DOE/R6/10986--T1

HEATING AND COOLING OF MUNICIPAL BUILDINGS WITH WASTE HEAT FROM GROUND WATER

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DOE/R6/10986--T1

DE84 003539

October, 1980

Contract No. DE-FG46-79R610986

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I. INTRODUCTION

A. Project Objective:

The purpose of this study is to determine the feasibility of using waste heat from municipal water wells to replace natural gas for heating of the City Hall, Fire Station, and Community Hall in Wilmer, Texas. At present, the 120°F well water is cooled by dissipating the excess heat through evaporative cooling towers before entering the distribution system. The objective of the study is to determine the pumping cycle of the well and determine the amount of available heat from the water for a specified period. This data will be correlated with the heating and cooling demand of the City's buildings, and a conceptual heat recovery system will be prepared. The system will use part or all of the excess heat from the water to heat the buildings, thereby eliminating the use of natural gas.

B. Project Location

The City of Wilmer is located in the southern portion of Dallas County, 15 miles south of downtown Dallas. Figure I-1 shows the general location of the City with respect to the Dallas metropolitan area. An estimated 2,200 people reside within the City limits as of 1980.

FIGURE I - 1

LOCATION MAP

City of Wilmer

Scale:

0 1 2 3 4 5 miles

II. EXISTING CONDITIONS

A. Trinity Sands Aquifer

1. Location

Renner and Vaught reported on the known and potential geothermal resources in the eastern United States.⁽¹⁾

Abnormally warm aquifer water is known or inferred to exist in several areas of the eastern United States. The largest region with this potential lies in Texas and Arkansas in the Ouachita structural belt and in the Balcones and Luling-Mexia-Talco fault zones. Numerous warm-water wells have been drilled here, and measured geothermal gradients range from 25 to 45°C/km (1.4 to 2.5°F/100 ft) within 1 kilometer (3,300 feet) of the surface.⁽²⁾

Figure II-1 depicts the approximate location of the warm Trinity Sands Aquifer associated with the Balcones and Luling-Mexia-Talco Fault Zones.

Woodruff, et. al., has prepared a comprehensive study of the regional geothermal resources associated with the Balcones and Luling-Mexia-Talco Fault Zone of Central Texas.⁽³⁾ There are five aquifers in the fault zone comprised of the Hosston/Trinity Sands, the Hensel Sand, the Paluxy Sand, the Edwards Limestone, and the Woodbine Sand. The Hosston/Trinity Sands aquifer have the greatest geothermal potential of the aquifers studied because it covers the largest area, provides the most towns across the area with water, is the deepest and consequently the hottest aquifer, and has generally moderate dissolved solids content.⁽⁴⁾ The Hosston/Trinity Sands Aquifer lies along a line from the Red River to San Antonio.

2. Geologic Information

The City of Wilmer obtains their municipal water supply from the Trinity Sands Aquifer, which is the deepest of the three aquifers underlying Dallas County. Approximately a million years ago, the study region was at the edge of the old Gulf Coast embayment and was covered by a shallow cretaceous sea. The sediment that was deposited in this sea consists of sand, silt, clay and limestone layers which dips eastward toward the embayment at an average rate of 45 feet per mile. A portion of the deposits overlie the Ouachita structural belt and lie between the Balcones Fault Zone and the Luling-Mexia-Talco Fault Zones.

The geothermal resource or the increased water temperature anomalies lie mostly along the main zones of normal faulting in the Balcones system, which is also superjacent to the Ouachita structural belt and its zones of thrust faulting.

There are several explanations for the geothermal anomalies as described by Dr. Woodruff in the following paragraph.

"Geothermal anomalies may be due to structural setting or to hydrologic factors. Clearly, there appears to be a relation between the location of faults and the abnormal gradients. This may be due to two divergent mechanisms; the faults may be conduits for upwelling fluids (i.e. hot brines), or the faults might retard fluid flow, thus resulting in a stagnating hydrologic system and a long-term increase in temperature. The local sources of the heat either trapped or conveyed by faults include (1) exothermic chemical reactions among deep-seated fluids, (2) buried plutons that are still cooling, (3) the presence of radiogenic rocks at depth, and (4) zones of rock possessing relatively high thermal conductivity properties. As noted by Plummer and Sargent (1931), these and other factors might act singularly or in concert to contribute to abnormal geothermal gradients in the Gulf Coast region."⁽⁵⁾

Figure II-2 depicts a cross section through Dallas County and shows the various geologic units.

The Trinity Sands net sand thickness in Dallas County ranges from about 200 feet along the western edge of the County to over 500 feet along the eastern portion of the County.

3. Depth to Trinity Sands and Net Sand Thickness

Table II-1 is the Driller's Log of the formations encountered by the Wilmer Well.

The subsurface geology of Dallas County was described by Mr. Paul W. Foster.⁽⁶⁾ He states that the Trinity Sands is the best source of ground water in the County.⁽⁷⁾ Mr. Foster also describes the lower portion of the Wilmer well, and states that the top of the Trinity Sands occurs between 3310 to 3340 feet and ends at about 3600 feet. The sands from 3600 feet to the end depth of 3670 are "older and differ lithologically from normal Trinity Sands and shales" and are probably equivalent to the lower Cotton Valley or Jurassic in composition and age.

Figure II-3 shows the net thickness of the Basal Trinity Sands.

4. Artesian Pressure

The Trinity Sands formation is a confined aquifer, which means the system is under pressure and if tapped, the water will rise toward the surface without being pumped. The first wells that were drilled into the Trinity Sand aquifer either flowed water or rose within a couple of feet from the surface. The water levels are now down from between 300 to 1000 feet below the surface.⁽⁸⁾

The Wilmer well was drilled in 1959 to a depth of 3,669 feet. A well pump was placed 450 feet below the surface and had a static level of 230 feet above the pump.⁽⁹⁾ Therefore, in 1959, the water level in the well was 220 feet below the surface. In 1977, the pump was lowered to 710 feet and had a static water level of 200 feet which placed the water table at 510 feet.⁽¹⁰⁾ The current water table is 550 feet below the surface with 160 feet of water over the pump.⁽¹¹⁾ The water level dropped 330 feet, from 1959 to 1980, with an average decline of 16.1 feet per year between 1959 to 1977 and an average decline of 13.3 feet per year between 1977 and 1980. The recent reduction in the water level decline may

TABLE II-1

DRILLER'S LOG

Trinity Well Number One - Wilmer, Texas

WELL DRILLED BY: J. L. MYERS' SONS DALLAS AND DENTON
 WELL COMPLETED: DECEMBER, 1959 DRILLER: D. P. NELSON

DEPTH OF STRATA		EACH STRATUM	FORMATION
0	- 4	4	Surface Soil
4	- 60	56	Sand & Gravel
60	- 600	540	Chalk Rock
600	- 1068	468	Shale
1068	- 1170	102	Sand and Shale
1170	- 1205	35	Sand
1205	- 1545	340	Shale and Sand
1545	- 1587	42	Lime
1587	- 1996	409	Broken Lime & Shale Streaks
1996	- 2173	177	Lime
2173	- 2189	16	Broken Sand
2189	- 2200	11	Shale
2200	- 2210	10	Sand
2210	- 3315	1105	Broken Lime W/Sand Streaks
3315	- 3325	10	Sand
3325	- 3348	23	Shale
3348	- 3430	82	Broken Sand and Shale
3430	- 3470	40	Lime and Shale
3470	- 3590	120	Sand
3590	- 3615	25	Red Bed
3615	- 3643	28	Shale
3643	- 3669	26	Sandy Shale

Above depths based on rotary table 8' above ground level.

FIGURE II-3

NET POROUS SAND THICKNESS
IN
BASAL TRINITY SANDS
 (AREA HAVING 200' + OF
POROUS WATER SAND
 ○ WATER WELL LOCATION
 ● WELL LOCATION - This Study
 CONTOUR INTERVAL = 50'

be attributed to the fact that several towns in the area are now using surface water supplies and have eliminated pumping ground water.⁽¹²⁾

A pump test was performed on the well in 1959. A decline of the water level occurred when pumping at 300 gallons per minute (g.p.m.) but when the pump was cut back to 200 g.p.m. the water level rose.⁽¹³⁾

5. Water Quality

The total dissolved solids (TDS) of the Trinity Sands water range from about 500 mg/l in the western portion of the aquifer to more than 10,000 mg/l in the eastern portion. In general, the water quality degrades with depth.

The Wilmer well water has a (TDS) content of approximately 1,450 mg/l which is above the State maximum permissible level of 1,000 mg/l. Table II-2 tabulates the results of several water quality analyses of the City's number one well.

The water quality is influenced by the depth and temperature. Generally, deeper and hotter water is correlated with higher total dissolved solids.⁽¹⁴⁾

The water is well suited for the proposed project, because it contains less than 2ppm of calcium. The low concentrations of calcium will inhibit the precipitation of calcium sulfate and calcium carbonate. The pH of the water is 8.85 thus, the water is not expected to be corrosive, but may deposit solids.

6. Water Temperature

Water temperatures of the Trinity Sands Aquifer range from around 70°F (21°C) near the outcrop of the recharge sands in the western portion of the aquifer to more than 140°F (60°C) in Falls County to the east.⁽¹⁵⁾ Generally, water temperatures increase with depth and sand thickness. Figure II-4 illustrates the temperature contours of the groundwater.

TABLE II-2
WATER QUALITY ANALYZES
WELL NUMBER ONE
WILMER, TEXAS

Type Analysis	Sample No. 1	Sample No. 2	No. 3
Calcium	7.2	6	1.3
Magnesium	0.5	2	-
Sodium	525.0	529	482
Bicarbonate	620.7	548	600
Carbonate	19.2	16	12
Sulfate	179.6	198	165
Chloride	307	349	314
Fluoride	-	2.3	4.4
Total Dissolved Solids	1667.8	1,370	-
Total Hardness as Calcium carbonate	20	23	-
pH	8.2	8.6	8.8
Total Hardness	-	-	510
Hypothetical Combination			
Calcium Bicarbonate	29.1		
Magnesium Bicarbonate	3.0		
Sodium Bicarbonate	821.3		
Sodium Carbonate	33.9		
Sodium Sulfate	265.8		
Sodium Chloride	506.2		
Silica	8.0		
Iron	0.5		
Total Dissolved Solids	1667.8		

Sources:

- * The Pope Testing Laboratories, 1959 - Water Sample of Completed Well.
- ** Dallas County Health Department, 1977.
- *** Dr. Homer Klonis - Chemist, 1980.

FIGURE II-4

**WATER TEMPERATURE
OF TRINITY SANDS
AQUIFER**

A bimetal thermometer was installed in the wellhead of the Wilmer No. 1 wellhead to measure the water temperature. The temperature of the water first existing in the well is about 115°F, but will steadily increase to 120°F within a few minutes. The temperature of the Wilmer water at the wellhead holds steady at 120°F (49°C) and has been observed at 122°F.

B. City of Wilmer Water Distribution System

The City of Wilmer owns and operates its water supply and distribution system. Most of the houses within the Wilmer city limits are served. A utilities survey, conducted in June, 1979, showed that 701 residences were served by the City water system, out of a total of 854 structures located within the City's extraterritorial jurisdiction.⁽¹⁶⁾

The City operates two municipal water wells. Well No. 1 is located in Davidson Plaza in the center of town, while well No. 2 is located to the north of town off Swango Road. This study will concentrate on Well No. 1, located close to the municipal buildings.

1. Facilities at Well No. 1

Well No. 1 is powered by a 75 horsepower submersible pump. The water discharges into a cooling tower, then flows to a 50,000 gallon ground storage tank. Electrodes located in the top of the ground storage tank regulate the well pump or pumping cycle which is dependent on the water demand.

The water is chlorinated as it enters the ground storage tank. The water is finally pumped to a 50,000 gallon elevated storage tank before entering the distribution system. The deep well pump is rated at 300 gallons per minute, where as the two booster pumps are 25 and 7.5 horsepower motors which deliver water to the distribution system.

Figure II-5 illustrates the location of the City's municipal buildings in relation to the Well Number One water distribution system.

2. Water Production from Well No. 1

The quantity of water pumped from well number one was obtained from monthly City records and from daily monitoring for two weeks. The monthly pumping records are presented in Figures II-6 to 18, and are summarized in Table II-3. The water usage correlates with the time of year with less water being pumped in the winter months. The minimum daily average was 75,200 gallons in November and ranged from 80,800 to 101,000 gallons for the rest of the winter months.

The average daily volumes of water provide an abundance of available heat for potential recovery. However, the availability of the geothermal water in relation to the heating demand of the buildings was not known.

A Rustrac Model 292 strip chart recorder was installed in the pump-house to record the duration and time of day the well pump was operating. The recorder registers electrical events, which in this case correspond to the period when the pump was on or off. The recorder strip chart speed was geared at one inch per hour. The water flow was measured by a dial flow meter at the wellhead. The average gallons per minute of water being pumped was calculated by dividing the total gallons pumped per day by the total minutes of pump operation. Table II-4 tabulates the results of daily well monitoring, and Figures II-19 and 20 illustrate the occurrence and duration of pumpage on a daily basis.

The first monitoring period, March 19 through 27, show the pump run an average of seven hours per day and turns on an average of six times daily. The majority of the pumping occurred in the morning and evening. The second monitoring period, April 29 through May 4, indicated that the well pump ran an

FIRST STREET

FIRE
STATION

POST OFFICE

DALLAS AVE.

LIBRARY

COMMUN.
CENT.

CITY

BELT LINE ROAD

FIGURE II-5

EXISTING PUBLIC BUILDING

**DAVIDSON PLAZA
WILMER, TEXAS**

ALBERT H. HALFF ASSOC. INC. - DALLAS, TEXAS

SCALE: 1" = 40'

TABLE II-3
AVERAGE DAILY PUMPING VOLUMES PER MONTH
WELL NUMBER ONE, WILMER, TEXAS

<u>Month</u>	<u>Total for the Month</u>	<u>Daily Average</u>
1979		
August	3,756,700	121,200
September	3,850,700	128,400
October	3,143,400	101,400
November	2,255,900	75,200
December	2,847,140	91,800
1980		
January	2,504,900	80,800
February	2,925,300	100,900
March	3,058,900	98,700
April	3,532,400	117,700
May	5,003,800	161,400
June	5,954,100	198,500
July	5,179,000	167,000
August	5,096,000	164,400

CITY OF WILMER, TEXAS

Figure: II-6 Well Number One Daily Pumping Volumes — August 1979

CITY OF WILMER, TEXAS

Figure: II-7 Well Number One Daily Pumping Volumes — September 1979

CITY OF WILMER, TEXAS

Figure: II-8 Well Number One Daily Pumping Volumes — October 1979

CITY OF WILMER, TEXAS

Figure: II-9 Well Number One Daily Pumping Volumes — November 1979

CITY OF WILMER, TEXAS

Figure: II-10 Well Number One Daily Pumping Volumes — December 1979

CITY OF WILMER, TEXAS

Figure: II-II Well Number One Daily Pumping Volumes — January 1980

CITY OF WILMER, TEXAS

Figure: II-12 Well Number One Daily Pumping Volumes — February 1980

CITY OF WILMER, TEXAS

Figure: II-13 Well Number One Daily Pumping Volumes — March 1980

CITY OF WILMER, TEXAS

Figure: II-14 Well Number One Daily Pumping Volumes — April 1980

CITY OF WILMER, TEXAS

Figure: II-15 Well Number One Daily Pumping Volumes — May 1980

CITY OF WILMER, TEXAS

Figure: II-16 Well Number One Daily Pumping Volumes — June 1980

CITY OF WILMER, TEXAS

Figure: II-17 Well Number One Daily Pumping Volumes - July 1980

CITY OF WILMER, TEXAS

Figure: II-18 Well Number One Daily Pumping Volumes — August 1980

TABLE II-4

DAILY PUMPING LOG - WELL NUMBER ONE
WILMER, TEXAS

24hr. Cycle 8:00 a.m. - 8:00 a.m.

Date	Total Gallons	Total Minutes	Average Gallons Per Minute
Wed. 3/19	102,400	370	277
Thurs. 3/20	114,800	460	250
Fri. 3/21	120,600	452	267
Sat. 3/22	82,150	356	230
Sun. 3/23	100,200	343	292
Mon. 3/24	123,800	477	260
Tues. 3/25	115,200	444	260
Wed. 3/26	135,800	530	256
Thurs. 3/27	113,600	454	250
Tues. 4/29	124,100	475	261
Wed. 4/30	208,000	807	258
Thurs. 5/1	191,400	741	258
Fri. 5/2	190,600	764	250
Sat. 5/3	191,400	853	224
Sun. 5/4	198,700	725	274

CITY OF WILMER, TEXAS

Figure : II-19

Well Number One Daily Pumping Cycle

March 19 to 28

CITY OF WILMER

Figure : II-20

Well Number One Daily Pumping Cycle

April 29 to May 5

average of twelve hours per day and turned on an average of eleven times daily. The majority of the pumping occurred in the morning and evening. The second set of pumping records are abnormally high, due to the fact that Well No. 2 was shut down for repairs and, therefore, Well No. 1 was supplying all of water for public consumption.

C. Municipal Buildings

Most of the City of Wilmer's public buildings are located in a centralized plaza containing the majority of a square City block. The predominant municipal buildings located in the plaza are:

1. The City Hall,
2. Community Hall,
3. Fire Station,
4. Library, and
5. The Post Office.

The City Hall, Community Hall, Fire Station and Library were the only buildings considered for the geothermal retrofit because of their daily occupancy, size and location to the well.

The City Hall was constructed in 1963 and contains 1200 square feet of office space. The building is constructed of cinder blocks with brick veneer and has three inches of insulation in the ceiling. The building provides offices for City personnel as well as the Police Department. The building is occupied 24 hours a day seven days a week. The heating unit is located in a closet in the northeast corner of the building. The building is heated by a one-ton natural gas heating system.

The Wilmer Community Hall was built in 1971 and is constructed of belted steel. The building has three inches of insulation in the ceilings and walls. The building measures 60 feet by 40 feet and contains a large meeting room, a kitchen, a storeroom and restrooms. Two one-ton natural gas heating units are located in a closet at the south end of the building. The heated air is distributed throughout the building by a duct system. The building is only occupied periodically and then for City Council and Municipal Court meetings as well as other public or private meetings, social events and voting.

The Wilmer Fire Station was built in the 1950's and is constructed of brick. The building contains five fire engine bays, an office, a kitchen and restrooms. The building is heated by two natural gas-fired unit heaters suspended from the ceiling, one gas-fired convector heater built into the wall and one portable natural gas-fired radiant heater. The building is occupied only periodically with the greatest demand occurring at night during training meetings.

The City Library was formerly used as an appliance store and is believed to have been built in the 1930's or 1940's. The building is constructed entirely of wood, contains no insulation and contains approximately 3,000 square feet. A portion of the building is used by the Wilmer Water Department. The Library is occupied a total of 12 hours per week, while the Water Department office is used from 8 to 5 five days a week. The building is heated by three portable natural gas-fired radiant heaters.

III. DESIGN CRITERIA

The water produced from Well No. 1 is not hot enough to be used for powering air conditioning equipment; therefore, the scope of the study is limited to the heating requirements of the buildings.

A. Building Design Conditions

The City Hall and Community Hall will be heated to 70°F, with set back to 60°F when unoccupied. The fire station will be heated to 50°F for equipment protection only. The ambient design temperature in the Dallas area is + 10°F. The average heating season is 162 days from October 27 to April 6. During this season, there are 2,272 65°F (base) degree days. The monthly diurnal climatological data for 1977 and 1978 is shown in Figures III-1 and III-2. Figure III-3 depicts the anticipated heating demand curves for each building. Table III-1 lists the hourly heating demand for each building.

B. Water Heat Content

The municipal well water maintains virtually a constant temperature of 120°F. The well pump delivers water at a rate ranging between 260 and 300 gpm. At the present time, the 120°F well water is cooled to about 90°F in an evaporative cooling tower before distribution.

Pumping data for the monitored week was plotted to show actual "on" and "off" time. The pumping rate of 260 gpm of 120°F water has a total heat capacity of 2.33×10^6 BTU/HR for a 20°F temperature drop. This is greatly in excess of the heating requirements of the municipal buildings so that only a minor portion of the domestic well water needs to be diverted to supply the heating requirements.

Figure : III- I

Average Diurnal Variation - 1977

FROM NOAA CLIMATOLOGICAL DATA D/FW TX

Figure : III-2 Average Diurnal Variation - 1978

FROM NOAA CLIMATOLOGICAL DATA D/FW TX.

Figure :III-3

Total Heating Demand Curves of Municipal Buildings

TABLE III - 1
HOURLY HEATING DEMAND
OF MUNICIPAL BUILDINGS
WILMER, TEXAS

<u>TIME</u>	<u>CITY HALL</u>	<u>COMMUNITY HALL</u>	<u>FIRE STATION</u>	<u>LIBRARY</u>	<u>TOTAL (1000 BTU/Hr.)</u>
Mid	45.5	57.6	113.6	23.0	239.7
1 AM	46.3	58.2	114.2	23.0	241.7
2	46.9	58.6	114.6	23.0	243.1
3	47.5	59.0	116.2	23.3	246.0
4	48.3	63.0	119.0	23.8	254.1
5	49.0	61.6	122.2	24.3	257.1
6	50.0	66.6	123.0	24.5	264.1
7	49.0	66.0	122.2	28.8	266.0
8	65.1	115.0	120.0	32.8	332.9
9	64.8	113.0	116.0	32.0	325.8
10	62.0	113.4	109.2	30.8	315.4
11	59.3	113.4	103.0	29.3	305.0
Noon	56.7	105.0	97.0	27.8	286.5
1	53.9	108.6	91.4	26.5	280.4
2	51.5	104.0	86.2	25.5	267.2
3	48.3	99.6	85.2	25.5	258.6
4	50.8	102.4	88.5	26.5	268.2
5	53.0	105.4	92.0	27.3	277.7
6	37.5	108.4	96.0	28.0	269.9
7	39.2	112.6	100.3	28.5	280.5
8	41.1	116.0	105.3	25.8	288.7
9	43.3	120.0	108.8	22.3	294.4
10	44.0	89.1	110.5	22.8	266.4
11	44.8	57.2	112.3	23.0	237.3

The longest "off" period, 13½ hours, occurred between 8:45 p.m. Saturday and 10:15 a.m. Sunday. More typically, the off period during the week generally ranges from 11:00 p.m., to 7:00 a.m. The capacity of the hot water storage tank was based upon a 9-hour "off" period during which the heat demand would be 2.81×10^6 BTU. Allowing for a temperature differential of 20°F (120°F to 100°F) would require storage capacity of about 16,000 gallons. An insulated tank 12 feet in diameter by 20 feet high would be adequate. The hot water would be pumped to the buildings at a rate of about 150 gpm. A 90 gpm line is required for the City Hall and Community Hall, while a 60 gpm flow will supply the required heat for the Fire Station. A liquid level in the storage tank would automatically start the well pumps to replenish hot water to the storage tank.

The total amount of water required to be diverted through the heating system storage tank depends upon the heating demand and efficiency of the heat exchanger for peak building heating demand. Under design conditions, building demand will be 5.9×10^6 BTU/Day. We assumed a 65 percent efficiency for a heating coil exchanger with 120°F entering temperature installed in the heating ducts of the existing heating system.

Based on the building heating demand, the 65 percent efficiency of the heat exchanger and the 20°F temperature differential of the water, the heating system will require an average of 54,600 gallons per day. The utilization of the existing heating system was given high priority in order to keep the initial capital costs low.

C. Water Reuse and Health Protection Problems

The problem of health and protection of the water quality is of major importance as the geothermal system will utilize water that is distributed for human consumption. Consideration was given to using a two-stage separate heat

exchanger system to transfer heat from the domestic water to the building's heating units. This would offer the greatest possible protection against contamination, but is not required by either the City of Wilmer, the National Plumbing Code, nor the Texas Health Department. However, it is the best design to avoid problems arising from misuse of the system. The two-stage heat exchanger system was abandoned in favor of a single-stage system where the well water passes directly through the heating coils and is then returned to the water supply system. There were two strong reasons for this choice: 1) The additional coil heat exchanger would nearly double the inefficiencies of the system. Immersion type heat exchangers were to be submerged in the insulated storage tank to transfer heat from the well water to the heating system circulating water units suitable for low pressure. Low temperatures heat transfer are not easily available and are considered to have low coefficients of transfer. 2) The additional heat exchanger would also increase the initial capital costs of the system.

At 50 percent overall efficiency and 10°F differential of the storage tank, this would require 140,000 gallons per day. This is about an average daily use so virtually all municipal water would circulate through the storage tank. Therefore, a single-stage water-to-air heat exchanger was used in the design of the system.

The single greatest unknown is the efficiency or effectiveness of heat exchangers operating at temperatures of 120°F . Some data indicate that it is impractical to provide comfort heating of 70°F using supply water at 120°F . Other sources state that it can be done.

A 1.5 square foot fin and tube (water-to-air) heating coil was selected for the design because they would fit into the existing heating unit ductwork with minor modification. Each coil was calculated to produce 35,000 BTU/hr output. The air flow was calculated to be 1200 cubic feet per minute.

The number of coils required for each building, based on the design output data, is as follows: City Hall, 2 coils; Community Hall, 4 coils; and Fire Station, 4 coils.

IV. HEAT RECOVERY SYSTEM DESIGN

A. Alternative Systems

The City of Wilmer's municipal buildings are heated by natural gas using a variety of furnaces, unit heaters, and radiant heaters. The possible systems which have been analyzed and considered as substitutes for the existing gas-fired equipment are:

1. Hot water radiation systems which include radiation, convectors, baseboard, fin-tube heaters.
2. Forced air systems using water-to-air heat exchanger elements.
3. Water-to-air heat pump systems.

A previous investigation studied the economical aspects of geothermal heating, and concluded that each of the above systems has advantages under certain conditions.⁽¹⁷⁾ The study made the following conclusions:

1. The most economical use of geothermal energy is in baseboard connectors, if the entering water temperature is not less than 140°F, but 150°F minimum is desirable.
2. Forced air systems can be designed for water temperatures as low as 120°F. Lower temperatures require greater air and water circulation with increased pumping power requirements and costs.
3. Water to air heat pumps are economically feasible with entering water temperatures as low as 70°F for the heating cycle. This type system becomes particularly attractive when space cooling is included in the design. However, smaller units in the residential size range are not readily available for entering water temperatures higher than 90°F.

The particular situation at Wilmer presents several obstacles to the economical use of geothermal energy. First of all, the usual temperature of the well water is not optimum for any of the possible systems, and actually rules out several possibilities. The temperature is too low for connectors, fin-tubes or raditors, and too high for commercially available heat pumps. Secondly, the cost of retrofitting a new system must be kept low, because the present total cost of utilities is relatively small and the new equipment must be amortized at reasonable terms.

The forced-air system is the recommended solution for the recovery of the geothermal energy in Wilmer. Forced-air heating systems will be able to utilize the majority of the existing gas-fired equipment by substituting a hot water coil for the existing air-to-air heat exchanger. The evaporator coil for cooling would remain in-place. Such a changeover provides an advantage by holding first-cost for equipment and installation to a minimum. However, the use of 120°F water in the heating coil will require an increase air flow which will require greater fan power. Existing fan drives will have to be enlarged to move a greater volume of air. In addition, a hot water circulating pump will also be required. This type system appears to have an overall advantage for maximum savings compared to the available alternatives.

B. Recommended Heating System

The recommended geothermal heating system is illustrated on Figure IV-1 in relation to the existing water system and municipal buildings.

Figure IV-1 depicts the existing water distribution system and the proposed geothermal additions. The operation of the geothermal system is described below and correlates to Figure IV-2.

FIRST STREET

FIRE
STATION

60 GPM

15
Hr

60 GPM

POST OFFICE

DALLAS AVE.

LIBRARY

COMMUN
HALL

Units 1-4
60 GPM

Unit 3
CITY HALL
30

BELT LINE ROAD

FIGURE IX-1
**PROPOSED GEOTHERMAL
 HEAT RECOVERY SYSTEM**
WILMER, TEXAS

ALBERT H. HALFF ASSOC. INC - DALLAS, TEXAS
 SCALE: 1" = 40'

EXISTING SYSTEM

- P-1 WELL PUMP 300 CPM.
- C-T COOLING TOWER
- T-1 125,000 GAL. STORAGE TANK
- C-1 CHLORINATION SYSTEM
- P-2 BOOSTER PUMPS
- T-2 50,000 GAL. STORAGE TANK
- AC-1 7 1/2 TON AIR CONDITIONING UNIT.
- AC-2 4-TON AIR CONDITIONING UNIT.

PROPOSED ADDITION

- V-1 SOLENOID VALVE (NCR)
- P-3 HOT WATER CIRCULATING PUMP
- V-2 MOTORIZED THREE-WAY VALVE
- T-3 INSULATED WATER STORAGE TANK
- UNIT #1, #2 HOT WATER MODULATING VALVES
- EXISTING H & A.C. UNIT PER UNIT.
- UNIT #3 NEW 100,000 BTU/H
- VH-1 THRU 4 MODULATING VALVES
- TH-1 THERMOSTAT IN RETURN
- TH-2 " " " SUPPLY

ALLY OPEN)

PUMP, 150 GPM. 30' HEAD I.H.P.

VALVE

E TANK, 1600 GAL. @ 120°F

ICATION OF

S - 100,000 BTU/HR.

HR. HOT WATER UNIT

ES

VE

FIGURE IV-2

**PROPOSED GEOTHERMAL
HEAT RECOVERY SYSTEM**

WILMER, TEXAS

ALBERT H. HALFF ASSOC. INC - DALLAS, TEXAS

The normal operation of the existing water system is regulated by a series of liquid levels in the water storage tanks. The well pump P-1 runs in response to the water level in the ground storage tank T-1. The booster pumps P-2 delivers water to the elevated storage tank T-2 in response to the water level in the tank T-2 or pressure in the water distribution lines.

The proposed additional components to the heating system are described below. Two new diverting valves V-1 and V-2 will regulate the amount of water entering and leaving the heating system. Modulating valves VH-1, VH-2, VH-3 and VH-4 regulate the volume of water circulating through the heating coils in each unit. The modulating valves will be regulated by thermostats in each building. A 1600 gallon insulated ground storage tank T-3 will be used to store the hot water. A new water pump P-3 and an electrical control system have been added to distribute the water when the demand arises.

The operation of the proposed system when heating load is "OFF" will require valve V-1 to remain open while valve V-2 is set for diverting return flow to T-3. When Pump P-1 runs, some flow is diverted to tank T-3 until pressure in T-3 equals pump discharge head. The tank is, therefore, kept filled awaiting heating system turn-on.

The operation of the proposed system when the heating demand is "ON" is discussed below. Valve V-1 is open so that the water flows to cooling tower C-T. Valve V-1 is closed only when the heat demand is ON and when there is no municipal water demand and tank T-2 is full. Valve V-2 is set to divert the water to T-3. Pump P-3 is operating and delivering water to the heating units. The modulating valves VH-1, VH-2, VH-3 and VH-4 are open and are controlled by the room thermostats. The well pump P-1 turns on in response to either heating or domestic Water System Demands. A portion of the hot well water is diverted

through a new four-inch supply line to the insulated storage tank T-3. Pump P-3 then circulates the water from T-3 to the heating units. The unit heater modulating valves operate in response to the heating demand as sensed by the room thermostats. Excess hot water flow is diverted through by-pass valves keeping the amount of circulating water constant. Return hot water, which is above 100°F, returns to the insulated tank T-3 and is recirculated. When the return water drops to 100°F, diverting valve V-2 goes to "flow-through" position under control of the thermostat Th-1 in the return line. The rejected 100°F water is returned to the cooling tower and the water supply system. The water level in the insulated storage tank T-3 will drop due to no return flow. The liquid level switch in T-3 will turn on the well pump P-1 for a minimum of three minutes. If tank T-1 is full, a control switch will close V-1 to prevent an overflow while Tank T-3 is filling up with hot water. The same re-filling operation of the insulated storage tank T-3, as described above, will occur if the temperature of the water in T-3 drops to 100°F as sensed by the thermostat Th-2 in the supply line.

C. Cost of Proposed Geothermal System

The cost of retrofitting the existing natural gas heating system with the geothermal system was calculated to cost \$33,300 and is presented in Tables IV-1 and IV-2. These costs include both materials and labor for installation.

TABLE IV-1
COST ESTIMATE FOR SITE WORK
(1980 Dollars)

	Quantity	Labor	Material	Total
1. Install 4" C.I. Tee in Pump Discharge Line	1	50.00	\$ 200.00	\$ 250.00
2. Excavate 400 L.F. Trench 2"-6" X 1' X 6" Wide	54 C.Y.	600.00		600.00
3. Place Bedding Sand (0'-6" dp)	12 C.Y.	300.00	100.00	400.00
4. Construct 2' X 3' X 3' Pump Pit	1	100.00	250.00	350.00
5. Erect 16,000 Gallon Insulation Tank	1	-	-	15,000.00
6. Install 150 GPM, 40 Ft. Hd Pump with motor	1	150.00	600.00	750.00
7. Install PVC Pipe Type II, Schedule 40				
4" diameter	30'	50.00	32.00	82.00
3" "	30'	50.00	22.50	72.50
2½" "	440'	450.00	325.00	775.00
2" "	280'	300.00	104.25	404.25
1½" "	550'	500.00	154.00	654.00
1" "	150'	150.00	26.25	176.25
Subtotal		\$1,500.00	\$ 664.00	
Fittings @ 15%		\$ 225.00	99.60	
Total		1,725.00	763.60	\$ 2,488.60
8. Install 4" C1 Valve	1	-	-	450.00
9. Backfill and Compact	45 C.Y.	-	-	800.00
TOTAL				\$21,088.60
			Say	\$21,100.00

TABLE IV-2
COST ESTIMATE FOR INTERIOR MECHANICAL/ELECTRICAL WORK
(1980 Dollars)

		Quantity	Labor	Material	Total
1.	Modify Ductwork (3 places)	Job	\$ 400.00	\$ 100.00	\$ 500.00
2.	Replace Blower Motors	3 Each	600.00	900.00	1,500.00
3.	Install Unit Heater (35 MBH) Fire Station	4 Each	1,000.00	2,400.00	3,400.00
4.	Install 12" x 18" Heating Coils (35 MBH)	6 Each	600.00	1,500.00	2,300.00
5.	Pipe and Valve Sets	10 Each	2,000	500.00	2,500.00
6.	Thermostatic Control System	Job			<u>2,000.00</u>
	Subtotal				\$12,200.00
Summary					
	Site Work		\$21,100.00		
	Interior Work		<u>12,200.00</u>		
	GRAND TOTAL		\$33,300.00		

V. ECONOMIC ANALYSIS

This chapter compares the costs of operating the existing natural gas-fired heating system versus the cost of installation and operation of the proposed geothermal system.

A. Existing Natural Gas Consumption and Cost

The City of Wilmer purchases natural gas from Lone Star Gas Company for heating the municipal buildings. The City buys the gas at the commercial rate. Figure V-1 plots the historic and projected cost of the gas.

Table V-1 lists the consumption and cost of the gas used during the winter of 1978 and 1979 and part of 1980. Table V-2 lists the average monthly gas consumption for the winter. The City uses an average of 300 MCF per winter to heat the Fire Station, City Hall and Community Hall. The 300 MCF per winter was held constant in the projections of future gas costs. The price of natural gas was assumed to increase 15 percent per year. Natural gas cost \$2.97 per 1000 cubic feet (1 MCF) in September 1980, and this figure was used as the base price for future projections.

B. Life Cycle Cost Analysis

Based on the various sizes of pumps and motors for the geothermal system, an operating cost for the system was formulated.

Table V-3 lists the 1980 operating and maintenance expenses and the offsetting natural gas savings. The price of electricity was assumed to increase 13 percent per year. Table V-4 lists the inflation factors which were used for calculating the 25-year O&M expenses versus natural gas saved.

Figure: V-1

Natural Gas Gate Rate Historic and Projected Cost Jan. 1970 - Sept. 1980

TABLE V-1

CITY OF WILMER WINTER GAS CONSUMPTION
OCTOBER THROUGH MARCH
1978 TO 1980

Date	City Library		Fire Station		City Hall - Community Hall		Water Works	
	MCF	Cost	MCF	Cost	MCF	Cost	MCF	Cost
1-13-78	18.0	51.37	32.8	91.40	37.6	104.30	5.9	18.09
2-14-78	43.5	119.21	60.7	165.04	29.2	81.10	6.3	19.07
3-15-78	23.1	67.35	32.7	94.09	26.8	77.71	4.9	15.74
10-13-78	0	0	0.9	4.11	0	0	0	0
11-13-78	4.2	13.06	2.4	8.00	1.2	3.71	0	0
12-13-78	14.8	43.34	18.3	53.05	3.9	12.67	0	0
Subtotal	103.6	294.33	147.8	415.69	98.7	279.49	17.1	52.90
1-16-79	20.3	59.43	16.5	48.74	64.4	182.00	4.3	13.99
2-14-79	24.5	72.08	20.0	59.26	67.4	192.60	3.3	11.16
3-15-79	13.4	40.68	15.0	45.25	30.0	88.01	1.3	5.16
10-15-79	0	0	2.3	8.17	0	0	0	0
11-13-79	0.3	6.91	7.2	27.99	0	6.00	0	6.00
12-13-79	10.6	38.56	24.2	80.34	67.2	211.43	2.8	14.60
Subtotal	69.1	217.66	85.2	269.75	229.0	680.04	11.7	50.91
1-16-80	13.8	48.34	37.0	119.52	85.5	268.31	2.6	13.98
2-15-80	17.0	58.52	35.6	115.95	69.7	221.35	2.5	13.72
3-17-80	10.4	38.45	15.9	55.62	24.2	81.52	2.5	13.80
Subtotal	41.2	145.31	88.5	291.09	179.4	571.18	7.6	41.50
Total	213.9	\$657.30	321.5	\$976.53	507.1	\$1,530.71	36.4	\$145.31

TABLE V-2

CITY OF WILMER, TEXAS
AVERAGE WINTER GAS CONSUMPTION FOR
CITY HALL - COMMUNITY HALL - FIRE STATION

	City Hall Community Hall (MCF)	Fire Station (MCF)	Total MCF Per Month
January	63	29	92
February	55	39	94
March	27	21	48
October	0	2	2
November	1	5	6
December	<u>36</u>	<u>21</u>	<u>57</u>
Total	182	117	299
Total MCF Per Heating Season	299 Say 300		

Current 1980 commercial gas rate is \$2.9724/MCF.

TABLE V-3
1980 BASE COSTS

<u>INITIAL CONSTRUCTION COST</u>	\$33,300
----------------------------------	----------

ANNUAL OPERATING COST

Electric Power	\$1,210
Operator (Part-time)	175
	\$1,385

MAINTENANCE

Annual

Clean Coils, Oil Motors 10 ea. @ \$5	50 \$ 50
---	----------------

5 Years

Clean & Check Motors	
3 Heater Motors @ \$25 ea.	45
4 Unit Heater Motors @ 25 ea.	100
1 Pump Motor @ \$25 ea.	125
	\$ 260

10 Years

Re-paint Exterior of Water Tank	
8 man days @ \$100	800
5 gallons @ \$10	50
	\$ 850

OFFSETTING COSTS - ANNUAL

Natural Gas	
300 MCF x \$2.97/MCF =	\$ 890

TABLE V-4
INFLATION FACTORS
(1980)

Year	Year No.	10%	Factor 13%	15%
1981	1	1.00	1.00	1.00
1982	2	1.10	1.13	1.15
1983	3	1.21	1.28	1.32
1984	4	1.33	1.44	1.52
1985	5	1.46	1.63	1.75
1986	6	1.61	1.84	2.01
1987	7	1.77	2.08	2.31
1988	8	1.95	2.35	2.66
1989	9	2.14	2.66	3.06
1990	10	2.36	3.00	3.52
1991	11	2.59	3.39	4.05
1992	12	2.85	3.84	4.65
1993	13	3.14	4.33	5.35
1994	14	3.45	4.90	6.15
1995	15	3.80	5.53	7.07
1996	16	4.18	6.25	8.14
1997	17	4.59	7.07	9.36
1998	18	5.05	7.99	10.76
1999	19	5.56	9.02	12.37
2000	20	6.11	10.20	14.23
2001	21	6.72	11.52	16.37
2002	22	7.40	13.02	18.82
2003	23	8.14	14.71	21.64
2004	24	8.95	16.62	24.89
2005	25	<u>9.85</u>	<u>18.78</u>	<u>28.63</u>
		98.32	155.55	212.78

The economic feasibility of the proposed installation depends on estimated savings in fuel costs, offset by interest on an amortization of the initial construction investment, operating, maintenance and repair or replacement costs during the estimated economic life of the installation.

Costs have been developed by analysis of normal operating procedures and requirements for maintenance and repair based on experience of similar facilities. Cost escalation, due to inflation, has been developed from a variety of sources. Electric power and natural gas rates were taken from current Department of Defense data used in "Life Cycle Casting for Total Energy Systems." Personnel rates were estimated from current rates for public employees in the Dallas area (about 7%) adjusted upward based on predicted employee demands for upgrading to 12-25 percent rates. A 10 percent rate was selected as a possible average rate over 25 years.

Interest on bonds are fluctuating markedly. The City of Wilmer pays 5.4 percent on their last issue of 1974. A prior issue of 1971 had a 6.55 percent rate. An estimated rate of 10 percent was selected.

Life cycle costs are determined by adding annually occurring maintenance and operating costs, annual volume of periodic repair or maintenance, and annual interest and amortization.

An investment of \$33,300 in changing the system from gas to hot water in 25 years will save 7500 MCF of natural gas, and use 516.6 MWH additional electric power. Fuel and power costs are a virtual trade-off over the 25 year span with \$189,400 saved in natural gas costs and \$188,200 spent for electric power. Therefore, total cost of installation and operation of \$105,000 for 25 years is unamortized expense.

VI. SUMMARY AND RECOMMENDATIONS

The Wilmer No. 1 well produces water with a temperature of 120°F at the wellhead. Operation of air conditioning equipment is not practical with water at this temperature. The proposed geothermal system could supply all of the heating demand for the City Hall, Community Hall and Fire Station. The municipal buildings have a total heating demand of 5.6×10^6 BTU/day. The heating system efficiency was determined to be 65 percent, which yields an overall heating demand of 9.1×10^6 BTU/day.

The No. 1 Well produces an average of 101,000 gallons per day, which contains 16.83×10^6 BTU per day, based on a 20°F drop in water temperature. Heating the municipal buildings would require 54,600 gallons per day.

The proposed geothermal retrofit of the existing natural gas heating system is not economical because the savings in natural gas does not offset the capital cost of the new equipment and the annual operating and maintenance costs. The geothermal system was estimated to cost \$33,300 installed and was calculated to have a 25 year operating life. In 25 years, the proposed geothermal system would save 7500 MCF of natural gas with a total value of \$189,400, while consuming 516.6 MWH of additional electricity at a cost of \$188,200. The fuel savings and power costs are therefore a virtual trade-off over the 25-year period. The installation and operation of the system was estimated to cost \$105,000 for 25 years which is an unamortized expense. In conclusion, retrofitting the City of Wilmer's municipal buildings is not feasible based on the economic analysis and fiscal projections as presented in Chapter V.

The geothermal resource is present and should be considered as an alternative heating supply system for future buildings. The City should search for potential users whose energy demand matches the City's heat supply. An industry which would utilize the hot water resource year round, would benefit much more from the geothermal resource than an industry that would only use the hot water for their winter heating.

The water level of the Trinity Sands aquifer is dropping an average of 10 to 12 feet per year. The resource will be available for many years before it becomes uneconomical to pump the water. An assessment of the long-range yield of the aquifer should be conducted before any substantial geothermal systems are built.

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