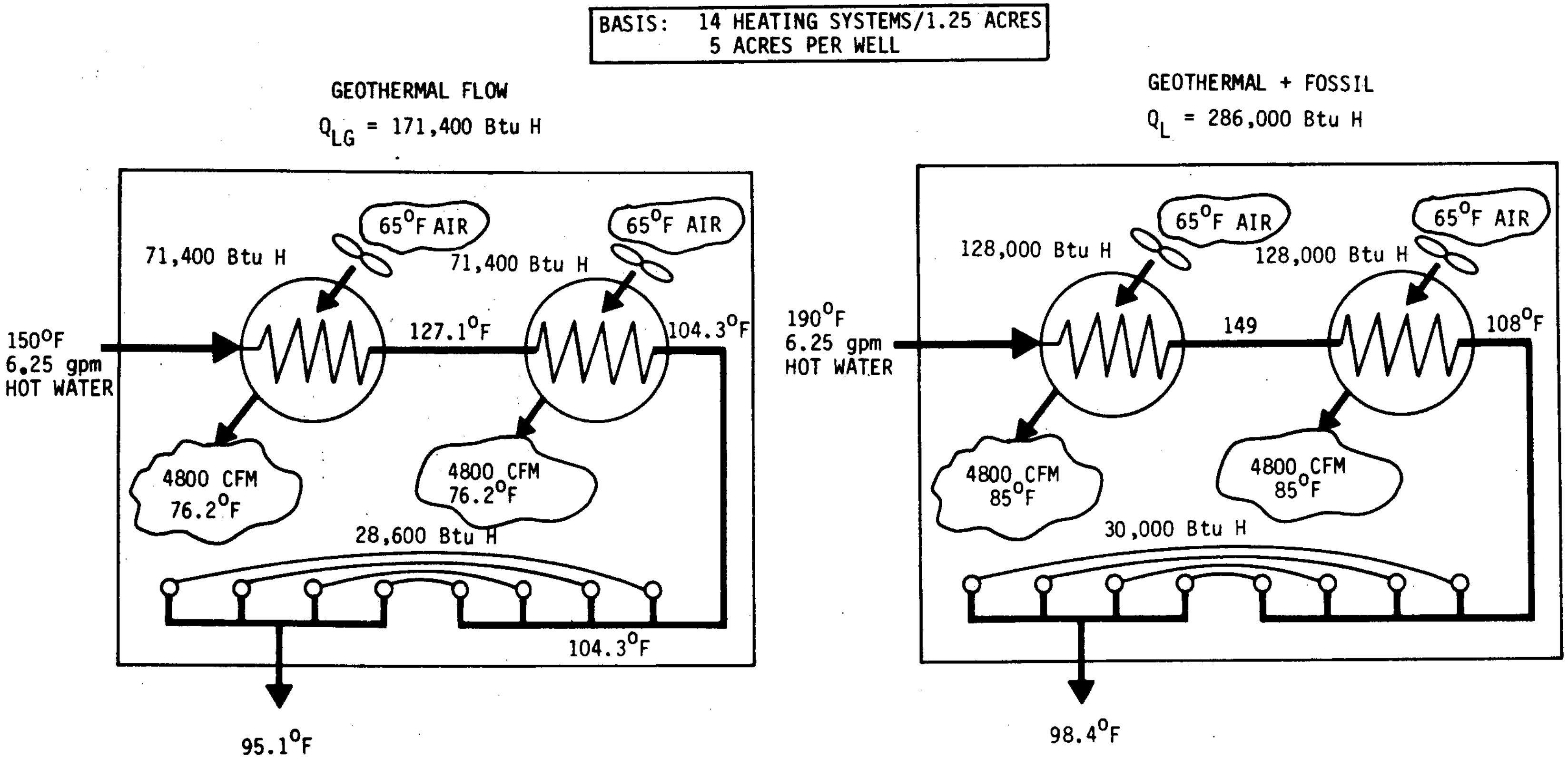


Figure 2. Greenhouse Energy Cascade

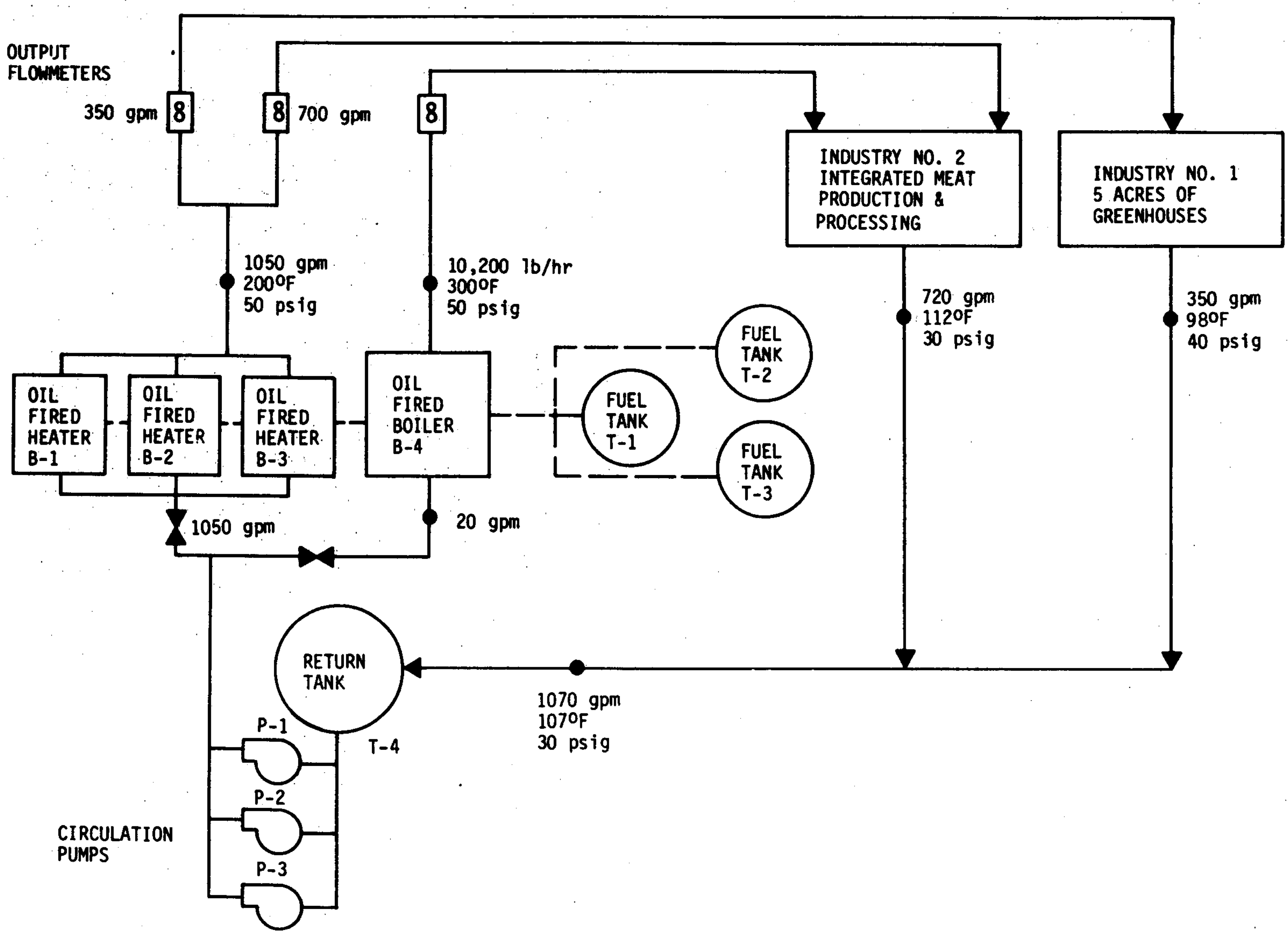


Figure 3. Susanville Park of Commerce Conceptual Fossil Plant Flow Diagram

TABLE 1

EQUIPMENT LIST & CAPITAL COST
CONCEPTUAL FOSSIL PLANT

TAG NO.	MAJOR EQUIPMENT	CAPACITY	EFF.	INSTALLED SIZE	UNITS	CAPITAL COST 1978 $	INSTALLATION COST	TOTAL COST
	HEATERS & BOILERS							
B-1	Oil Fired Heater	16,000,000	0.8	20,000,000	BTUH	50,000	25,000	75,000
B-2	" " "	"	"	"	"	50,000	25,000	75,000
B-3	" " "	"	"	"	"	50,000	25,000	75,000
B-4	Oil Fired Boiler	10,000,000	0.8	12,500,000	BTUH	56,000	28,000	84,000
	PUMP/MOTORS							
P-1	Pump/Motors	4.50	0.60	7-1/2	HP	1,600	400	2,000
P-2	" "	4.50	0.60	7-1/2	HP	1,600	400	2,000
P-3	" "	4.50	0.60	7-1/2	HP	1,600	400	2,000
	TANKS							
T-1	Fuel Oil Storage	20,000		20,000	Gal	9,200	1,200	10,400
T-2	" " "	"		"	"	"	"	10,400
T-3	" " "	"		"	"	"	"	10,400
T-4	Return Water Storage	64,200		64,200	"	20,000	2,600	22,600
	MAJOR EQUIPMENT TOTALS					258,400	110,400	368,800

TABLE 2

EQUIPMENT LIST & CAPITAL COST
CONCEPTUAL GEOTHERMAL PLANT

TAG NO.	MAJOR EQUIPMENT	CAPACITY	EFF.	INSTALLED SIZE	UNITS	CAPITAL COST 1978 $	INSTALLATION COST	TOTAL COST
	HEATERS/BOILERS							
B-1	Oil Fired Heater	13,100,000	0.8	16,500,000	BTUH	47,000	23,500	70,500
B-2	" " "	"	"	"	"	47,000	23,500	70,500
B-3	Oil Fired Boiler	10,000,000	0.8	12,500,000	"	56,000	28,000	84,000
B-4	Heat Pump	5,775,000	6.8	6,000,000	"	86,000	43,000	129,000
	PUMPS/MOTORS							
P-1	Downhole Pump	18	0.6	30	HP	10,500	2,600	13,100
P-2	Boost Pump	12	0.6	20	HP	2,000	500	2,500
P-3	Boost Pump	12	0.6	20	HP	2,000	500	2,500
	TANKS							
T-1	Geo-Storage	350,000	-	350,000	Gals	93,500	12,200	105,700
T-2	Effluent Storage	350,000	-	350,000	"	93,500	12,200	105,700
T-3	Fuel Oil Storage	20,000	-	20,000	"	9,200	1,200	10,400
	WELLS							
W-1	Production	350	-	350	GPM	130,000	25,000	155,000
	MAJOR EQUIPMENT TOTALS					576,700	173,000	750,500

TABLE 3

OPERATING COST COMPARISON OF FOSSIL & GEOTHERMAL CENTRAL PLANT

OPERATING COST ITEM	COST FACTOR	FOSSIL FUELED PLANT			GEOTHERMAL PLANT		
		ITEM	UNITS	COST	ITEM	UNITS	COST
FUEL OIL COSTS							
#2 Fuel Oil	$3.57/10^6 BTU	116,200 X 10^6	BTU/YR	415,000	40,700 X 10^6	BTU/YR	145,000
ELECTRIC COSTS							
Circulation Pumps	$11.07/10^6 BTU	68.7 X 10^6	BTU/YR	800	122 X 10^6	BTU/YR	1,400
Downhole Pumps	"	-	-	-	91.8 X 10^6	BTU/YR	1,000
Heat Pump	"	-	-	-	1700 X 10^6	BTU/YR	18,800
OPERATION & MAINTENANCE							
Manpower	$14,400/Man	2	Men	28,800	3	Men	43,200
Equipment Replacement	5% of Equip.	258,400	$	13,000	455,200	$	22,800
TOTALS				457,600			232,200

APPENDIX C

HEAT PUMP TECHNOLOGY

1.0 INTRODUCTION

A heat pump is a device which is used to transfer heat from a lower temperature to a higher temperature utilizing a waste heat source and energy. In a vapor compression heat pump, an electric motor drives a compressor which extracts the heat from the lower temperature source and "pumps" it to the higher temperature sink. A measure of the heat pump performance is the coefficient of performance. The coefficient of performance for heating is defined as the heat out of the condenser ratioed to the electric power required to operate the machine. It is defined in this fashion because when operating in the heating mode the heat out of the condenser is the useful energy produced. By virtue of the fact that heat is added to the machine at the low temperature source, the heat pump can also act as a refrigerator. The coefficient of performance for cooling is defined as the heat into the evaporator divided by the electric power input. Since the heat out of the condenser is the sum of the heat into the evaporator plus the compressor work, the coefficient of performance for heating is equal to the coefficient of performance for cooling plus one. For the remainder of this report, coefficient of performance will refer to the coefficient of performance for heating, unless otherwise stated, and will be abbreviated COP.

The theoretical maximum COP that can be attained is the so-called Carnot COP and is the condenser temperature divided by the difference between the condenser and evaporator temperatures. A heat pump efficiency can be defined as the actual COP divided by the maximum COP.

2.0 SELECTION OF WORKING FLUID

Table 1 lists the various heat pump working fluids considered. The first four are Freons. There are many other possible working fluids, but these candidates were chosen based on previous experience. Table 2 lists the critical properties of the candidate working fluids.

TABLE 1

POTENTIAL WORKING FLUIDS FOR HEAT PUMPS IN 150-225°F RANGE

Refrigerant Designation	Refrigerant Name	Chemical Formula
R-22	Chlorodifluoromethane	$CHClF_2$
R-32	Methylene fluoride	CH_2F_2
R-114	Dichlorotetrafluoroethane	$C_2Cl_2F_4$
R-115	Chloropentafluoroethane	C_2F_5Cl
R-600a	Isobutane	C_4H_{10}
R-717	Ammonia	NH_3

TABLE 2

CRITICAL POINT CONSTANTS FOR POTENTIAL WORKING FLUIDS FOR HEAT PUMPS

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

In order to determine the best working fluid, a computer model simulating the basic heat pump cycle was developed. Figure 1 is a heat pump block diagram and shows the basic components. The numbers correspond to state points shown on a generalized temperature-entropy diagram, shown in Figure 2. Based on a parametric study of the various candidate working fluids under the probable conditions encountered at Susanville, R-114 was selected as the best working fluid. It is interesting to note that Westinghouse uses R-114 in its Templifier at these temperatures. Carrier uses either R-114 or R-11.

3.0 PERFORMANCE STUDIES

In addition to investigating various working fluids, the effect of subcooling was investigated. The addition of a subcooler has a marked effect upon heat pump performance. Figure 3 shows COP plotted against evaporator leaving temperature with results shown for both no subcooling and subcooling. The evaporator inlet temperature (equal to the geothermal resource temperature) was 150°F. The condenser leaving temperature (temperature to the load) was 185°F. The condenser inlet temperature (temperature from the load) was 150°F. At an evaporator leaving temperature of 140°F the basic cycle COP is 3.8. With subcooling, the COP increases by 18% to 4.5. For an evaporator leaving temperature of 80°F the basic COP is 1.9. Subcooling increases it by 15% to 2.2. Also shown is the required motor power versus evaporator leaving temperature. The motor power increases with decreasing evaporator leaving temperature, while the COP decreases in an inverse fashion.

Once the basic cycle and refrigerant were established, various methods of increasing the heat pump performance were investigated. In general, there are three main thermodynamic losses. The first is caused by the sometimes large superheat produced in the compressors. The second is caused by the work loss since no energy is recovered in the expansion process. There is also a loss due to non-isentropic expansion. R-114 does not have a large superheat loss, therefore it is not very important. Methods of reducing the remaining two losses were investigated.

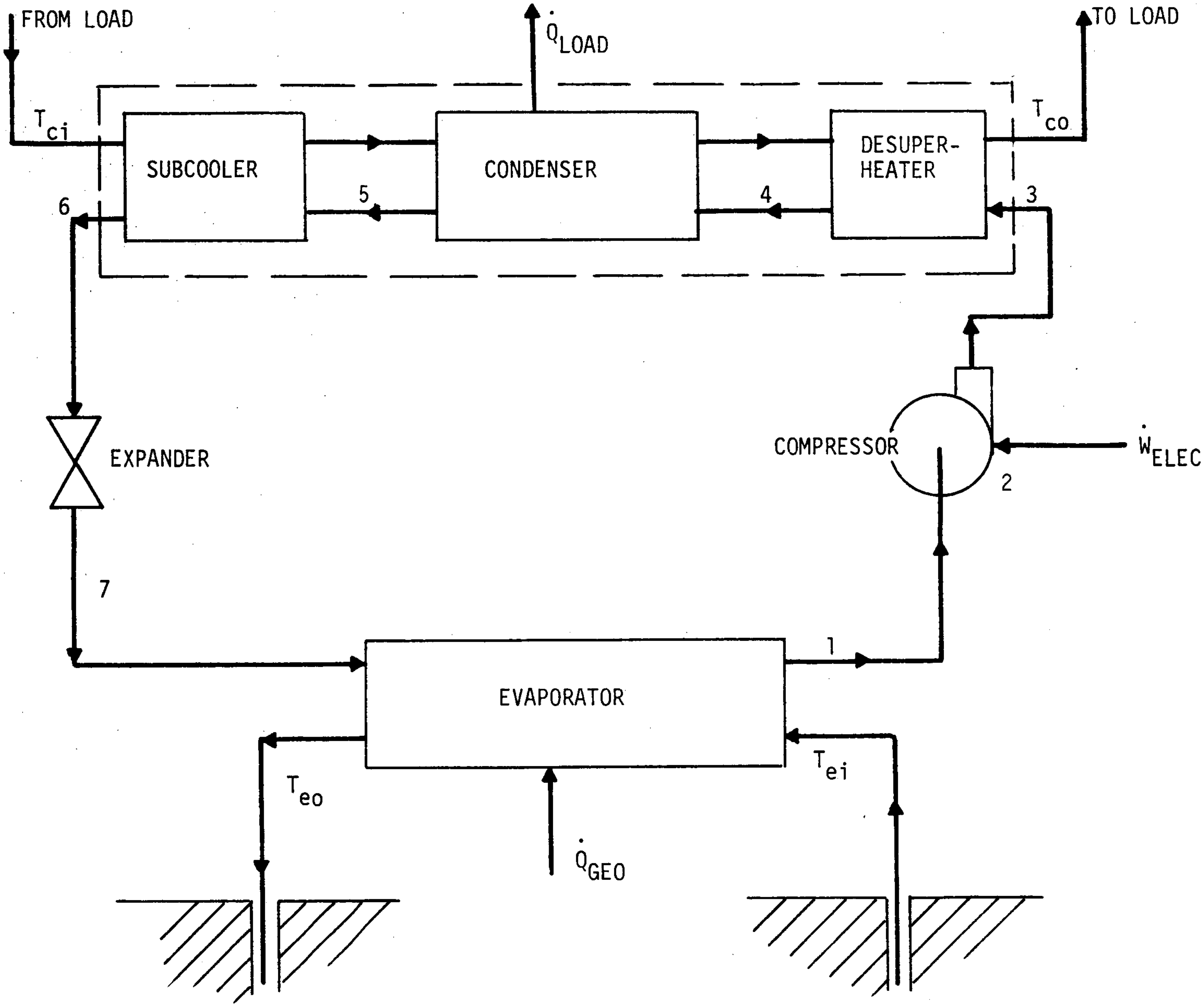


Figure 1. Basic Heat Pump Arrangement

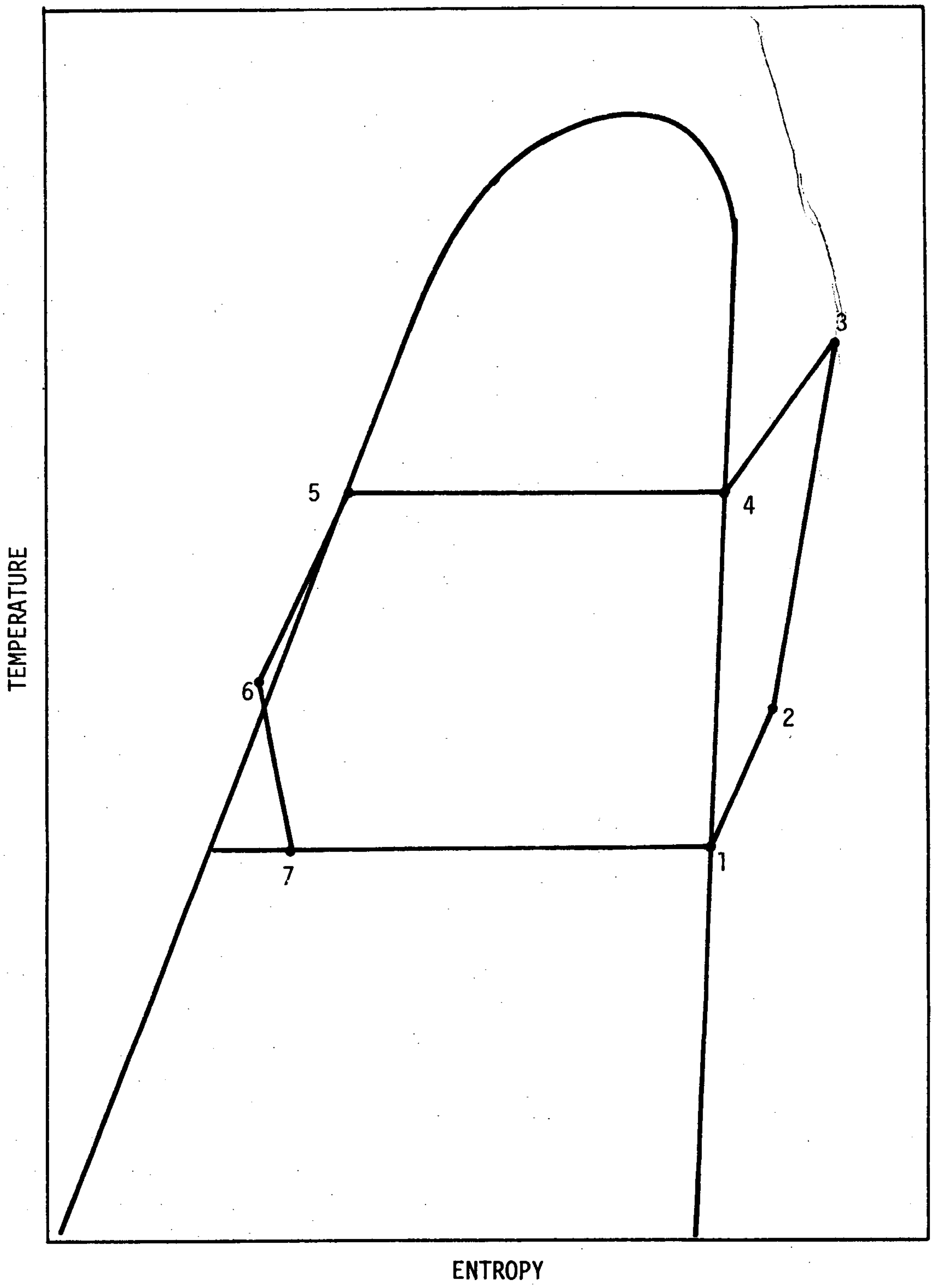


Figure 2. Generalized Freon T-S Diagram

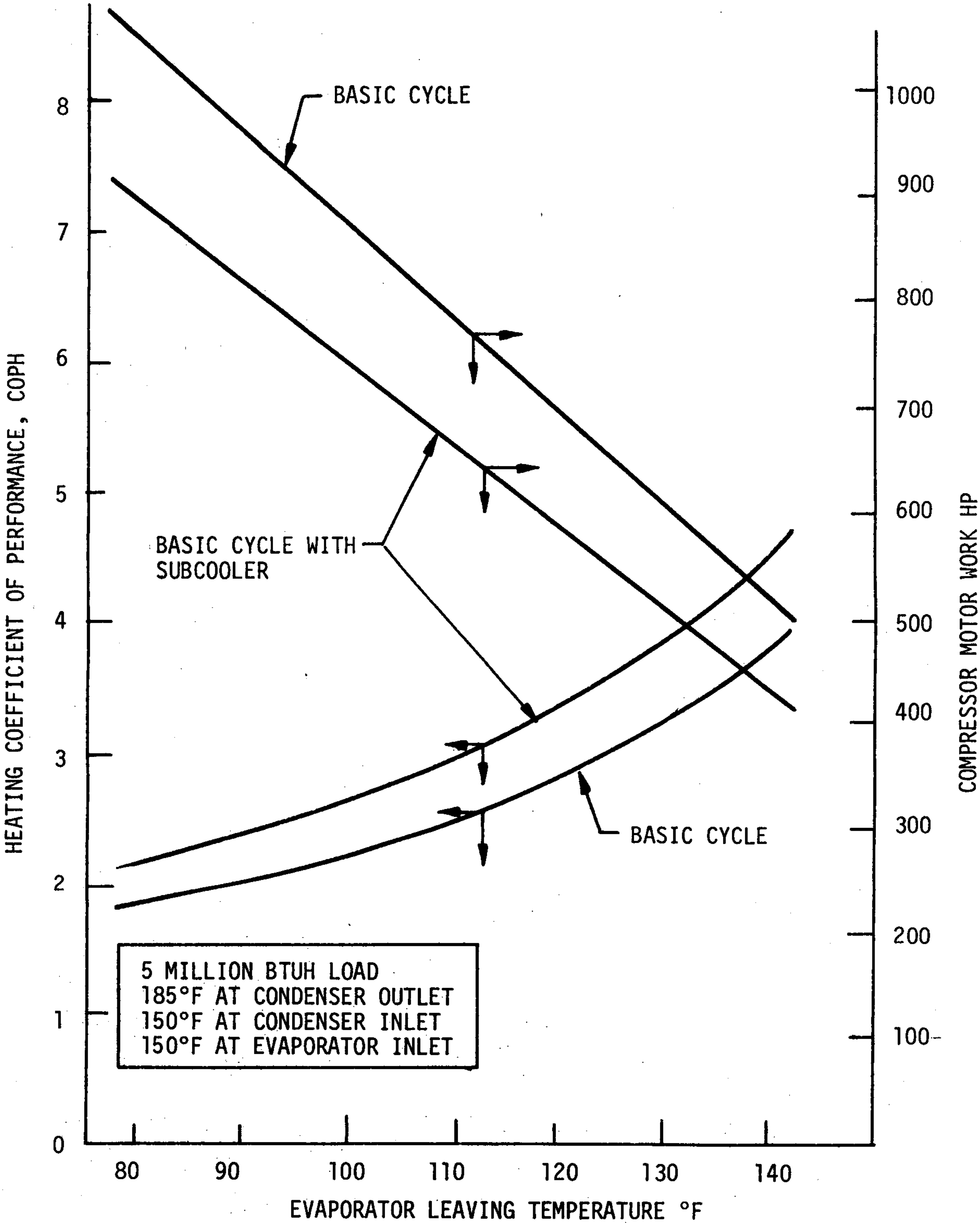


Figure 3. Performance of Basic Heat Pump Cycles

Figure 4 shows a portion of a temperature-entropy diagram for R-114, for our temperature range. The basic cycle with ideal compression is shown by the state points 1-4-5-E-1, where 1-4 is compression, 4-5 is condensation, 5-E is expansion and E-1 is evaporation. The area outlined by the state points 5-B-E is the loss due to the loss of available work in the two phase expansion process. Minimizing the area 5-B-E will make the actual cycle approach more of a Carnot cycle, and increase the COP. It is desirable to increase the COP since this translates directly to reduced operating costs. Also, a throttling loss of magnitude $T_e(S_E-S_5)$ can be reduced by using an expander closely approaching isentropic expansion.

As shown in Figure 4 a number of possibilities arise for reducing the area 5-B-E. Subcooling to the load lowers the temperature of the refrigerant out of the condenser to point A, adding heat to the load and reducing the loss triangle to A-B-D. Subcooling to the load cannot be carried beyond point A since the condenser inlet water is fixed at 150°F and a 6°F minimum approach temperature is needed. Intercooling transfers the heat represented between points A to 6 to preheat the vapor from 1 to 2 before compression. Thus, the loss triangle is reduced further. This produces a superheat horn out of the compressor. This does not cause a large increase in compressor power since the constant-pressure lines in the superheated vapor region for R-114 are roughly parallel. Thus, the heat from points A to 6 is added to the compressor inlet and is finally transferred to the load through the desuperheat section of the condenser, 3-4. The net effect is to reduce the area of the loss triangle. Subcooling from A to 6 can be accomplished by using an external coolant supply. This reduces the loss triangle, but at the same time, that heat is lost from the system, which is not useful. Finally, combining the inter-cooling and subcooling with an external cooling supply, points A-6-B, reduces the loss triangle to nothing. However, some heat is still lost from the system.

In addition to the above methods of reducing the loss triangle, staged compression, improves performance. The refrigerant is partially expanded to an intermediate pressure. The vapor is added to the compressor at the

BASIC CYCLE (1-4-5-E-1)
BASIC CYCLE & SUBCOOLING TO LOAD (1-4-5-A-D-1)
BASIC CYCLE AND SUBCOOLING TO LOAD + INTERCOOLING (1-2-3-4-5-A-6-C-1)
BASIC CYCLE AND SUBCOOLING TO LOAD & SUBCOOLING WITH EXTERNAL COOLANT (1-4-5-A-6-C-1)
BASIC CYCLE & SUBCOOLING TO LOAD + INTERCOOLING + SUBCOOLING WITH EXTERNAL COOLANT (1-2-3-4-5-A-6-B-1)

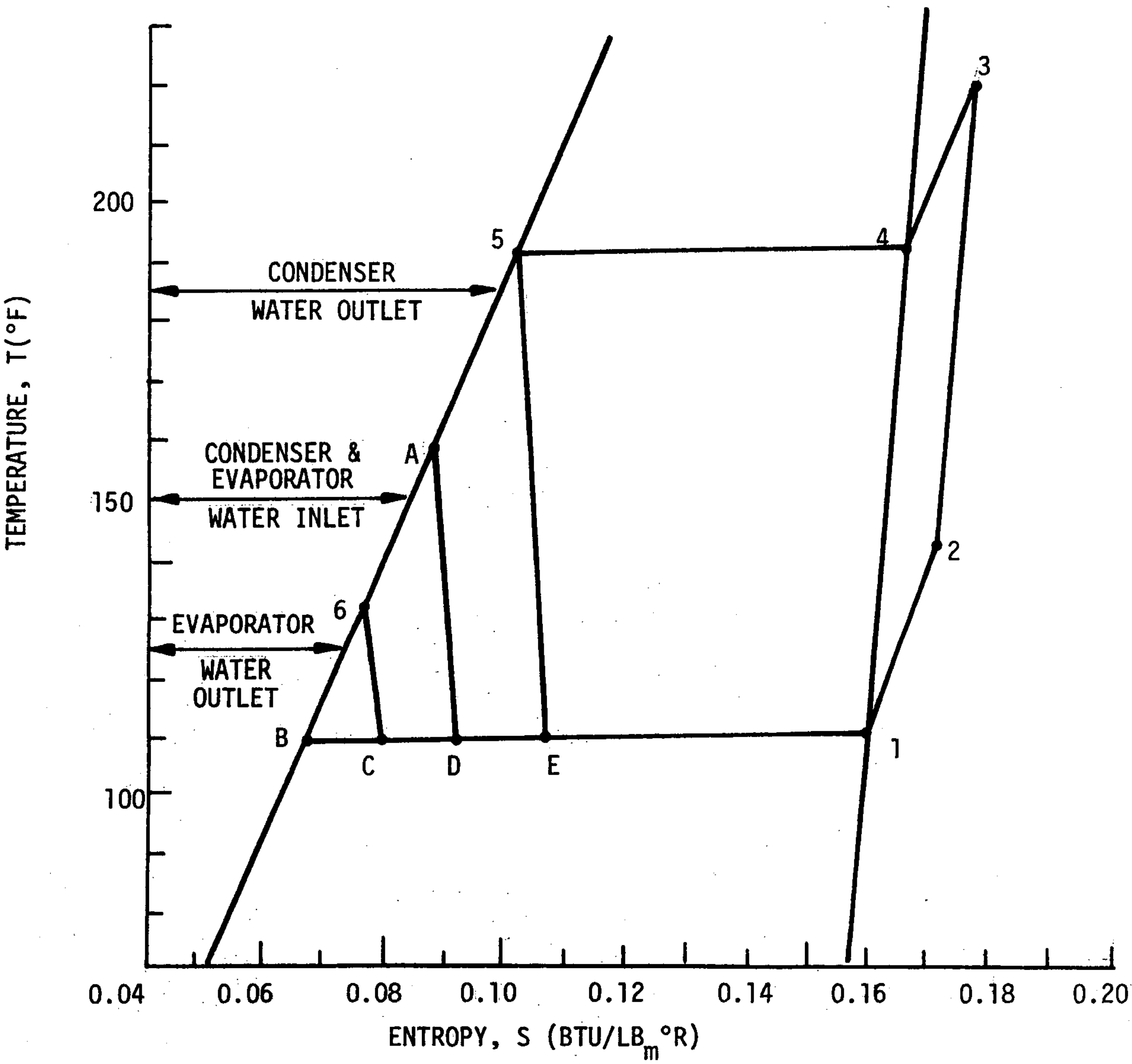


Figure 4. Comparison of Cycle Options at the Design Point

intermediate stage while the remaining liquid is expanded to the evaporation pressure. This will reduce the loss triangle. Staging is represented in the T-S diagram for R-114 in Figure 5. In addition, intercooling between compressor stages is used. Figure 6 is a schematic block diagram showing such a machine. The refrigerant out of the compressor is subcooled from 7 to 8 (or 8' depending upon temperature) and expanded from 8 (or 8') to 9'. The vapor is separated in an economizer and sent to the compressor at 4. Intercooling is down with liquid from 10 to 11 against vapor from 1-2. Compression takes place in stages from 2 to 3 and 4 to 5. As an additional option, intercooling before the first stage, instead of subcooling, can be done. This is shown in block diagram form in Figure 7 and on T-S coordinates in Figure 5. The difference is that heat is added at the compressor inlet 2 to 2', with compression 2' to 3' and 4' to 5', and the heat being put back into the load in the desuperheater instead of in the subcooler. Subcooled load rejection cycle (Figure 6) has a slightly higher COP than the intercooler staged cycle because of the inherent compressor inefficiencies in the latter. However, subcooling to the load is not always feasible, depending upon the condenser water inlet temperature.

4.0 COMPARISON OF COMPUTER DESIGNED COMMERCIAL HARDWARE PERFORMANCE

Computer models of all of the above methods of reducing the cycle losses were run. Figure 8 shows COP versus evaporator leaving water temperature for the various methods compared to commercial data. Carrier and Westinghouse both use subcooling and intercooling. The basic one stage cycle with subcooling is shown as lower limit on performance. The basic two-stage cycle with subcooling increases the performance by about 15 to 18%. One and two-stage cycles with subcooling and intercooling shows increases of 45% to 60% in COP over the two-stage cycle with subcooling. Westinghouse R-114 results lie roughly 10% below the computer designed one and two-stage cycles with subcooling and intercooling. Carrier R-114 is 20% below the one and two-stage cycles with subcooling and intercooling at 130°F evaporator leaving temperature and is 10% below at 100°F. The reason one and two-stage cycles with subcooling and

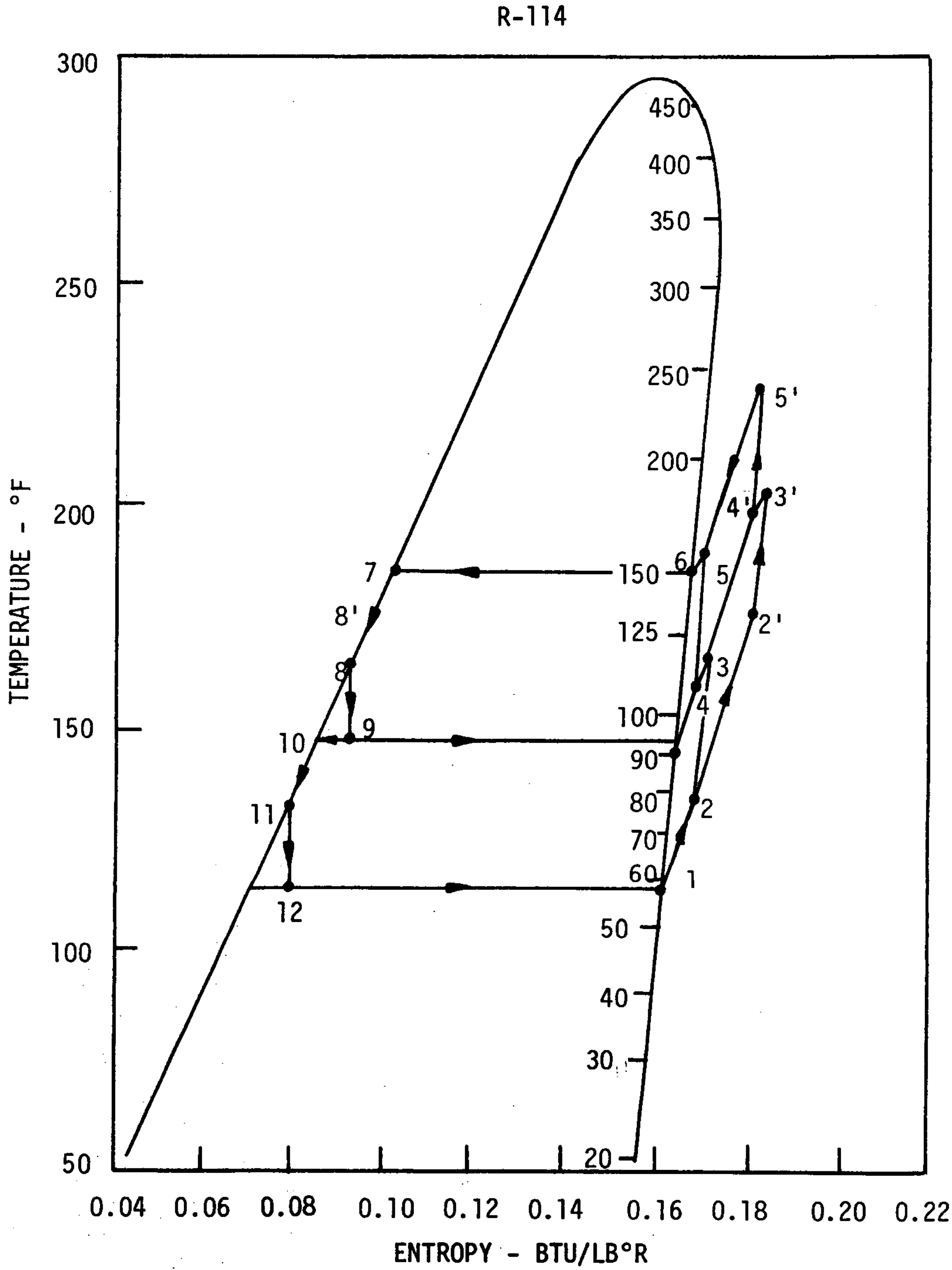


Figure 5. Examples of Staged Cycle Options at Design Point

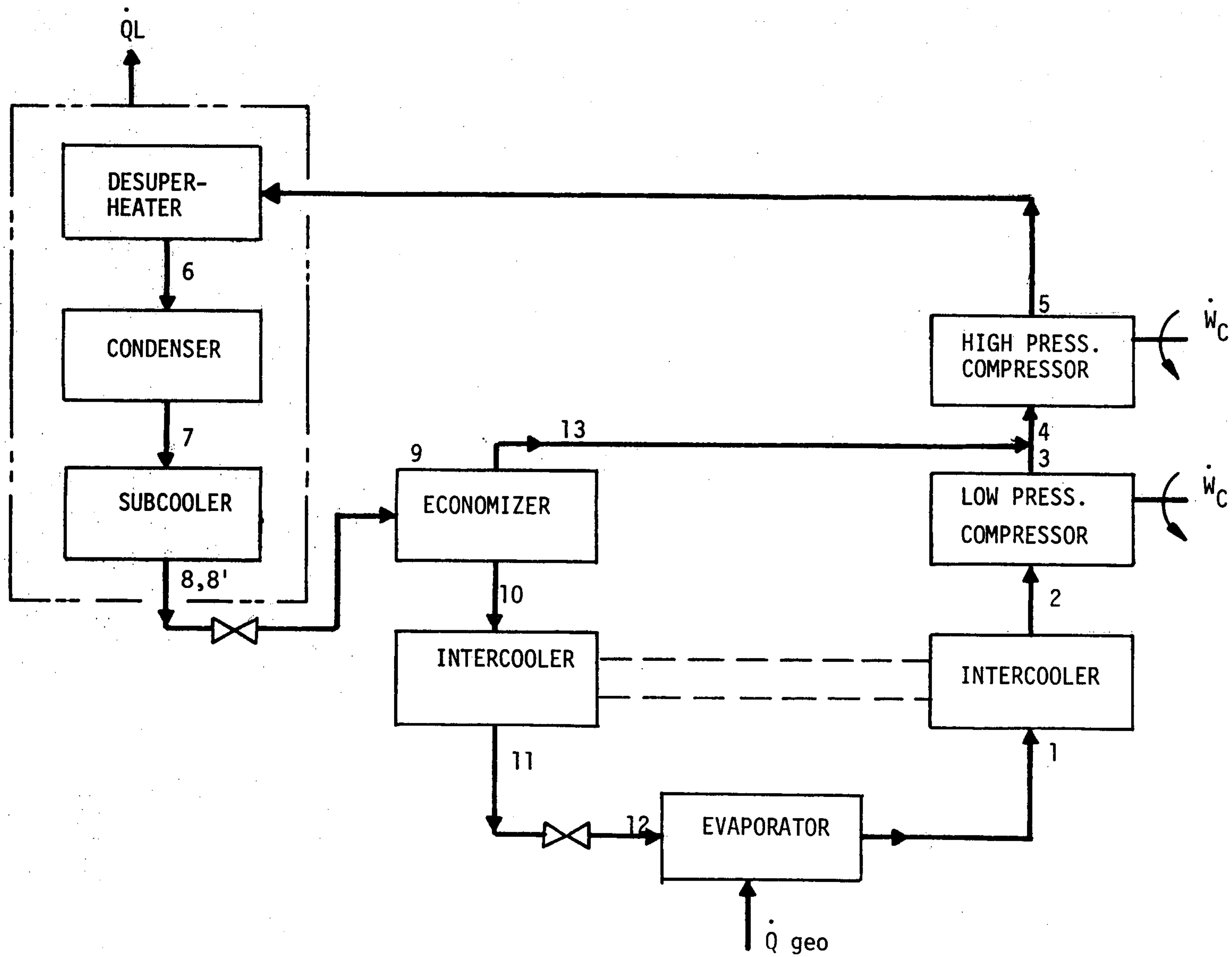


Figure 6. Subcooled Load Rejection Cycle

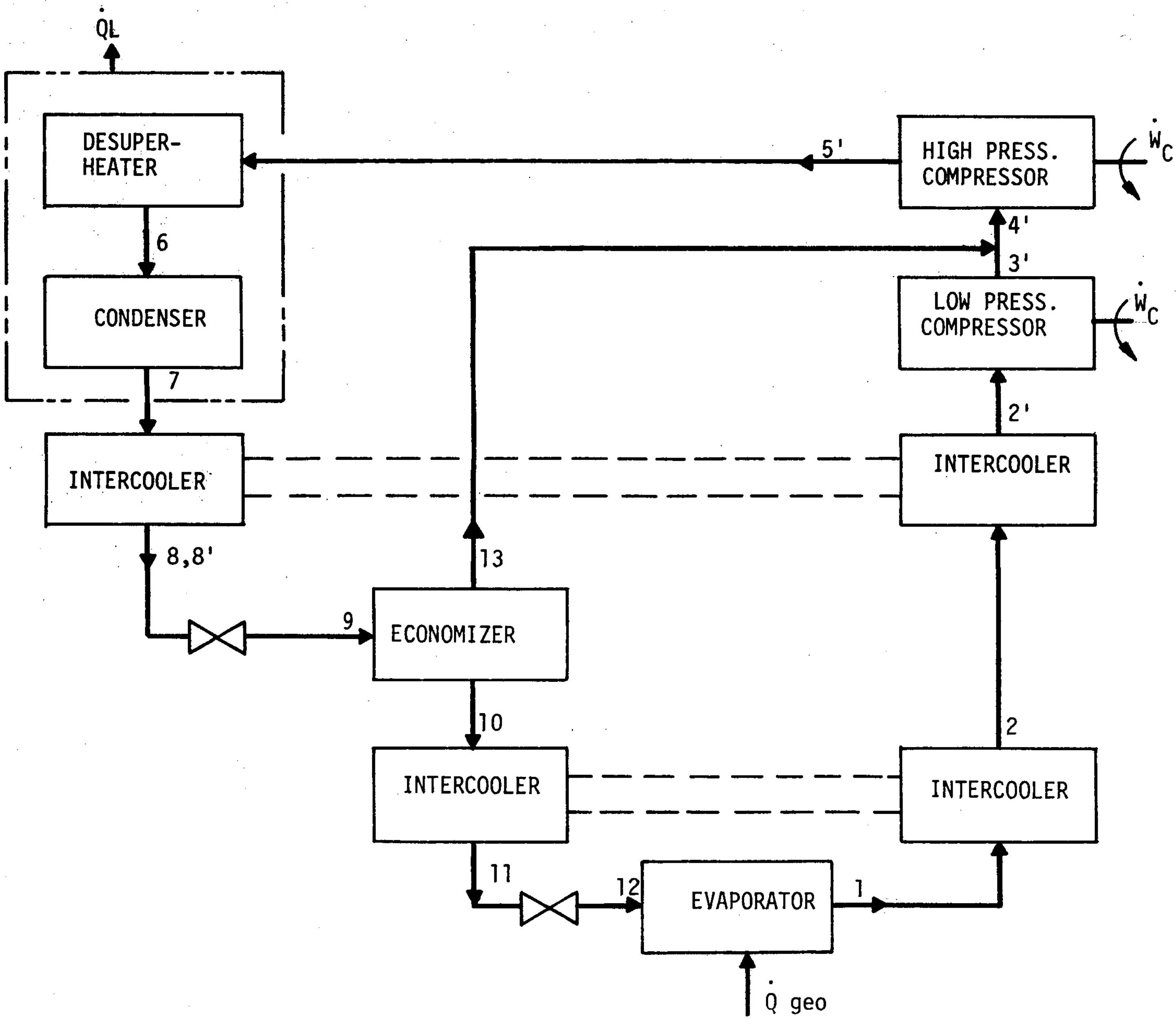


Figure 7. Intercooler Staged Cycle

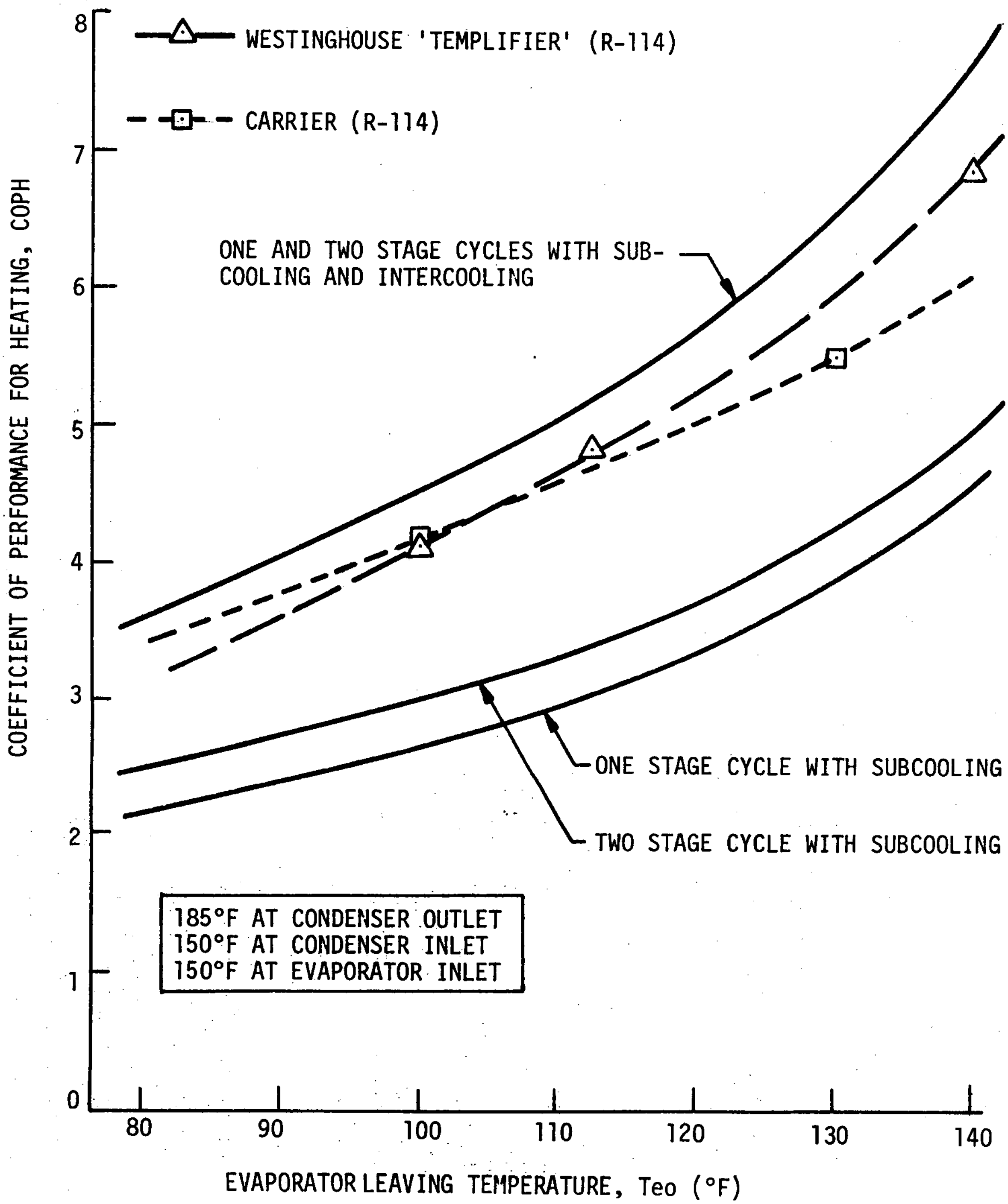


Figure 8. Performance Comparison Between Commercial Heat Pumps and Computer Designed Heat Pump

intercooling become essentially identical is because the loss triangle of the top stage becomes very tiny for two-stage compression. The above results are demonstrated further in Figure 9, where compressor motor power is plotted against evaporator leaving temperature. The same results apply. Thus, significant increases in COP, and hence a reduction in operating costs, can be demonstrated by subcooling and intercooling a single stage machine.

The difference between the computer designed data and the manufacturers data cannot be precisely explained because details on the manufacturer equipment were not available. The computer model did not account for pressure drop in the refrigerant loop, and an optimum compressor efficiency was used. In addition to these two factors, the commercial equipment appears to have less than optimum heat transfer surface for intercooling and subcooling. A combination of all these factors accounts for the higher performance of the computer designed machine.

5.0 REPLACEMENT OF THROTTLE VALVE WITH WORK PRODUCING EXPANDER

Even with subcooling and intercooling, a small loss triangle will remain, as shown in Figure 4. This occurs because of the required approach temperature in the evaporator. A work producing expander, helping to drive the compressor, could be utilized to extract the remaining enthalpy and reduce the loss triangle further. Significant improvements in COP can be made for expander efficiencies greater than about 50%. With an expander efficiency of 75% about $5,000 in operating cost per year could be saved for a 5 million BTUH machine with 7% inflation in fuel costs per year, a 25 year life, and 20% value of capital, the expander could add about $35,000 capital cost to the machine and still be an economical alternative.

A two phase expander which will operate at 75% efficiency and can be coupled to the compressor either as a direct or geared drive, does not exist today. Many design problems would have to be overcome with this two-phase turbine. However, a 75% efficient turbine for this purpose maybe possible in the near future as technology advances are made.

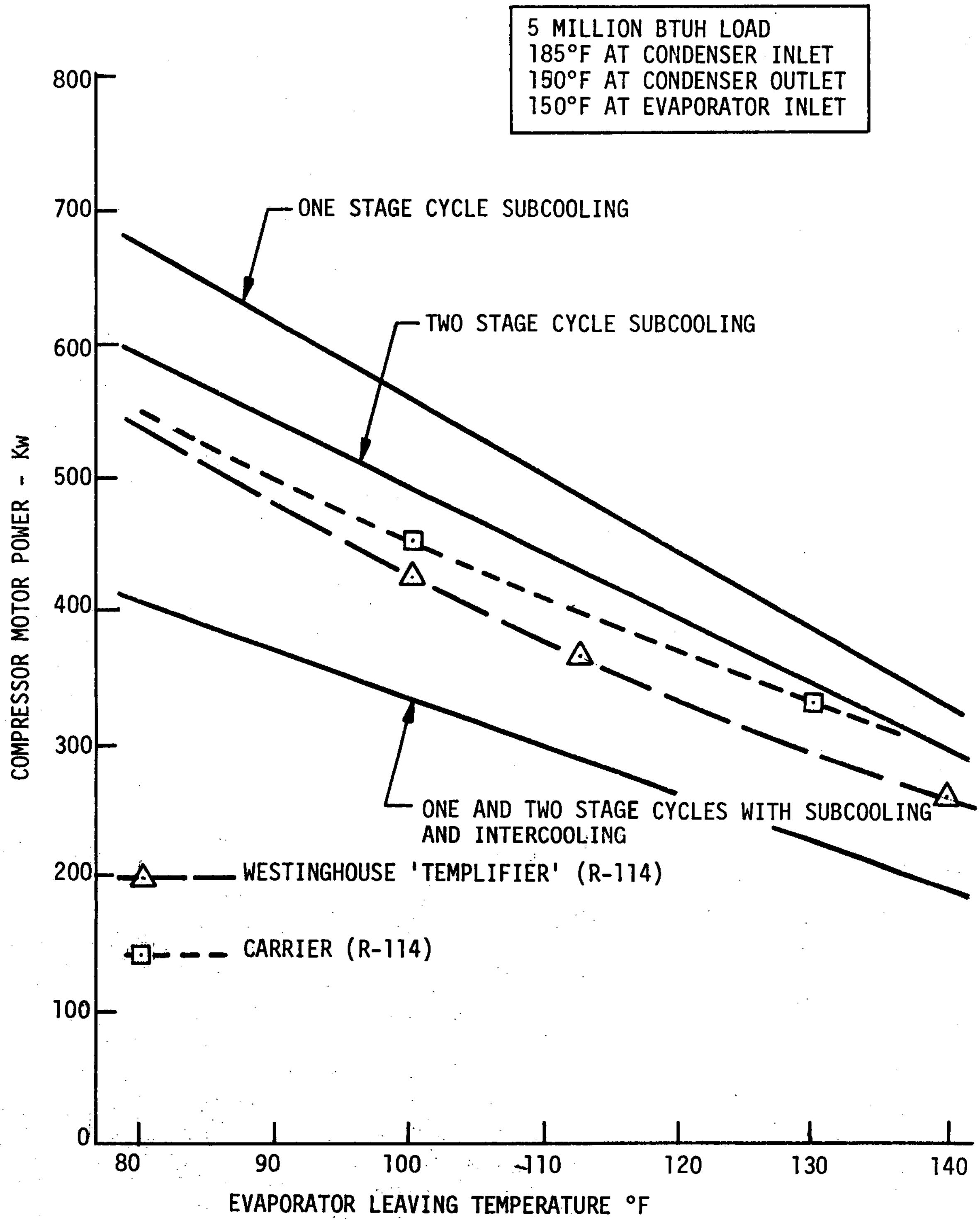


Figure 9. Comparison of Power Requirement Between Commercial Heat Pumps and Computer Designed Heat Pump

6.0 SELECTION OF OPERATING POINT FOR A GEOTHERMAL HEAT PUMP

The coefficient of performance of any heat pump with fixed condenser entering and leaving temperatures and fixed evaporator entering temperature is a function of evaporator leaving temperature. Therefore, it is necessary to optimize the evaporator leaving temperature in order to minimize the annual operating cost.

One of the reasons for performing this study is to determine the feasibility of operating a heat pump at Susanville. A comparison, thus, must be made between the geothermal direct heating system and the geothermal assisted heat pump system. When making such comparisons, efficiencies based upon the First Law of Thermodynamics give meaningful results only when such systems have like inputs and like outputs. Available energy, which is the maximum useful work transport associated with energy and its surroundings, is an equivalent measure regardless of the qualities of the energies being compared. Since energy, and not available energy, is conserved, First Law efficiencies do not reflect the loss in available energy, or irreversibilities, in a heating system. The major irreversibility in a heating system is the requirement that heat be transferred across a tempeature difference. Geothermal energy, at temperatures close to that of the surroundings, is thermodynamically different from conventional energy sources. Effectiveness, based upon the Second Law of Thermodynamics, reflects the losses in available energy when comparing heating systems with different inputs and outputs (Reference 11).

Figure 10 is a schematic block diagram showing the geothermal direct heating system (GDHS) being compared with the geothermal assisted heat pump system (GAHPS). For this comparison, the following assumptions are made:

(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.

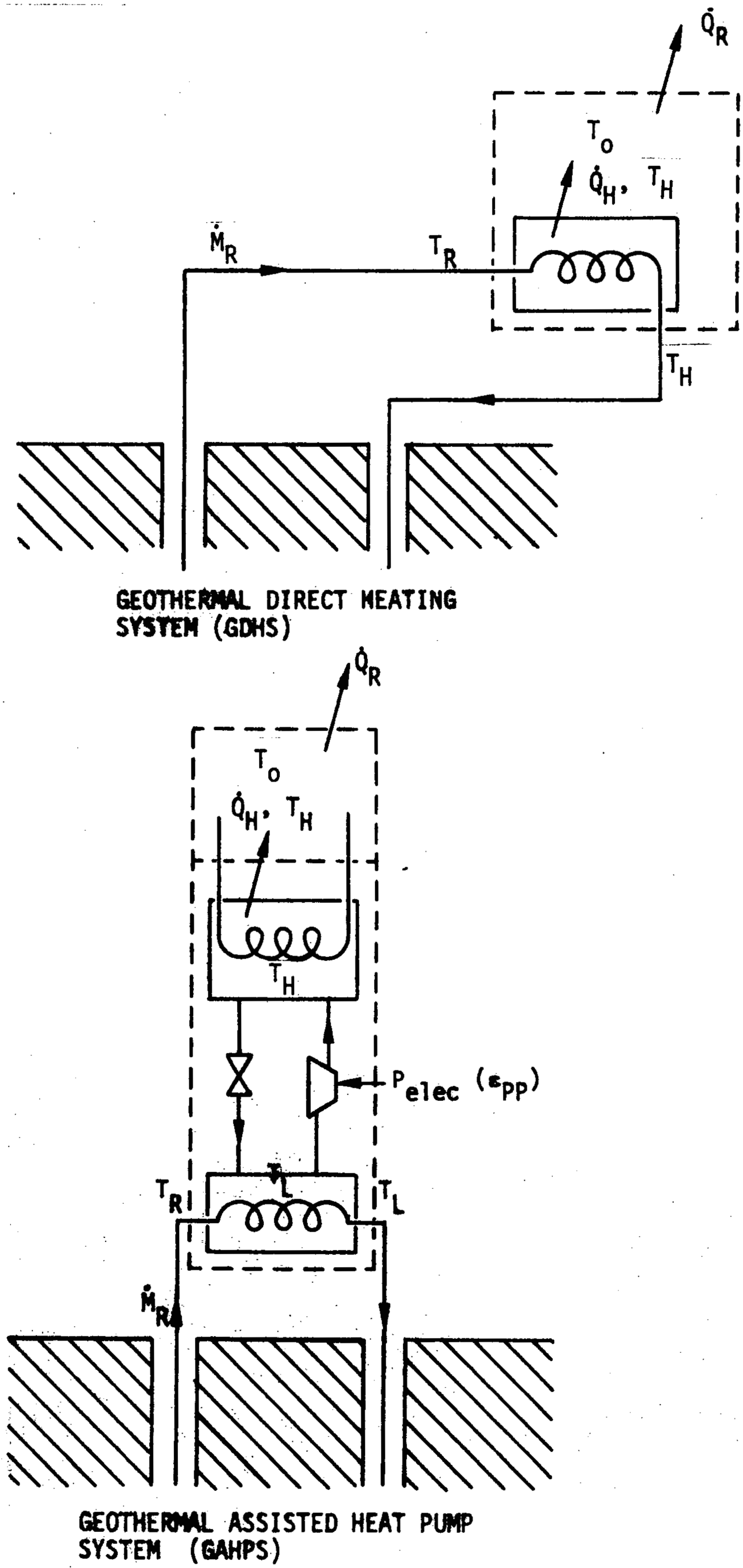


Figure 10. Second Law Comparison of Systems

(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 exchanger, 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.

Effectiveness is defined as the increase in available energy of the desired output relative to the decrease in available energy of the input.

Geothermal Direct Heating System (GDHS)

Geothermal Direct Heating System effectiveness is:

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

where T_o is the sink temperature, T_H is temperature at which the heating occurs, 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:

$$\dot{m}_R = \frac{\dot{Q}_H}{C_p\,(T_R - T_H)}$$

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

Geothermal Assisted Heat Pump System (GAHPS)

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

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

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:

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

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 law analysis based on conservation of energy indicated that the optimum evaporator outlet temperature occurred at about 115°F.

Figure 12 is a comparison of the Geothermal Assisted Heat Pump System (GAHPS) with the Geothermal Direct Heating System, for two different geothermal temperatures, plotted against resource temperature. For the 185°F geothermal

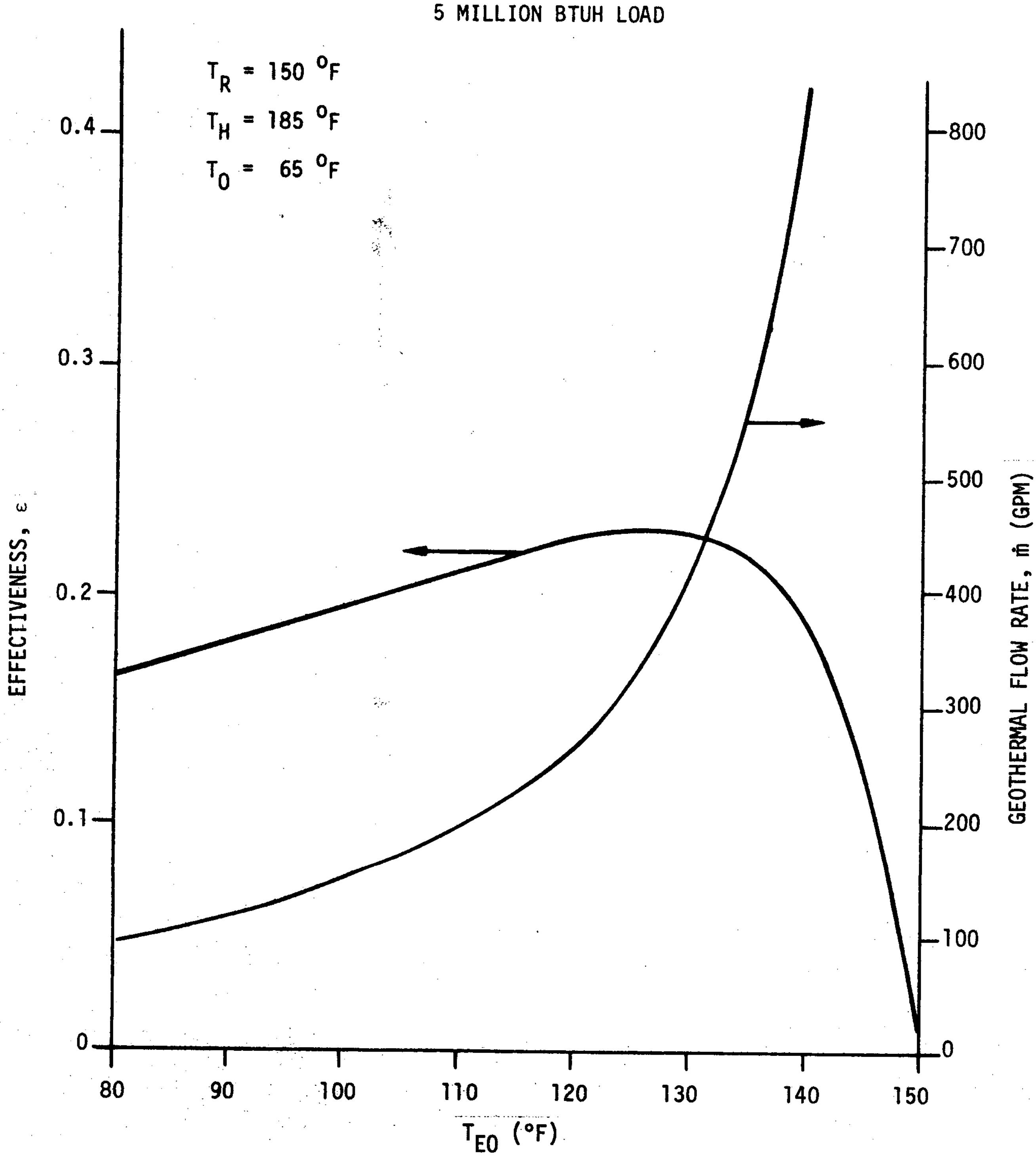


Figure 11. Second Law Effectiveness vs Evaporator Outlet Temperature

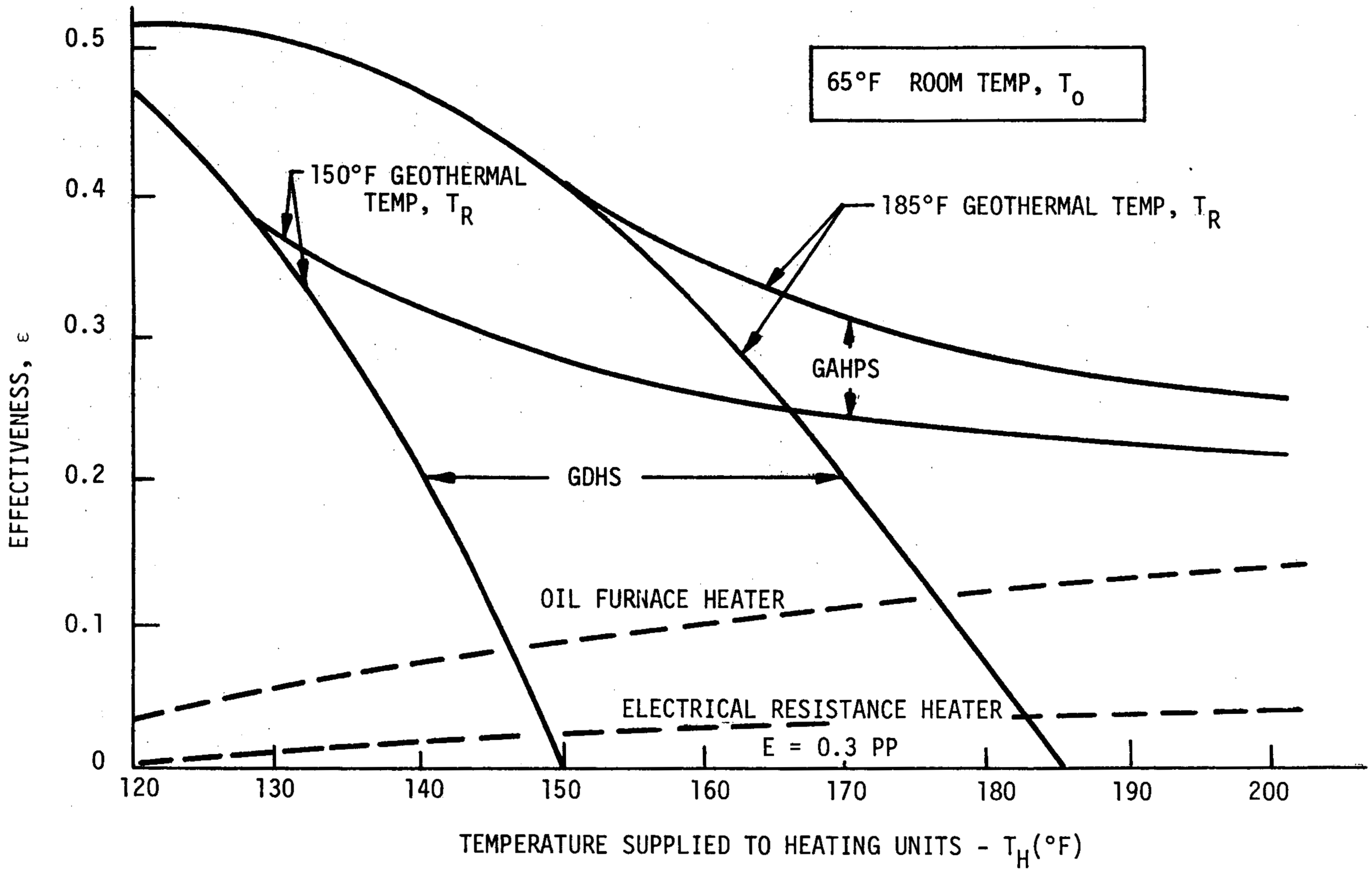


Figure 12. Comparison of Heating System Based on Effectiveness

resource, the curves for the GAHPS and GDHS merge to a single curve at a heating temperature of about 150°F. Thus only when heating temperatures greater than about 165°F are needed does the GAHPS show a clear advantage with 185°F resource. Note that in the above analysis, it is assumed that only heat is being supplied (no cooling) and that is why the two curves merge. For the 150°F resource, the GAHPS is clearly superior for heating temperatures greater than about 135°F. It is also shown that the oil fired furnace and the electrical resistance heating are much less effective in the utilization of energy in this temperature range.