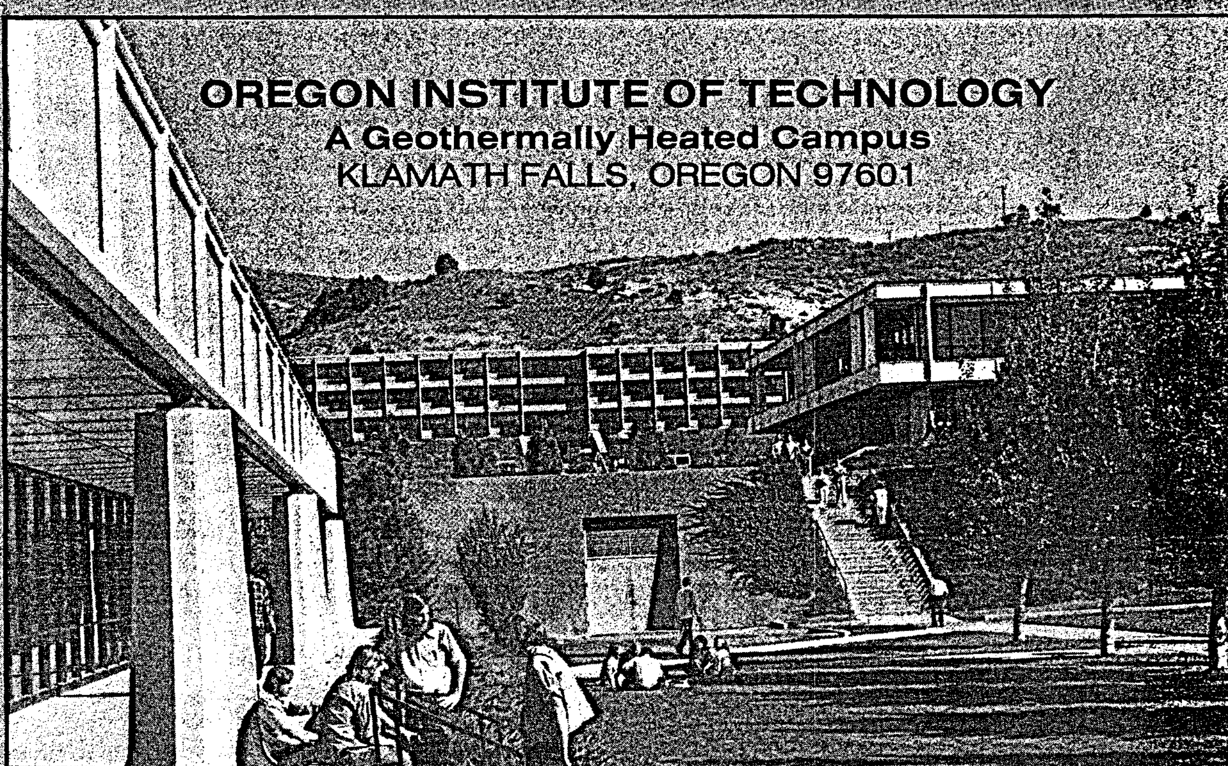
MASTER

GEO-HEAT CENTER



HEATING FACILITIES FOR THE CITY SCHOOLS

Ephrata, Washington

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11-79

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

Introduction

The City of Ephrata, Washington has an existing well that has the capability of pumping 2200 gallons per minute of 86°F water into the City drinking water system. Other wells exist, however this well by itself can meet the City's water demand. City officials have asked if this water can be utilized to heat the City schools, which are now heated with oil fired steam and water boilers. The schools consist of two elementary schools, a middle school, and a high school with a separate boiler for the wood/agricultural shop. Except for the shop, each school has a pair of boilers. Total area for the school buildings is 216,635 square feet, and the average annual fuel oil consumption over the past five years is 148,368 gallons. An additional consideration is the desirability of utilizing the water as drinking water, after the heat has been extracted. To determine the economic practicality of using the City water to heat the schools, one school (Middle School) was selected for evaluation. Two cases were considered. Case 1 uses a two stage water-to-water heat pump to produce a 190°F circulating hot water stream. This would be compatible with the existing system and essentially no retrofit costs for the room convective heating system would be incurred. Case 2 uses a single stage water-to-water heat pump to produce a 140°F circulating hot water stream. Retrofit costs would incur for additional room convection equipment. In both cases the heat pump is sized to furnish the total heating and hot water requirements of the school. However, one of the existing boilers is left in place to serve as standby.

Summary of Conclusions

It is economically practical to heat the schools using water-to-water heat pumps. The Middle School evaluation shows the single stage heat pump to be most cost effective, having a return on invested capital of about 19%. Projecting the single stage evaluation to include all the schools, the total conversion cost would be about $800,000. This includes a retrofit allowance of $100,000. The return on investment would be about 19%. Total annual savings in fuel oil consumption would be nearly 150,000 gallons, amounting to a first year savings of about $134,000. Peak water usage would be 1,000 gallons per minute, about 45% of that available. Annual water usage would be about 90 million gallons, about 14% of the water used during 1978. This water would be returned to the drinking water system after extraction of heat.

Heat Requirements for Schools

Peak and annual heating requirements were estimated using methods based on the size of the schools (square footage) and the climatical conditions. Calculated annual requirements were compared to the average annual fuel oil usage taken over a five year period. Results are tabulated in Table 1. Important numbers are:

1. Total peak energy requirement for all schools,
   10.674×10^6 BTU/HR

2. Total annual energy requirement for all schools,
   15.618×10^9 BTU/YEAR

3. Total annual fuel oil consumption,
   148,368 gallons.

Description of the Water-to-Water Heat Pump System

The schools are heated with low pressure steam, or circulating hot water. The heat source is fuel oil fired boilers. Water-to-water heat pumps were selected for evaluation since they have the capability of producing a hot water circulating stream at an elevated temperature.

Case 1 utilizes a two stage heat pump to elevate the temperature. See Figure #1 City water at 80°F is pumped through a heat exchanger, then returned to the water system at 60°F. On the other side of the exchanger water is heated from 50°F to 75°F. The first stage boosts the water temperature to 130°F and the second stage boosts the temperature to 190°F. This corresponds to the temperature produced by the water boilers. No retrofit work related to the room convective heaters occurs when this heat pump replaces a water boiler. When substituted for a steam boiler, the condensate return piping needs to be larger, and additional room convective heating surface is required. At peak operating conditions Case 1 requires 145 gallons per minute of City water and requires 273 KW of electric power for operation of the centrifugal compressors. When the added pumping power (18 KW) is taken into consideration the overall coefficient of performance is 2.4. This means that the system puts out 2.4 times more heating energy than available from the electricity consumed.

Case 2 uses a single stage heat pump to elevate the 80°F City water to 140°F. See Figure 2. In this case water is returned to the City system at 65°F. Since the circulating water is cooler than that produced by the boiler, retrofit work will be necessary. Where the heat pump is substituted for a water boiler the circulating piping will be large enough, but added room convective heating surface is required. When substituted for a steam boiler the condensate return line must be enlarged, and an even larger amount of convective heating surface will be required. Case 2 requires 225 gallons per minute of City water and 217 KW of electricity for pumps (14 KW) and the compressor. The overall coefficient of performance is 3.2.

Comparing the two cases, Case 2 has a higher coefficient of performance (3.2 vs. 2.4), therefore, using a larger amount of City water (225 GPM vs. 145 GPM), but will require a considerable amount of retrofit work.

Method for Utilizing City Water

Figure 3 presents a method for extracting heat from the City water, then returning it to the system. The water is isolated from the heat pump refrigerant fluid, and piping must be in accordance with applicable code requirements for potable water. As noted in Figure 3, check valve #1 prevents recycling of the discharge from the circulating pump back to the suction. This is necessary to insure that the heat exchanger sees only 80^{o}F water. Check valve #2 minimizes the possibility of the cooled discharge water diluting the major flow stream, since other heat pump systems downstream require the 80^{o}F water. This system maintains many of the advantages of the existing loop system. If all the schools, using single stage heat pumps, are connected in this manner the peak requirement for City water would be 1000 gallons per minute. This is less than 50% of the existing pumping capacity of City well #10. For the three coldest winter months, the monthly water used would be 12%, or less, of the amount used by the City during those months in 1978. The annual water passing through the single stage heat pump system is estimated to be 90 million gallons. This is about 14% of the water use tabulated for 1978. For the single stage water-to-water heat pump system about 94 gallons of 80^{o}F water are needed for each million BTU/HR of heat produced.

Capital and Operating Costs

Table 2 summarizes the capital and operating costs for Middle School, as well as the costs for all the public schools projected from Case 2. Capital cost for Case 2 includes an allowance of $20,000 for retrofit costs to provide additional room convective heat transfer surface. An allowance of $100,000 for similar work is included in the capital costs tabulated for all the schools. This allowance does take into consideration the increased retrofit costs incurred when a steam boiler system is replaced.

Comparing Case 1 (two stage) to Case 2 (single stage), Case 1 has the highest capital cost ($220,000 vs $180,000) and the highest operating cost ($17,696 per year vs $12,751 per year).

Projecting costs using Case 2 to include all the schools, the estimated capital cost is $800,000 and the first year operating cost is $56,697 per year.

Economic Comparison

With Middle School as the basis for evaluation, two heat pump systems were compared against an annual savings of 36,191 gallons of fuel oil. At a value of $.90 per gallon the first year savings amounts to $32,571.90, for each of the two cases. For both cases, over the 20 year life used in comparisons, fuel oil costs were inflated at 8.5% per year, maintenance at 7.0% per year, and insurance at 1% per year. The inflation rate on electricity are those forecasted for Oregon by the State Department of Energy, and amount to 9.5% through 1986 and 8.58% thereafter. After 20 years this inflates to a cost of $.0853 per KWH. A price after 20 years at Ephrata of $.05 per KWH was suggested by Grant County PUD. However, the higher figure was used here, since it produces a more conservative result in these cases where electricity is an operating cost.

Referring to Table 3, (Case 1), which is a two stage heat pump that produces 190°F circulating water, the rate of return on a 100% equity investment would be about 13%. Referring to Table 4, (Case 2), a single stage heat pump producing 140°F circulating water, the rate of return on a 100% equity investment would be about 19%. Thus, Case 2 using the less complex and less expensive single stage heat pump has a higher and very favorable rate of return. Projecting Case 2 to all the schools, as previously indicated the capital investment would be $800,000, and the annual savings of 148,368 gallons of fuel oil at $.90 per gallon would amount to a first year savings of $133,531.

HEAT REQUIREMENTS CITY SCHOOLS
EPHRATA, WASHINGTON
TABLE 1

ITEM	SCHOOL: COLUMBIA RIDGE ELEMENTARY	MIDDLE SCHOOL (JR HIGH SCHOOL)	GRANT ELEMENTARY	HIGH SCHOOL	HIGH SCHOOL WOOD & AGR. SHOP	TOT…
AREA (FT^2)	35000	48650	21426	101209	10350	2166…
EST. NUMBER OF STUDENTS	300	170	180	330	—	
SPACE HEATING LOAD						
PEAK (10^6 BTU/HR)	1.645	2.287	1.007	4.757	.486	
ANNUAL (10^9 BTU/YEAR)	2.488	3.459	1.523	7.196	.736	
WATER HEATING LOAD						
PEAK (10^6 BTU/HR)	.162	.092	.058	.180	—	
ANNUAL (10^9 BTU/YEAR)	.049	.051	.018	.098	—	
TOTAL ENERGY						
PEAK (10^6 BTU/HR)	1.807	2.379	1.065	4.937	.486	10.6
ANNUAL (10^9 BTU/YEAR)	2.537	3.510	1.541	7.294	.736	15.6
NUMBER OF BOILERS	2	2	1	2	1	
MAKE	SPENCER	SUPERIOR	INTERNATIONAL	ECONOMIC	CALORIC	
TYPE	STEAM	HOT WATER	HOT WATER	STEAM	STEAM	
SIZE						
(HP) EACH	40	60	40	100	38	
(10^6 BTU/HR) EACH	1.339	2.009	1.339	3.348	1.272	
5 YEAR FUEL OIL USAGE						
GALLONS/YEAR	22082	36191	14248	68824	7023	148…
APPARENT EFFICIENCY (%)	82	70	78	76	75	76 (A…

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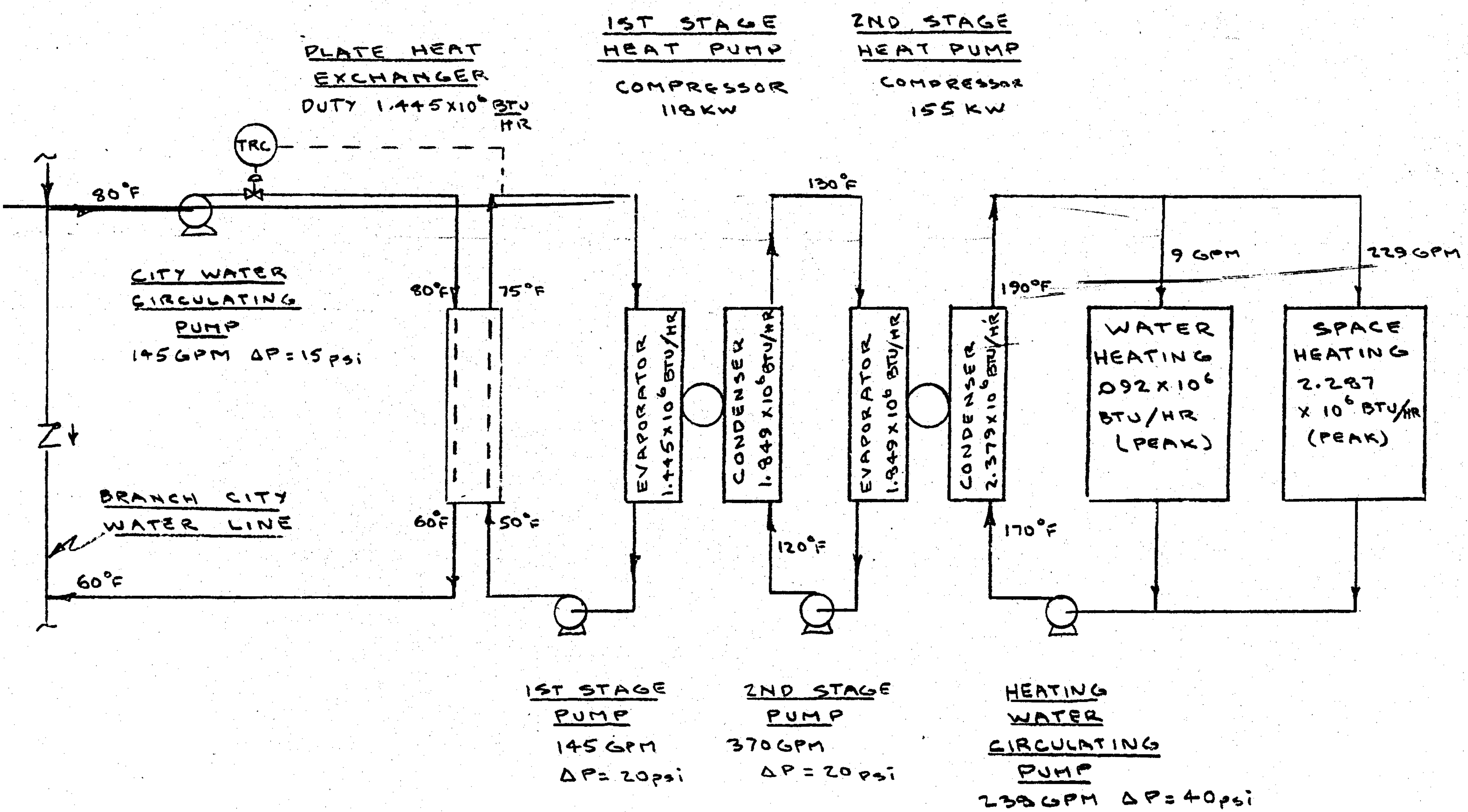
TWO STAGE WATER/WATER HEAT PUMP SYSTEM

MIDDLE SCHOOL, EPHRATA, WASHINGTON

FIGURE #1



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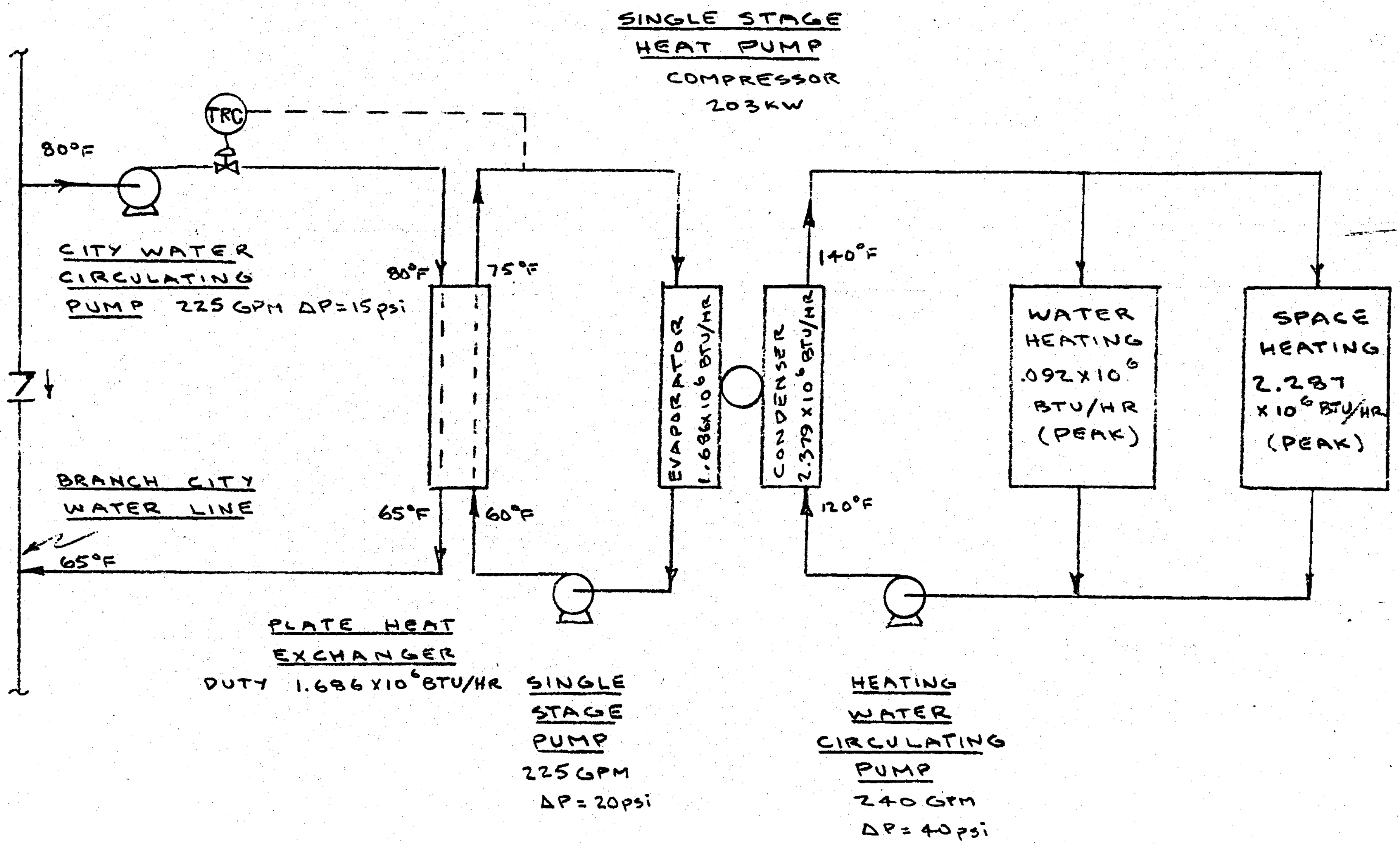
SINGLE STAGE WATER/WATER HEAT PUMP SYSTEM
MIDDLE SCHOOL, EPHRATA, WASHINGTON
FIGURE #2



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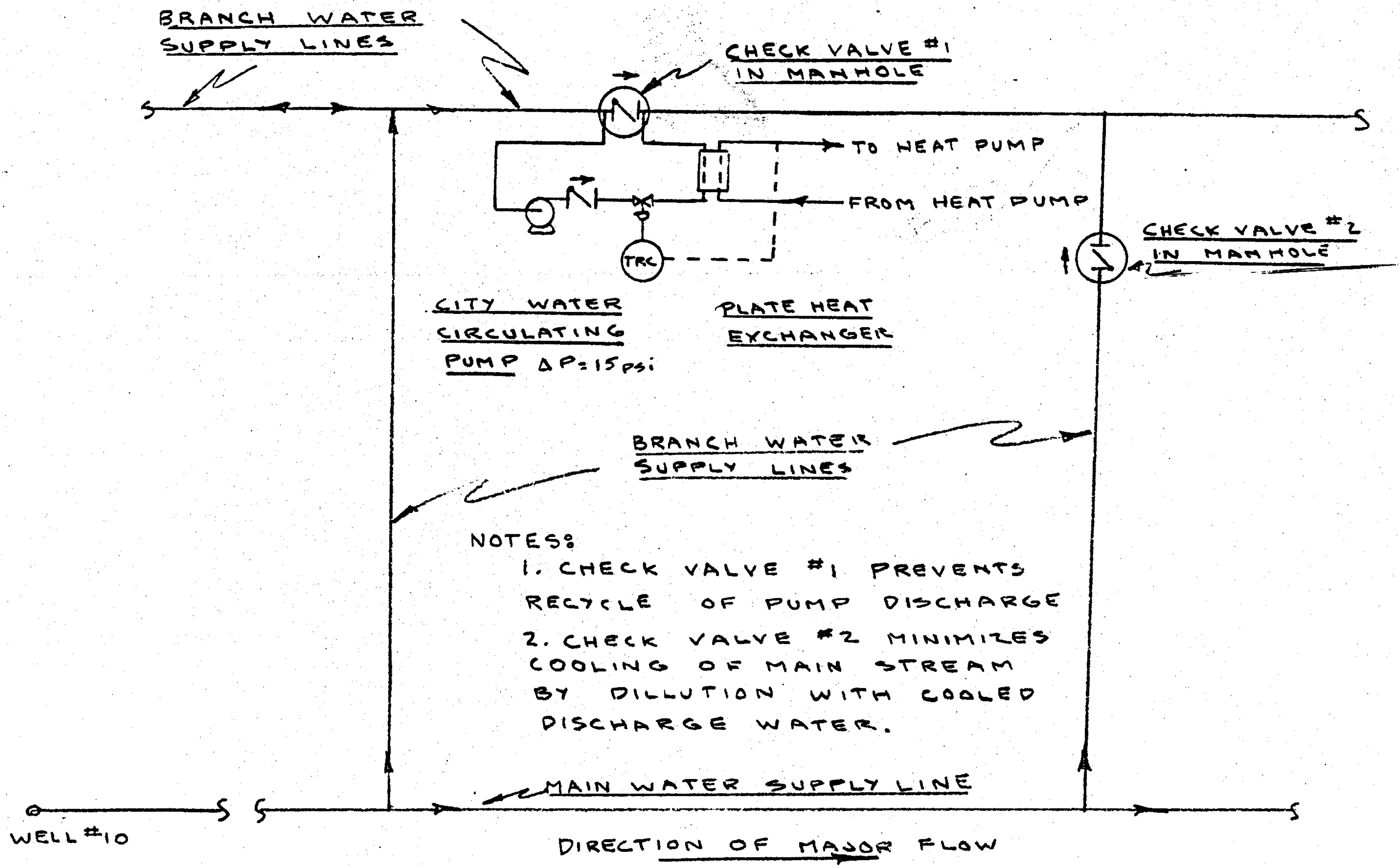
METHOD FOR UTILIZING CITY WATER
MIDDLE SCHOOL, EPHRATA, WASHINGTON
FIGURE #3



NOTES:

1. CHECK VALVE #1 PREVENTS RECYCLE OF PUMP DISCHARGE
2. CHECK VALVE #2 MINIMIZES COOLING OF MAIN STREAM BY DILLUTION WITH COOLED DISCHARGE WATER.

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SUMMARY OF CAPITAL & OPERATING COSTS
WATER / WATER HEAT PUMP SYSTEM
TABLE 2

ITEM	MIDDLE SCHOOL CASE 1 TWO STAGE	MIDDLE SCHOOL CASE 2 SINGLE STAGE	(2) TOTAL FOR ALL SCHOOLS SINGLE STAGE
CAPITAL COST			
HEAT PUMP	160000	93000	415000
PUMPS & SPARES	14000	16000	71000
PLATE HEAT EXCHANGER	4000	4000	18000
PIPING	14000	16000	71000
RETROFIT EXISTING ROOM HEATERS (ALLOWANCE)	—	20000	100000
MISC. MECHANICAL & ELECTRICAL	10000	10000	45000
SUB TOTAL	202000	159000	720000
CONTINGENCY	18000	21000	80000
TOTAL CAPITAL COST (1)	$220000	$180000	$800,000
OPERATING COST (1ST YEAR)			
MAINTENANCE			
HEAT PUMPS, EXCHANGER, PUMPS	9693	6356	28249
PIPING	261	529	2351
TOTAL MAINTENANCE	9954	6885	30600
TAXES & INSURANCE	1100	900	4000
ELECTRIC POWER @ $.0155/KWH	6642	4966	22097
TOTAL OPERATING COST (1ST YEAR)	$17696/YEAR	$12751/YEAR	$56697/YEAR

(1) EXCLUDES ANY ENGINEERING OR CONTRACTORS FEES, PERMITS OR LICENSES, OR COST ESCALATION.

(2) PROJECTED FROM CASE 2

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ECONOMIC COMPARISON

TWO STAGE WATER/WATER HEAT PUMP REPLACING EXISTING FUEL OIL FIRED BOIL

CASE I

MIDDLE SCHOOL, EPHRATA, WASHINGTON

TABLE 3

FUEL COST	O + M GTHML COST	INSURANCE GTHML COST	ELECT GTHML COST	S/YR	P.W. 13. %
32571.90	9954.00	1100.00	6642.00		
35840.51	10650.78	1111.00	7272.99	16305.74	14429.86
38344.45	11396.33	1122.11	7963.92	17862.09	13988.63
41603.73	12194.08	1133.33	8720.50	19555.83	13553.17
45140.05	13047.66	1144.66	9548.94	21398.78	13124.27
48976.96	13961.00	1156.11	10456.09	23403.75	12702.62
53140.00	14938.27	1167.67	11449.42	25584.63	12288.77
57656.90	15983.95	1179.35	12537.12	27956.48	11883.20
62557.73	17102.83	1191.14	13612.80	30650.96	11529.66
67875.14	18300.02	1203.05	14780.78	33591.28	11182.03
73644.53	19581.02	1215.08	16048.97	36799.45	10840.69
79904.31	20951.70	1227.24	17425.97	40299.41	10505.96
86696.18	22418.32	1239.51	18921.12	44117.23	10178.11
94065.35	23987.60	1251.90	20544.55	48281.30	9857.33
102060.91	25666.73	1264.42	22307.28	52822.48	9543.78
110736.09	27463.40	1277.07	24221.24	57774.38	9237.59
120148.65	29385.84	1289.84	26299.42	63173.55	8938.82
130361.29	31442.85	1302.73	28555.91	69059.79	8647.52
141442.00	33643.85	1315.76	31006.01	75476.38	8363.71
153464.57	35998.92	1328.92	33666.33	82470.40	8087.38
166509.06	38518.84	1342.23	36554.90	90093.11	7818.49
				876677.02	216701.59

ECONOMIC COMPARISON

SINGLE STAGE WATER/WATER HEAT PUMP REPLACING EXISTING FUEL OIL FIRED BOIL

CASE 2

MIDDLE SCHOOL, EPHRATA, WASHINGTON

TABLE 4

FUEL COST	O + M GTHML COST	INSURANCE GTHML COST	ELECT GTHML COST	S/YR	P.W. 8. %	P.W
32571.90	6885.00	900.00	4966.00			18.9318
35340.51	7366.95	909.00	5437.77	21626.79	20024.81	18184.20
38344.45	7882.64	918.09	5954.36	23589.37	20224.08	16677.09
41603.73	8434.42	927.27	6520.02	25722.02	20418.97	15290.13
45140.05	9024.83	936.54	7139.42	28039.25	20609.69	14014.40
48976.96	9656.57	945.91	7817.67	30556.81	20796.45	12841.57
53140.00	10332.53	955.37	8560.35	33291.75	20979.45	11763.83
57656.90	11055.81	964.92	9373.58	36262.59	21158.87	10773.90
62557.73	11829.71	974.57	10177.83	39575.62	21381.47	9886.53
67875.14	12657.79	984.32	11051.09	43181.94	21601.72	9070.27
73644.53	13543.84	994.16	11999.28	47107.25	21819.77	8319.70
79904.31	14491.91	1004.10	13028.81	51379.49	22035.78	7629.78
86696.18	15506.34	1014.14	14146.69	56029.01	22249.89	6995.79
94065.35	16591.78	1024.28	15360.47	61088.81	22462.23	6413.39
102060.91	17753.21	1034.53	16678.40	66594.77	22672.93	5878.52
110736.09	18995.93	1044.87	18109.41	72585.87	22882.09	5387.44
120148.65	20325.65	1055.32	19663.19	79104.49	23089.85	4936.66
130361.29	21748.44	1065.87	21350.30	86196.67	23296.28	4522.98
141442.00	23270.83	1076.53	23182.15	93912.48	23501.51	4143.42
153464.57	24899.79	1087.30	25171.18	102306.30	23705.60	3795.25
166509.06	26642.78	1098.17	27330.87	111437.24	23908.66	3475.93
				1109588.52	438820.11	180000.78