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DOE/R8/00430--T1

DE84 015681

# Geothermal Heating From:

# PINKERTON HOT SPRINGS

## At Colorado Timberline Academy
## Durango, Colorado

MASTER

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*Initiated with the aid of a Department of Energy - Appropriate Technology Grant Number DE-FG 48-79R800430*

Nov. 8, 1981

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civil & solar engineering

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civil & solar engineering

Tom Stroud
Appropriate Technology Program
Project Manager
DOE
Denver, Colorado

Tom:

Find enclosed the final report for Grant No. DE FG 48 79R800430 of the Appropriate Technology Small Grants Program. This grant was for the period Nov. 15, 1979 to Nov. 15, 1981 and every effort is made here to have this report to you by the latter date.

The primary capital expenses and construction have been performed for the grant program. A heat exchanger building with all equipment and controls has been constructed and heat circuits led to three buildings on the Colorado Timberline Academy campus. A series of experiments has been conducted to determine the expected rate of heat loss for panels at the temperature of the geothermal waters of the Pinkerton Hot Springs.

Unfortunately, the objective of having the spring water rerouted has not been met. The Colorado Highway Department agreed (not in writing unfortunately) to route the spring water past a chosen location in insulated pipe to the original waste location of historical use, thus ending the present "temporary" situation of spring routing due to construction of a highway in 1977. The matter of whether or not the springs will eventually be routed as promised hinges on available construction funds with the CDH.

The project is not without good results and a useful effort toward completion, however. The panel heat loss tests were successfully run and summarized. Classes on the geothermal resource were conducted at Colorado Timberline Academy , and CTA students were able to observe the effort throughout the period. The heat exchange tank has been heated by other means and the circuits tested for their capabilities.

The present plan is to conduct a series of data collection experiments over the course of the winter during cold weather with the alternate tank heat source to assess the performance of the system when the geothermal waters are routed through it. Part of the last payment for this grant will be spent on the necessary valving, etc to allow connection of the geothermal waters when rerouted.

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While the actual objective of heating with the geothermal water has not yet been met, the program was still successful. Students were able to understand first hand the potential of the resource, plumbing, electrical and carpentry skills were learned by a few, and the experimental situation of panel testing was very valuable and I believe produced some interesting results.

The heat exchanger building and associated instruments have been constructed with an eye toward collecting more information over time and that process will be a continuing one.

Thank you,

Cap Allen
11/8/81

DOE/R8/00430--T1

# LOW TEMPERATURE SOURCE GEOTHERMAL HEATING PROJECT

AT COLORADO
TIMBERLINE ACADEMY,
DURANGO, COLORADO

DEPARTMENT OF ENERGY
APPROPRIATE TECHNOLOGY PROGRAM
Grant Number DE-FG48-79R800430

November 1979 to November 1981

## ABSTRACT

This Technical Report describes the efforts to establish a greater pool of knowledge in the field of low temperature heat transfer for the application of geothermal spring waters to space heating.

A comprehensive set of heat loss experiments involving passive radiant heating panels is conducted and the results presented in an easily interpretable form. Among the conclusions are the facts that heating a 65-70 F° space with 90-100 F° liquids is a practical aim. The results are compared with the much lower rates published in the American Society of Heating Refrigeration and Air Conditioning Engineers SYSTEMS , 1976.

A heat exchange chamber consisting of a 1000 gallon three compartment, insulated and buried tank is constructed and a control and pumping building erected over the tank. The tank is intended to handle the flow of geothermal waters from Pinkerton Hot Springs at 50 GPM prior to the wasting of the spring water at a disposal location. Approximately 375,000 BTU per hour should be available for heating assuming a 15 F° drop in water temperature.

A combination of the panel heat loss experiments, construction of the heat exchange devices and ongoing collection of heat loss numbers adds to the knowledge available to engineers in sizing low temperature heat systems, useful in both solar and geothermal applications where source temperature may be often below 110 F°.



Report Preparers:

C. C. Allen
R. W. Allen
J. Beldock

CONTENTS

I. REPORT INTRODUCTION
II. REPORT AND EXPERIMENT CONCLUSIONS
III. PANEL HEAT LOSS TESTS
IV. DESCRIPTION OF HEAT EXCHANGER BUILDING
V. RESULTS TO DATE
VI. ONGOING DATA GATHERING
VII. APPENDIX
VIII. BIBLIOGRAPHY

# I
## INTRODUCTION

The Pinkerton Hot Springs are located North of Durango, Colorado approximately 13 miles at the present Colorado Timberline Academy. The history of the use of these spring waters has been for spa and swimming pool uses as the Pinkerton Hot Springs Resort and the El Rancho Encantado in the 1950's and 1960's. The spring fell out of any use of any kind in the 1970's and now is simply emptying upon the grounds of Colorado Timberline Academy and wasting its heat to the atmosphere.

The potential of 375,000 BTU's per hour available for space heating purposes could serve to lower greatly the heat needs of Colorado Timberline Academy and its 25 buildings with proper application of low temperature heating technology. Any system to be developed could be augmented by solar collectors etc, as the heat range is a similar one in which to operate.

The proposal made to the Appropriate Technology Program was made with this future use in mind. In addition information could be collected and made available on low temperature heat transfer for other similar projects. There are a large number of low temperature warm geothermal sources, as well as a number of low temperature solar applications that such knowledge could be applied to.

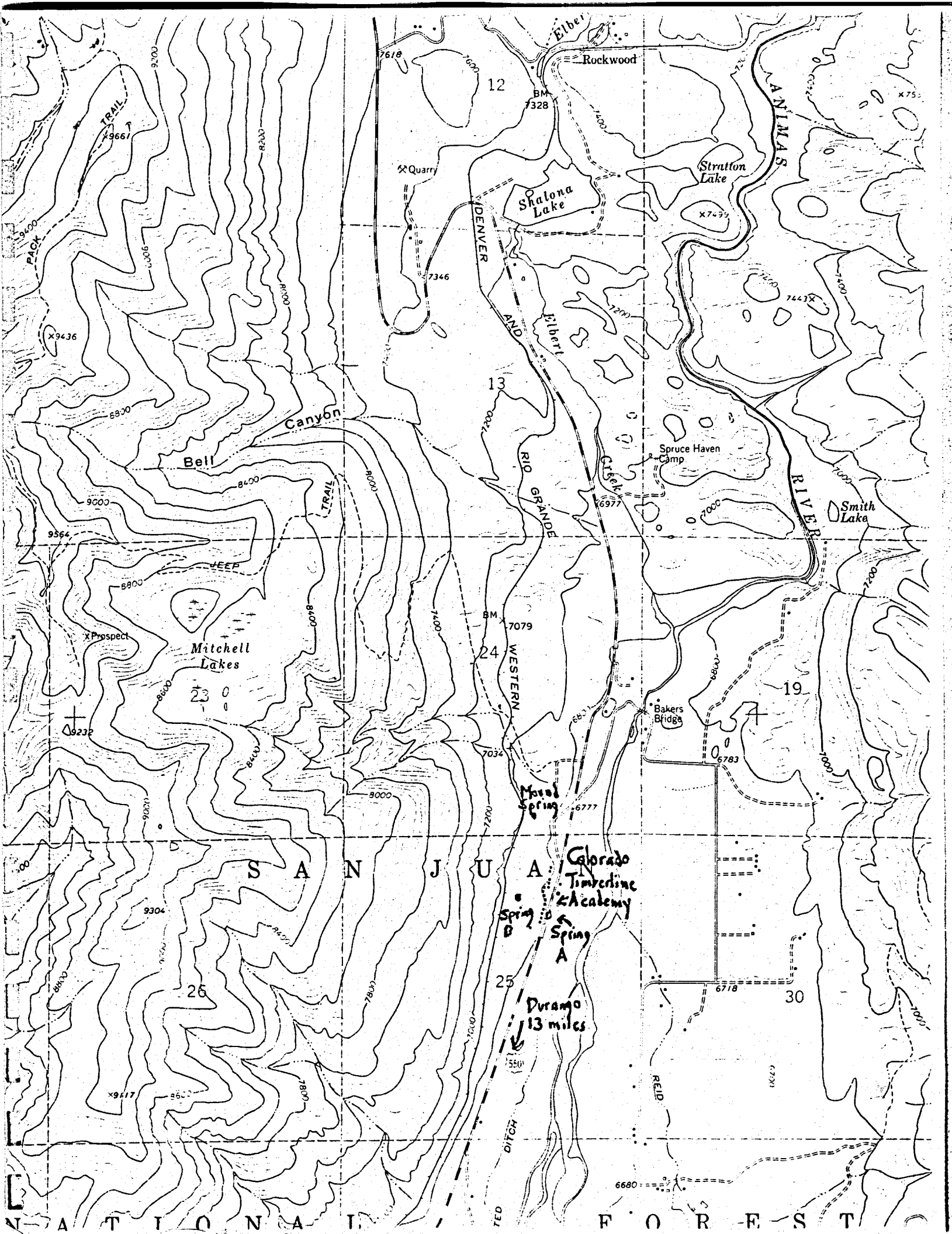
Panels manufactured in Durango, Colorado by the San Juan Solar Systems Company were tested for their performance in the heat region of interest. These panels were flat plate aluminum with a copper tubing affixed to the back. A number of well distributed heat runs were made to determine a relation between the BTU per hour per square foot to be expected from such panels and the difference between air temperature and panel temperature. There is little commercially available data on such heat transfer. Forced hydronic convectors typically have described the heat loss characteristics in a similar manner. The experiment continues by installing passive panels in one cabin of 12 by 24 foot dimension and two different types of forced convector in two other identical cabins, to compare the performance of these heaters at low temperatures within 30 F° of the ambient air temperature.

The primary capital expenditure of this project is the construction of a heat exchange tank and pump and control room. This consists of a 1000 gallon concrete buried tank, insulated to R-16 on five sides with a 5 foot by 8 foot house built on the top. This house encloses three complete heating loops consisting of pump, heat exchanger, piping, heating device, expansion tank, water meter, hour meter, differential temperature thermostat, pressure gauges, air release valves, and extensive thermometry in the heated buildings and on the heating circuits themselves. The construction of this portion consumed the time of one individual and sometimes two for four months.

Initial test were then run to determine what heat loss rates could be expected in situ from the three heating systems. These initial sets of data will be expanded on in coming years through a continuing effort at the Colorado Timberline Academy.

Another important part of this grant program was educational. Courses in energy and geothermal applications were offered at the Colorado Timberline Academy in the Spring of 1981 and Fall of 1981. Notes from that course are included with the report in the appendix. The result of these course offerings was a heightened interest in the geothermal resource flowing across the school property by some of the students involved. Additionally, a geothermal presentation was made at the Energy Fair in Durango on September 25,26 and 27 1981.

Funds from this grant were also used to collect information from and visit Pagosa Springs Colorado and its under construction project for geothermal heating. Also the Ouray, Colorado geothermal resource was visited as well as the small local springs.



Elbert
Rockwood
12
BM 7328
ANIMAS
Stratton Lake
Quarry
Shalona Lake
DENVER AND RIO GRANDE WESTERN
Elbert Creek
13
Spruce Haven Camp
RIVER
Smith Lake
Bell Canyon
TRAIL
PACK
JEEP
Prospect
Mitchell Lakes
23
24
BM 7079
19
Bakers Bridge
Moved Spring
Colorado Timberline Academy
Spring B
Spring A
S A N J U A
25
26
30
Durango 13 miles
REID
DITCH
N A T I O N A L F O R E S T

## II
## REPORT CONCLUSIONS

The proposal for the grant for this project was written as a Project Development Proposal, defined in the 1979 Program Announcement to "bring a concept through the design, assembly and laboratory scale testing in order to determine its technical feasibility and potential use". "A proposal in this category should examine a specific energy problem and develop a solution. This category includes studies investigations, and developement of hardware, systems or other means for experimental or operational tests."

Using the above definition as a guide, the funding by DOE has been very successful. Colorado Timberline Academy has installed on its campus a heat exchange facility for the purpose of heating building space with geothermal energy. The equipment for the heat exchange building, tank, distribution system, and test equipment and recording devices have been procured and or constructed with the grant funds, and are successfully operational. This is a capital investment that CTA would not have been likely to make on its own in the near future due to a very stringent operating budget that just meets operation and maintenance with little left for capital expenditure. Thus, the program has allowed CTA to have in place a geothermal heating system that can guide future building construction, once data from the system is gathered and conclusions drawn, as to methods of using the geothermal waters for further heating.

An important aspect of the project development idea is the utilization of techniques that are first conceived through much thought and discussion, the existing materials market examined for adaptable components, and the assembly of those components in a way assumed to be effective. To this end the panel heat loss experiments were very valuable. The literature on low temperature heat transfer is scarce, and in the case of ASHRAE information seems to contradict our findings. The results of those experiments gave us a better idea of what could be expected in the installed heating systems at water temperatures of 90 degrees F. The plotted results, appearing elsewhere in this report, are derived from a great deal of experimental data. While not as reliable as data that might have been gathered

in a national laboratory, the most important ingredient of any experiment, reproducibility, is there for any one to test.

While much data remains to be gathered as the ongoing process of providing space heat to the CTA dwellings begins, the foundation making such collection possible exists. The construction of the physical heat collection building was a time consuming and reasonably difficult task and is satisfactorily complete. The future collection of data will be a simple task.

# III

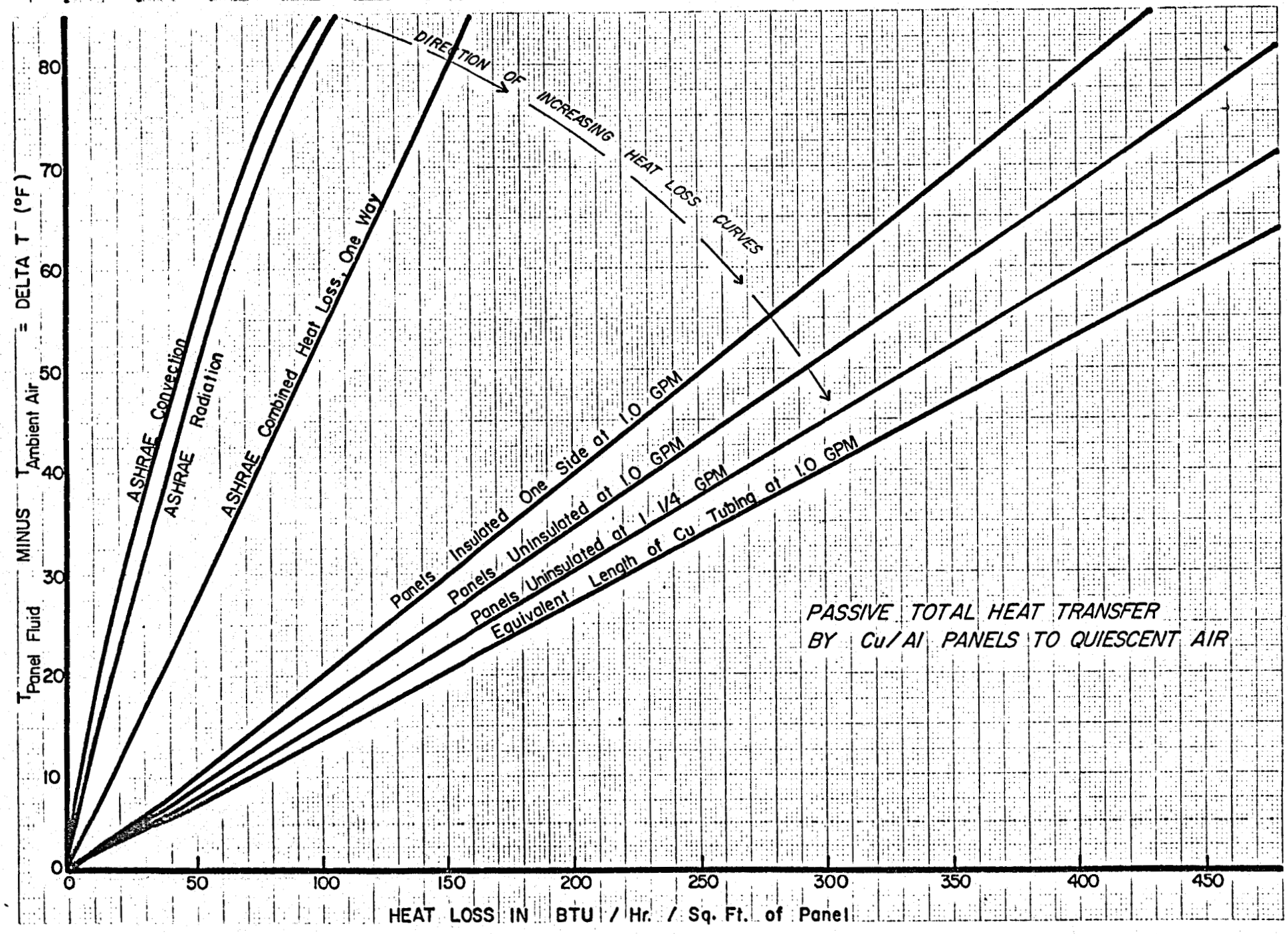
# PASSIVE TOTAL HEAT TRANSFER EXPERIMENTS

## Introduction

During June of 1981, a series of low temperature heat transfer experiments were conducted. The purpose of these experiments was to acquire low temperature heat transfer data that is not readily available in current engineering handbooks (ASHRAE) or any other commercial literature. Low temperature data was necessary in order to determine the feasibility of using the Pinkerton Hot Springs for space heating at Colorado Timberline Acadamy (CTA).

## Hypothesis

A heated panel transfers heat to or from a room by convection and radiation. Convection transfer is assumed to be the heat transferred by convection in BTUs per hour per square foot per farenheit degree difference between the air and panel temperatures. Given current ASHRAE experimental data for convection heat transfer for given temperature differences between air and panel temperatures ranging from 15$^{o}$F to 65$^{o}$F one would expect to find BTU output ranging from 8 BTU/ft$^{2}$/hr/$^{o}$F to 60 BTU/ft$^{2}$/hr$^{o}$F for 65$^{o}$F (refer to graph - Passive Total Heat Transfer by Cu/Al Panels to Quiescent Air).




10 Millimeters to the Centimeter

Given current ASHRAE experimental data for radiation transfer - BTU output for the same temperature difference range - one would expect to find heat output ranging from 11 BTU/ft$^2$ to 70 BTU/ft$^2$/hr/$^o$F.

The combined heat transfer from a panel to a room can be determined by adding the convective heat transfer and the radiant heat transfer. From the given ASHRAE data one could expect total heat transfer for the given temperature differences to range from 26 BTU/hr/ft$^2$/$^o$F to 124 BTU/hr/ft$^2$/$^o$F.

Materials

The radiating panels used in this experiment were supplied by San Juan Solar - a local solar installer. The panels consist of 3/8" soft copper refrigeration tubing fastened to an aluminum sheet (2'x4') with a silicone cement. The copper tubing is looped back and forth lengthwise on the aluminum sheet and spaced 4" on center. The side on which the CU tubing is fastened is silver and the opposite side is painted black.

Also used in the experiment were the following; two gate valves, two 0-60 psi pressure gauges, one flow meter, two lengths of 25' water hose, various thermometry, hygrometer, and a sling psychrometer.

Set-up

The experiments were run in a small 8' x 25' room of the main lodge at CTA.

Four of the San Juan Solar radiating panels were set up in series (system) approximately 1-2' from the back wall of the

room. Within the series, two panels had the painted black side facing the wall and two had that same side facing into the room.

Two gate valves and two 0-60 psi guages were placed at each end of the system (gate valves preceded guages in each case).

One flow meter was placed at the supply end of the system (this meter proved to be inaccurate at the experimental flow rates - 1 - 1.5 gpm).

The experiments were also run setting one side of the panels against fiberglass insulation. Copper tubing by itself - without the aluminum panels attached - was a third experimental test.

For all three experiments, the hot water was supplied by the hot water heater in the main lodge at CTA. The "return line" was simply discharged.

Procedure

For all the experimental tests, the main supply of hot water was heated to 150°F. Drawing water from this, the hottest water attained was 144°F.

Once this temperature was reached, the main hot water heater was turned off so that experimental data could be collected from 144°F to approximately 85°F.

As the hot water flowed in and out of the system, input and output temperatures were taken. Using 32 ft.$^2$ as the surface area of the panels, a value of BTU/hr/ft$^2$/°F was derived.

$$[\text{gpm} \times 8.34 \times T \times 60] - 32\ \text{ft}^2 = [\text{BTU/hr/ft}^2/^{\circ}\text{F}]$$

Input pressures and output pressures were also taken to estimate friction loss within the system. A flow rate given in gallons per minute was calculated using a five gallon bucket. (fill time ÷ 5 = gpm)

Results

Data for each of the experiments was compiled showing the following: ambient air (wet and dry bulb), relative humidity, input and output temperature, input and output pressure, gallons per minute (gpm), change in temperature (Delta T) and change in pressure (Delta P).

In order to compare and contrast the ASHRAE experimental data with the data collected at CTA, the data collected at CTA was arranged in order to easily make correlations.

A) Panels Uninsulated at 1.0 G.P.M.

As expected, the BTU output of the panels went down as the temperature difference between input fluid temperature and ambient air decreased. For these experiments, the input temperature varied from a high of 133°F to a low of 80°F with simultaneous output temperatures ranging from 114°F to 76°F respectively.

Experimentally obtained, the maximum BTU output of the panels occured at an input temperature of 132°F and an output temperature of 109°F ( T = 23°F). Given an ambient air temperature of 77°F, the temperature difference between the input fluid and the ambient air was 55°F. The BTU/hr/ft$^2$ of passive total heat transfer was 396 BTU/hr/ft$^2$.

A minimum, experimentally obtained, BTU output occurred with an input temperature of 83°F and an output temperature of 85°F ( T = 3°F). Given an ambient air temperature of 71°F, the temperature difference between the input fluid and the ambient air was 15°F. The BTU/hr/ft$^2$ of passive total heat transfer was 20 BTU/hr/ft$^2$.

Within the temperature range that this experiment was most concerned with (91°F - 86°F input temperatures), the resultant heat transfer ranged from 20 BTU/hr/ft$^2$ to 313 BTU/hr/ft$^2$. At an input temperature of 86°F and an output temperature of 85°F the minimum BTU output was 20 BTU/hr/ft$^2$ (ambient air = 71°F, relative humidity = 43%) At an input temperature of 90°F and an output temperature of 74°F, the maximum BTU output was 313°F (ambient air = 65°F, relative humidity = 41%).

B) Panels Uninsulated at 1.25 G.P.M.

For these experiments, the input temperatures varied from a high of 110°F to a low of 83°F with simultaneous output temperatures ranging from 90°F to 81°F respectively.

Experimentally obtained, the maximum BTU output of the panels occurred at an input temperature of 110°F and an output temperature of 90°F ( T= 20°F). Given an ambient air temperature of 67°F, the temperature difference between the input fluid and the ambient air was 43°F. The BTU/hr/ft$^2$ of passive total heat transfer was 391 BTU/hr/ft$^2$.

A minimum BTU output occurred with an input temperature of 86°F and an output temperature of 85°F. Given an ambient air

temperature of 71°F, the temperature difference between the input fluid and the ambient air was 15°F. The BTU/hr/ft$^2$ of passive total heat transfer was 20 BTU/hr/ft2.

Within the temperature ranges that this experiment was most concerned with (91°F - 36°F input temperatures) the resultant heat transfer ranged from 20 BTU/hr/ft$^2$ to 215 BTU/hr/ft$^2$. (The existing conditions when 20 BTU/hr/ft$^2$ was reached have been described.) At an input temperature of 90°F and an output temperature of 79°F, the maximum BTU output was 215 BTU/hr/ft$^2$, (ambient air = 81°F, relative humidity = 32%).

C) Panel Insulated One Side at 1.0 G.P.M.

Here, the input temperature varied from a high of 133°F to a low of 85°F with simultaneous output temperatures ranging from 125°F to 83°F respectively.

Experimentally obtained, the maximum BTU output of the panels occurred at an input temperature of 118°F and an output temperature of 107°F ( T= 11°F). Given and ambient air temperature of 74°F, the temperature difference between the input fluid, and the ambient air was 44°F. The BTU/hr/ft$^2$ of passive total heat transfer was 215 BTU/hr/ft$^2$.

A minimum BTU output occurred with an input temperature of 85°F and an output temperature of 83°F ( T = 2°F). Given an ambient air temperature of 74°F, the temperature difference between the input fluid and the ambient air was 11°F. The BTU/hr/ft$^2$ of passive total heat transfer was 39 BTU/hr/ft$^2$.

Within the temperature range that this experiment was mostconcerned with, the resultant heat transfer ranged from 39 BTU/hr/ft$^2$ to 98 BTU/hr/ft$^2$. (The existing conditions when 39 BTU/hr/ft$^2$ exchange rate was reached have been described.) At an input temperature of 91$^o$F and an output temperature of 86$^o$F, the maximum BTU output was 98 BTU/hr/ft$^2$ (ambient air = 72$^o$F, relative humidity = 65%).

D) Equivalent Length of Copper Tubing at 1.0 G.P.M.

The input temperatures varied from a high of 144$^o$F to a low of 94$^o$F with simultaneous output temperatures ranging from 112$^o$F to 80$^o$F respectively.

The maximum, experimentally obtained, BTU output occurred at an input temperature of 144$^o$F and an output temperature of 112$^o$F ( T= 32$^o$F. Given an ambient air temperature of 75$^o$; the temperature difference between the input fluid and the ambient air was 69$^o$F. The BTU/hr/ft$^2$ of passive total heat transfer was 500 BTU/hr/ft$^2$.

A minimum BTU output occurred at an input temperature of 94$^o$F and an output temperature of 84$^o$F ( T = 10$^o$F). Given an ambient air temperature of 78$^o$F, the temperature difference between the input fluid and the ambient air was 16$^o$F. The BTU/hr/ft$^2$ of passive total heat transfer was 156 BTU/hr/ft$^2$.

BTU output values were not experimentally obtained for the temperature ranges that this experiment was concerned with. But some can be estimated using the prepared graph. Given an ambient air of 70$^o$F and input temperatures of 91$^o$F and 86$^o$F, the

temperature difference between ambient air and input temperature would range from 21°F to 16°F. Given these temperature differentials the BTU output would range from 152 BTU/hr/ft$^2$ to 112 BTU/hr/ft$^2$ respectively.

Comments

The panel tests gather enough data to be reasonably conclusive. The actual rates of heat loss for a passive panel of this type in some cases correlate with ASHRAE guidelines, and in some cases prove ASHRAE to be conservative by a factor of 4 to 5.

A conventional heat system is sized with a duty factor less than one, say .2 to .3. Thus a boiler would be sized for a higher heat supply requirement, the steady state heat loss would be made up in 12 minutes to 20 minutes of each hour. This indicates that for a constant source, such as geothermal water, heating 60 minutes per hour, a higher heat loss figure may be reliable. Whether such a correlation with ASHRAE is real is suspect, but allows for a channel consolidating our information and that of ASHRAE.

It is evident that for low temperature heat loss, surface area is critical. The excellent results obtained from bare pipes support this and the better radiators may well be simply assemblages of "plumbers delight" attached to dwelling walls. Pagosa Springs, Colorado, geothermal heating systems in place many years bear this out with their myriad pipe manifold systems.

The interface between supply pipe and panel is critical. The panels tested used silicone as a cementing medium in this

region. It is likely that a cloth covered pipe manifold would have better heat exchange characteristics.

The heat loss numbers, when applied to a standard building are still short of heat requirements. For instance, a standard CTA cabin may use heat at 25,000 BTU/hr. at design temperature. This would require 100 to 200 sq. ft. of panel, an impossibility given the wall status. (It is noteworthy that the 200 sq. ft. floor would have been an ideal source, with implanted slab heating). As a result, the main heating experiment turns to active forced convection radiators rather than passive.

## IV
## HEAT EXCHANGER BUILDING

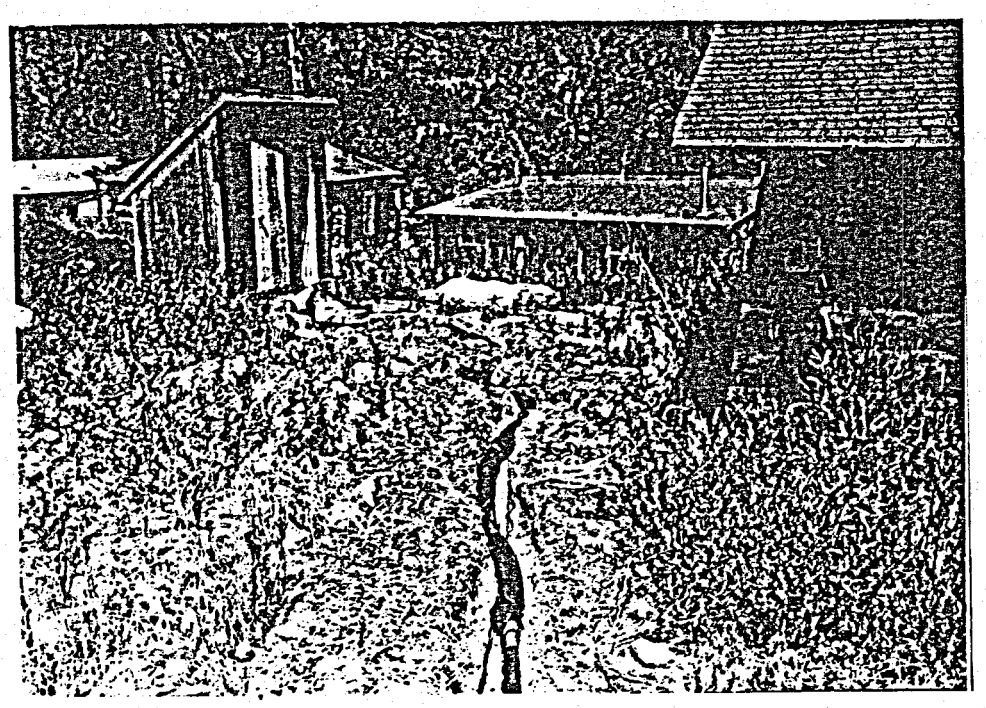
During the months of July and August, 1981, the geothermal space heating system was constructed.

A special, concrete, 96" x 60", 4 ton, 1000 gallon tank was acquired from Four Corners Pre-Cast. The tank is partitioned into three compartments with 5" ABS couplings - in each baffle and two short outside walls - being the only means of free flow. The tank is insulated by 2" Thermax insulating board on all four sides and the bottom.

A control and pump house was built using the tank as a foundation. The structure is 96" in length, 60" in width, and has a front elevation of 96" and a 48" rear elevation. The pump house is fully insulated and equipped with 115 VAC. (3 wall outlets, 1 ceiling light)

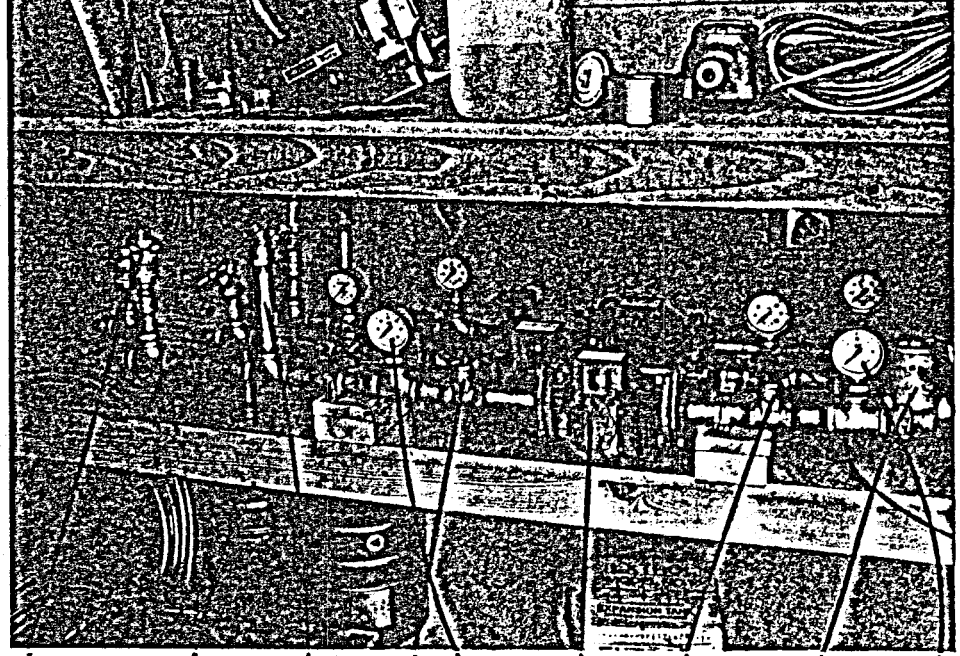
A closed loop space heating system was designed and built. In the pump house, there are three loops that supply three buildings. The plumbed loops use propylene glycol as the heat transfer fluid with Teel, 5 speed, circulating pumps circulating the fluid. Each loop is equipped with two 0 - 60 p.s.i. pressure guages, two gate valves, one fill valve, one air purge valve, one flow meter, one five gallon expansion tank, and 50' of L soft copper refrigeration tubing is used as the heat exchange method. (the tubing is suspended as a coil in the thermal water)

As part of the geothermal space heating experiment, all three loops are fully monitored by various forms of thermometry. A digital readout thermometer monitors supply and return temperatures of all three loops and, in addition, monitors control house temperature. A differential control thermometer is used to monitor the temperatures of the supplied geothermal water and each of the three buildings being heated. This paricular differential thermostat is based on a 3°F temperature differential. Therefore, the circulating pumps are turned on when the temperature difference between supply fluid and building temperature is greater than 3°F. When the same temperature difference is equal to or less than 3°F, the pumps are automatically turned off.



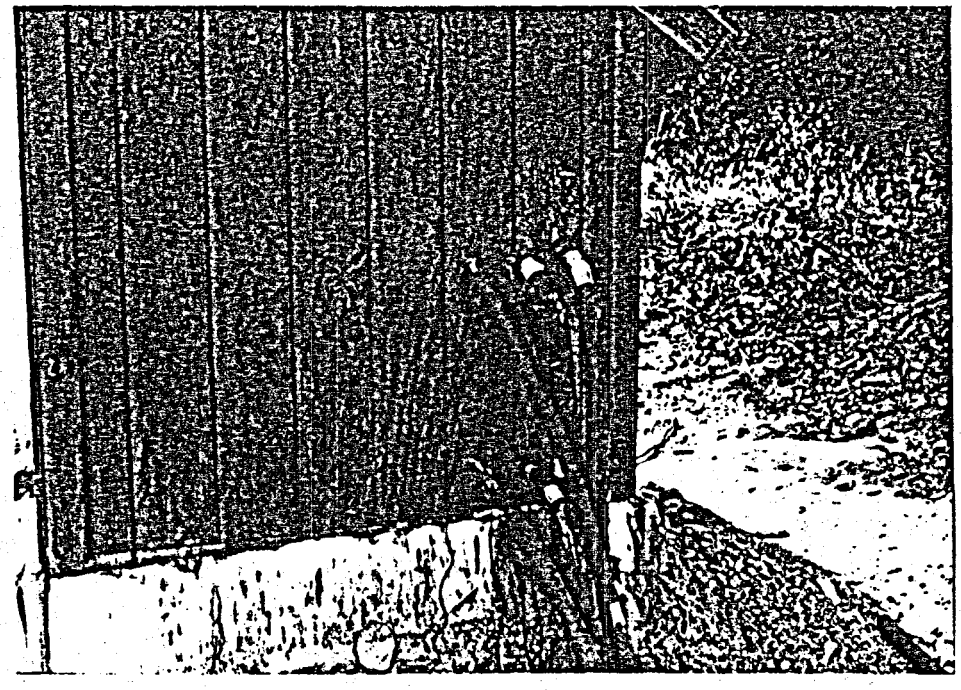
PUMP AND CONTROL HOUSE

SUPPLY AND RETURN LINES 1/2" L-SOFT COPPER TUBING ENCASED IN 5/8" ARMAFLEX INSULATION WRAPPED IN POLYETHYLENE PLASTIC



PLUMBING

AIR PURGE VALVE
FILL VALVE
GATE VALVE
5 SPEED PUMP
GATE VALVE
WATER METER
EXPANSION TANK
PRESSURE GAUGE
PRESSURE GAUGE



RETURN ENTRANCE

SUPPLY EXIT

## V

## RESULTS TO DATE

As of the writing of this report in November of 1981, the heat exchanger building has been constructed and is complete in all aspects, the piping and controls having been tested.

The panel heat loss experiments have provided a valuable base of knowledge to base any future heat source construction at Colorado Timberline Academy that would intend to utilize the geothermal source.

Unfortunately, of course, the springs have not been restored to their original course as yet and as such are unavailable for continued efforts in the performance of the equipment in the heat exchanger building. It is hoped that the Colorado Department of Highways will resolve this dilemma for CTA in the near future. An engineered pipeline routing was submitted to that organization in the Spring of 1980 to facilitate the construction of such a pipe facility. No action has been forthcoming from them as yet.

We are very optimistic about the beneficial effects of the heating available from the Pinkerton Hot Springs, and CTA will pursue the gathering of data on the installation as soon as the Hot Springs have been rerouted.

## VI
## ONGOING DATA GATHERING

The materials are installed and the equipment procured for testing and making it possible to collect a great deal of useful data over a period of a few years by the students and faculty of the Colorado Timberline Academy. There are very few installations in the country that would consider the use of 91° F water for space heating. The potential for success of water at this temperature was made obvious in the panel heat loss test experiments.

It is anticipated that the process continual data gathering will occur through classes and student projects at Colorado Timberline Academy. This document with its extensive appendices it meant to be a compiled introduction to any student or teacher that would wish at some future point to become involved in the geothermal heating project.

No additional requests will be made of the Department of Energy, having provided the initial facility funds, the project should be self guided from this point.

# VII

# APPENDICES

# APPENDIX

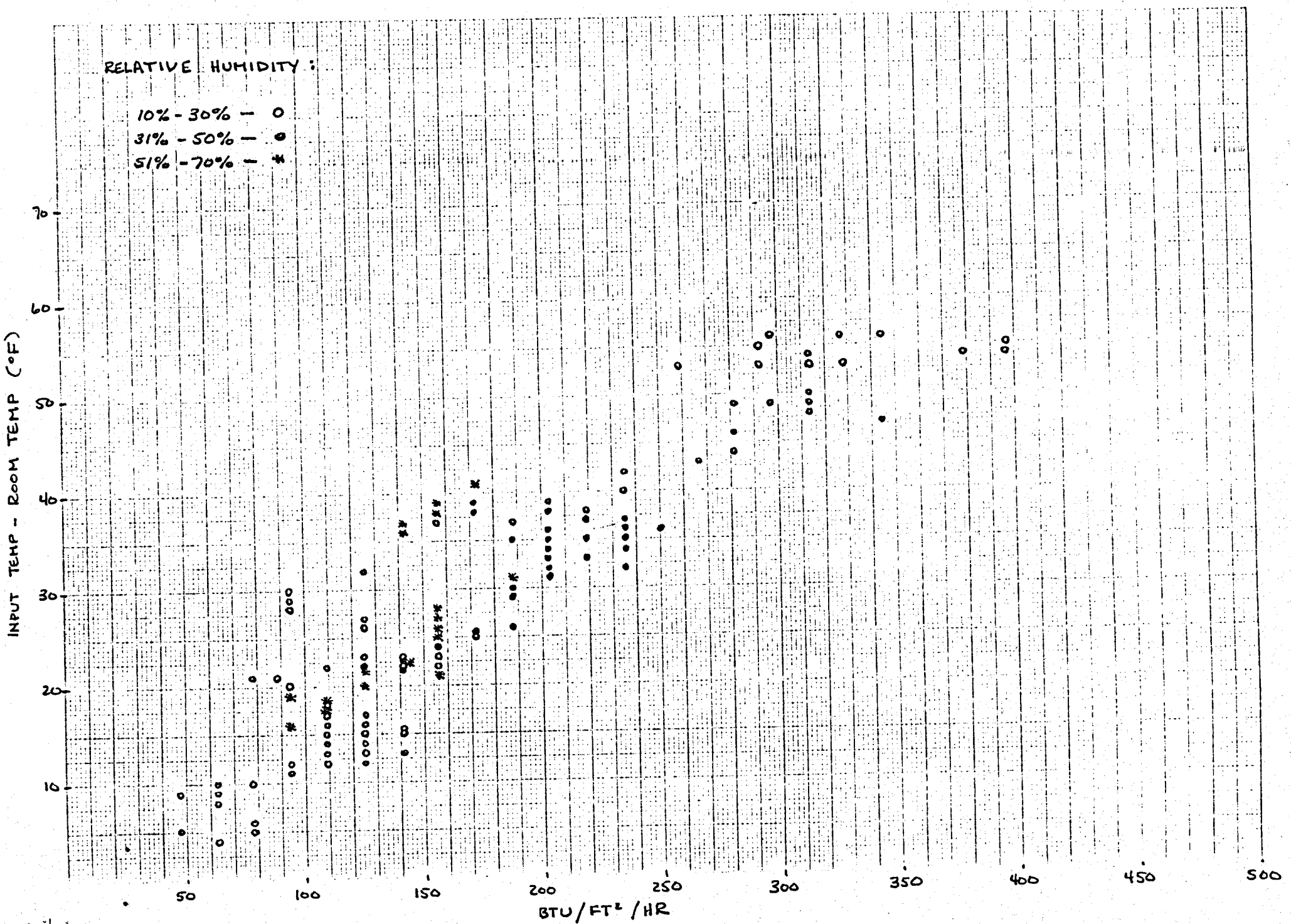
Excerpts from the ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers), section on Panel Heating and Cooling.

(Removed - copyrighted material)

# APPENDIX

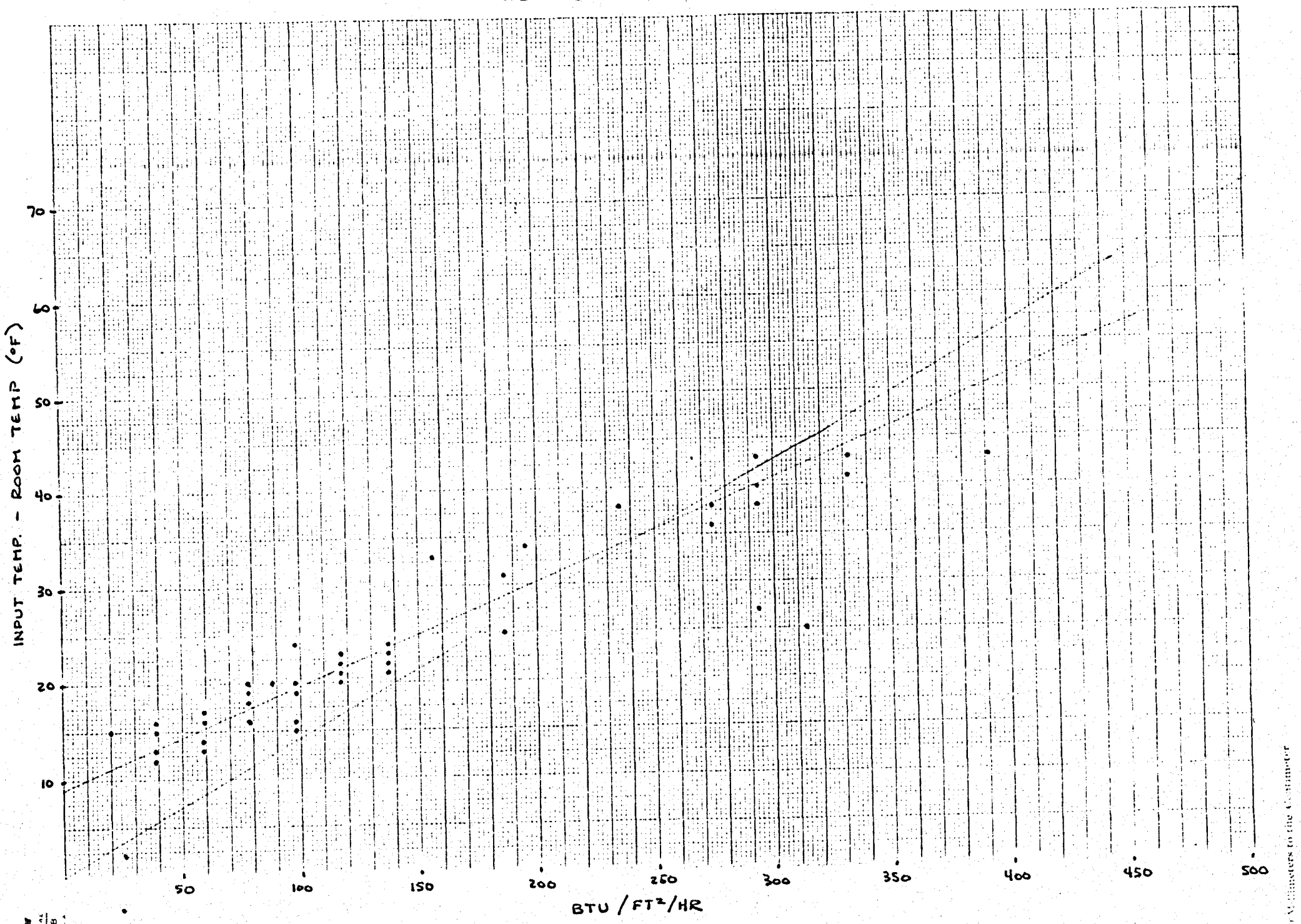
Actual results of panel tests in graphical form and a sample of the data format used.

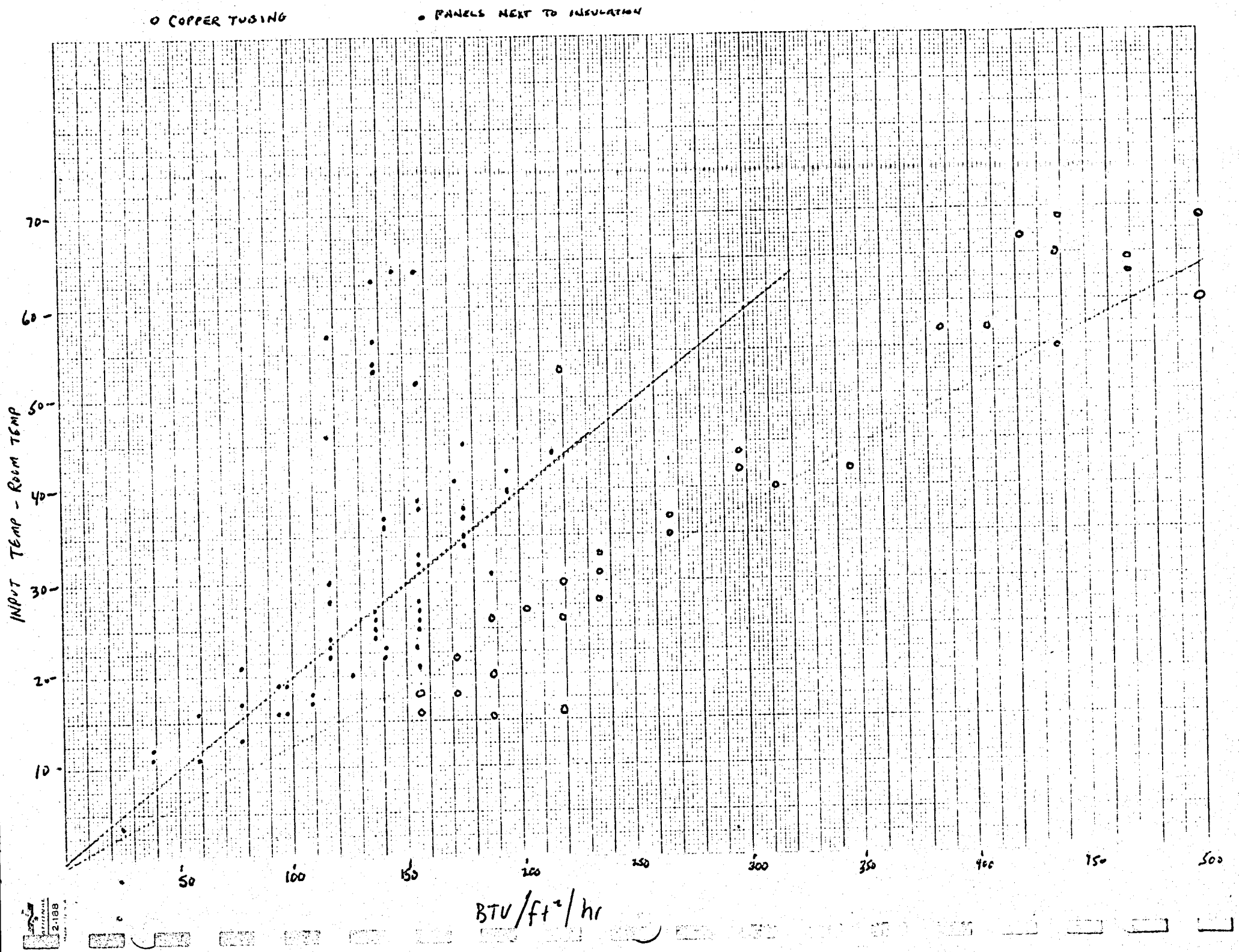
1.0 GPM



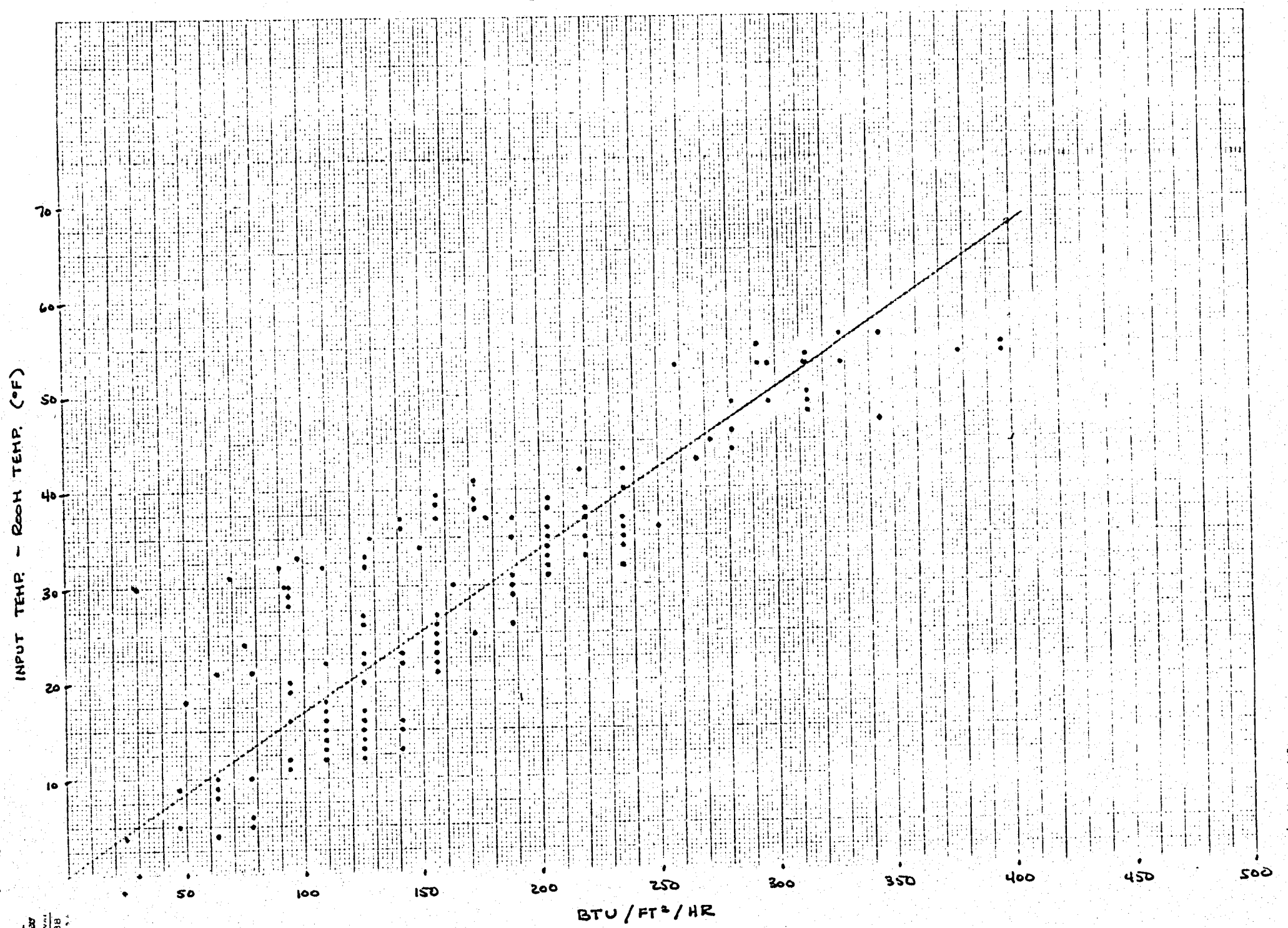

Millimeters to the Centimeter
12-188

1.25 GPM


INPUT TEMP. - ROOM TEMP (°F)
70
60
50
40
30
20
10
50
100
150
200
250
300
350
400
450
500
BTU / FT²/HR


O COPPER TUBING
• PANELS NEXT TO INSULATION
INPUT TEMP - ROOM TEMP
70
60
50
40
30
20
10
50
100
150
200
250
300
350
400
450
500
BTU/ft²/hr

1.0 GPM


INPUT TEMP. - ROOM TEMP. (°F)
10
20
30
40
50
60
70
50
100
150
200
250
300
350
400
450
500
BTU / FT² / HR

12-188

ITEM TESTED Heat Panels DATE 6/25/81 DATA BY BD / BA

AMBIENT AIR DRY 70° WET 55° % RELATIVE HUMIDITY 36% Psychrometer 43% Hygrometer

| TIME | TEMP | INPUT PRESSURE | OTHER | TEMP | OUTPUT PRESSURE | OTHER | FLOW START | FLOW END | GPM | DELTA T | DELTA P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7:00am | 84°F | 20psi | | 84°F | 0 | | | | 1.25 | 2 | 20 |
| 7:01am | 85°F | 20 | | 83°F | 0 | | | | 1.25 | 2 | 20 |
| 7:01am | 86°F | 20 | | 83°F | 0 | | | | 1.25 | 3 | 20 |
| 7:01am | 86°F | 20 | | 82°F | 0 | | | | 1.25 | 4 | 20 |
| 7:02am | 86°F | 20 | | 81°F | 0 | | | | 1.25 | 5 | 20 |
| 7:03am | 85°F | 20psi | | 82°F | 0 | | | | 1.25 | 3 | 20 |

COMMENTS/DIAGRAMS/CALCULATIONS-

132) 39 Btu/ft²/hr.
133) 39 Btu/ft²/hr.
134) 59 Btu/ft²/hr.
135) 78 Btu/ft²/hr.
136) 98 Btu/ft²/hr.
137) 59 Btu/ft²/hr

Typical Panel Test Data Sheet

# APPENDIX

Calibration of the sensors used in the heat exchanger building, derived through interpolation

cap allen • registered professional engineer
civil & solar engineering

# HELIOTROPE SENSOR CALIBRATION
## 3000 Ohm @ 25°C

| T°F | Resistance | T°F | Resistance | T°F | Resistance | T°F | Resist. | T°F | Resist. |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 9810 | 76 | 3084 | 120 | 1132 | 164 | 476 | 208 | 220 |
| 33 | 9567 | 77 | 3000 | 121 | 1106 | 165 | 468 | 209 | 217 |
| 34 | 9323 | 78 | 2936 | 122 | 1080 | 166 | 459 | 210 | 213 |
| 35 | 9080 | 79 | 2871 | 123 | 1058 | 167 | 451 | 211 | 209 |
| 36 | 8837 | 80 | 2807 | 124 | 1035 | 168 | 443 | 212 | 204 |
| 37 | 8594 | 81 | 2743 | 125 | 1013 | 169 | 435 | | |
| 38 | 8350 | 82 | 2678 | 126 | 991 | 170 | 427 | | |
| 39 | 8107 | 83 | 2614 | 127 | 969 | 171 | 418 | | |
| 40 | 7864 | 84 | 2549 | 128 | 946 | 172 | 410 | | |
| 41 | 7620 | 85 | 2485 | 129 | 924 | 173 | 402 | | |
| 42 | 7437 | 86 | 2420 | 130 | 902 | 174 | 394 | | |
| 43 | 7253 | 87 | 2369 | 131 | 879 | 175 | 386 | | |
| 44 | 7070 | 88 | 2318 | 132 | 864 | 176 | 378 | | |
| 45 | 6887 | 89 | 2267 | 133 | 849 | 177 | 372 | | |
| 46 | 6704 | 90 | 2216 | 134 | 835 | 178 | 367 | | |
| 47 | 6520 | 91 | 2165 | 135 | 820 | 179 | 361 | | |
| 48 | 6337 | 92 | 2113 | 136 | 806 | 180 | 355 | | |
| 49 | 6154 | 93 | 2062 | 137 | 791 | 181 | 350 | | |
| 50 | 5970 | 94 | 2011 | 138 | 776 | 182 | 344 | | |
| 51 | 5830 | 95 | 1960 | 139 | 761 | 183 | 338 | | |
| 52 | 5690 | 96 | 1920 | 140 | 747 | 184 | 332 | | |
| 53 | 5550 | 97 | 1880 | 141 | 733 | 185 | 327 | | |
| 54 | 5410 | 98 | 1840 | 142 | 720 | 186 | 321 | | |
| 55 | 5270 | 99 | 1800 | 143 | 706 | 187 | 315 | | |
| 56 | 5130 | 100 | 1760 | 144 | 692 | 188 | 310 | | |
| 57 | 4990 | 101 | 1720 | 145 | 679 | 189 | 304 | | |
| 58 | 4850 | 102 | 1680 | 146 | 665 | 190 | 298 | | |
| 59 | 4710 | 103 | 1640 | 147 | 651 | 191 | 293 | | |
| 60 | 4603 | 104 | 1600 | 148 | 637 | 192 | 287 | | |
| 61 | 4497 | 105 | 1568 | 149 | 624 | 193 | 281 | | |
| 62 | 4390 | 106 | 1536 | 150 | 613 | 194 | 275 | | |
| 63 | 4283 | 107 | 1504 | 151 | 602 | 195 | 271 | | |
| 64 | 4177 | 108 | 1472 | 152 | 591 | 196 | 267 | | |
| 65 | 4070 | 109 | 1440 | 153 | 580 | 197 | 263 | | |
| 66 | 3963 | 110 | 1408 | 154 | 569 | 198 | 259 | | |
| 67 | 3856 | 111 | 1376 | 155 | 558 | 199 | 255 | | |
| 68 | 3750 | 112 | 1344 | 156 | 547 | 200 | 252 | | |
| 69 | 3667 | 113 | 1310 | 157 | 536 | 201 | 248 | | |
| 70 | 3583 | 114 | 1285 | 158 | 525 | 202 | 244 | | |
| 71 | 3500 | 115 | 1259 | 159 | 517 | 203 | 240 | | |
| 72 | 3417 | 116 | 1234 | 160 | 509 | 204 | 236 | | |
| 73 | 3334 | 117 | 1208 | 161 | 500 | 205 | 232 | | |
| 74 | 3250 | 118 | 1183 | 162 | 492 | 206 | 228 | | |
| 75 | 3167 | 119 | 1157 | 163 | 484 | 207 | 224 | | |

64 ptarmigan lane • durango, colorado 81301 • (303) 247-0088

# APPENDIX

Formal notes used in the Colorado Timberline Academy Geothermal Heating classes

# GEOTHERMAL NOTES

This packet of information will prove useful to anyone interested in the field of application of energy systems in general and geothermal energy in particular.

Every effort has been made to simplify as much as possible all the concepts involved in what can be a very difficult subject. Some engineers spend years studying the nuances of thermodynamics and heat transfer in an effort to understand just what is going on. That should not be a barrier to anyone seeking the simple answers.

Possibly some of those answers are contained in these notes.

The use of geothermal energy is not a new idea as with solar or wind energy. There have been civilizations that have had a very good grasp of the wonderful resource available in hot water from the earth for thousands of years.
In the Durango area the Mountain Ute indians and their ancestors knew of the hot springs of the Animas Valley and made summertime pilgrimages to the better springs.
A large hotel once stood at Trimble Lane and was a stop on the D & RGW Railroad. This hotel was built around the supposed benefits of the Trimble Hot Springs, therapeutic or otherwise. After the hotel a hot spring pool existed for many years at Trimble.
The Pinkerton Hot Springs Spa was once a large swimming pool filled by the flow from the Pinkerton Springs. This pool emptied out onto the hillside east of the Golden Horseshoe Lodge. There was once a complex of outdoor pool (not the present one), and indoor pool in the "rainbow building", and Durangoans can tell you stories about the heritage and the fun they had at Pinkerton when they were young.
Other hot springs with spectacular settings in the mountains exist at Ouray, Dunton, Ridgway, Wolf Creek Pass, Pagosa Springs, and a beauty east of Villa Grove, northeast of Saguache. All of these are two hours or less from Durango.

Needless to say the world's search for energy is making us look at these as more than just play-places, and evaluate them for their heating potential.

# ENERGY

Energy takes many forms, and the study of it can get very complicated. Most people, however, are only really interested in one thing, is it there or not, and is there enough of it.

The energy we need to examine is mainly just heat. Heat can be distinguished by the presence or lack of temperature to most people, but there is a lot more to it than that. We are principally interested in the type of heat called kinetic energy, meaning it is doing something and is there.

First Law of Thermodynamics- (Thermodynamics is the science of how heat changes and moves). -Although energy can be transformed back and forth and all around the total amount is never diminished.

Second Law of Thermodynamics- This law unoptomistically states that the universe is slowly running down. It essentially says that even though energy doesnt disappear, in doing work for us it gets broken into such small pieces you really cannot use whats left very easily. (i.e. the energy is around but you need a very good net to catch it)

Heat Flow- Heat can do its work on something through three basic and simple mechanisms.

Radiation- The sun is good at this. To get heat from point A to B electromagnetic waves, or radiation can be used. This method of heat transfer can occur in a vacuum as easily as in the air, usually easier. The sun's heat comes to us through radiation and needs no air molecules or ether along the way to help it.

Conduction- Something that is warm, an object of some sort, can heat an object that it touches by passing the heat from molecule to molecule in the substance. Heat one end of a pan and the other end soon warms. That is conduction. Some things conduct better than others, and the best electrical conductors are the best heat conductors, gold being high on the list followed by copper and aluminum.

Convection- If a fluid such as water or air is heated and by some force flows to another place, that is convection. Convective currents in a leaky house are often called "drafts". A fan can be added to the scheme to cause forced convectic

The sun can stike the pavement of a street on a nice day and heat it through radiation. The ground under the pavement will be warmed after a while through conduction. And the air above the pavement will be warmed through natural rising convection. If the pavement is shiny, some re-radiation can occur to strike some other object and start the process over again.

Measurement of Heat-

There are two ways, units, to measure how much heat there is somewhere in something. One is a member of the metric system- the calorie.

One calorie will raise one gram of water (one milliliter) one degree Centigrade.

One thousand calories will raise one kilogram of water (one liter) one degree centigrade.

One thousand calories can also raise one gram of water one thousand degrees Centigrade

A thousand calories is often called a Kilocalorie or a Calorie and receives a lot of attention from people on diets.

The other measurement is British- the British Thermal Unit or BTU.

One BTU will raise one pound of water one degree Fahrenheit.

Fahrenheit is really not such a bad scale as we are all led to believe. The fellow who invented it divided the temperatures that occurred in Europe into one hundred parts 0° to 100°. Makes more sense than worrying about what water is doing, freezing (0° C) or boiling (100° C). Degrees Fahrenheit are what we will be using through most number games.

If you would like:

In the space that Centigrade goes from 0 to 100
Fahrenheit goes from 32 to 212

Thus 180 F° occur in 100 C°. or a C° is 180/100= 9/5 of a F°.
Since the C° started at 0 when the F° was already at 32, you must add that in any conversion, thus F°= 9/5 C° + 32°
and (C°= 5/9 (F°-32°))

Heat Quantity- A gallon of water weighs 8.34 pounds. (Figure out why a quart of water, at 32 ounces or two pounds multiplied by four doesnt quite make that come out right).

Every gallon per minute flowing past a pipe has 8.34 BTUs of energy for each degree F.

Ten gallons per minute of water at 95° F must have more energy than ten gallons per minute at 65° F. In fact:

95°-65° = 30°, 10gpm = 8.34 x 10= 83.4 pounds per minute,

30° x 83.4 pounds x 1 BTU/pound/F° = 2502 BTU/minute

We usually care about BTU/HOUR

2502 x 60 = 150,120 BTU/HOUR

Since the average medium insulated house needs about 30,000 to 50,000 BTU/ hour to stay warm on a cold winter day, if we can figure a way to get that 95° to 65° heat drop pumped into a house we can heat a few.

Pinkerton Spring- flows at about 55 gallons per minute, depending on the runoff situation, etc. The water of Pinkerton Spring stays about 95° F year around. If a way can be devised to yank heat from that water down to 70° F (human beings tend to think that is the lower limit of "heat"), how much energy is in the Pinkerton Spring?

55 gallons per minute x 8.34 pounds per gallon x 25° F drop (or delta) x 1 BTU per pound per degree F=
= 11,468 BTU per minute

60 x 11,468 = 688,050 BTU/hour (from 55x60=3300 gallons or 27522 pounds of water)

Thus there is conceivably (and that is all numbers are good for-conceiving enough heat in the hot springs to heat twenty 30,000 BTU/hour homes, and possibly one very leaky, old and poorly insulated lodge building. That is why we have the task of using the springs in the first place.

The Key- is to get that valuable heat out and into the air of the room we happen to be living and studying in. We arent sure how well that will work. It is not like going to the plumber and having the hot water heat installed. Most space heating systems and domestic hot water heating systems in the world need, or at least have grown accustomed to, much higher temperatures to work. Hot water base board systems when fired by a gas boiler are made to work at 170 to 180° F and when the radiators get clear down to 120° F, the water is sent back to the radiator for rewarming. You can calculate based on what you have just learned how much more heat is available from such temperatures.

At 70° F in a room, each gallon of 180° water has

$$(180-70) \times 8.34 = 751 \text{ BTUs}$$

at 70° F in a room, each gallon of 95° water has

$$(95-70) \times 8.34 = 209 \text{ BTUs}$$

This, coupled with the fact that most technological gadgets are built for the higher temperatures, makes the challenge complete.

The short summary of simple numbers above show how one can easily go about deciding if what he wants in something is there and if the amount is right There is no magic, witchcraft, or otherwise mysterious technique, just numbers.

There are a lot of other numerical lessons to be learned later.

## EFFICIENCY

The application of energy to a space for heating or to supply hot water usually reflects only part of the story. Destination or end use energy is often only a fraction of the energy that was set into motion to get that end product.

An electrical power plant burns coal or natural gas, or, sometimes, atoms, to produce electricity through the spinning of a large type of turbine first developed by Louis Nunn in Telluride, Colorado, who later sold his idea to a fellow named George Westinghouse. The coal, for instance, that is burned must heat a boiler which makes steam, which overcomes friction and momentum to spin a generator turbine. Generally, about 65% of the BTUs in that coal are lost through waste heat of the steam, friction, etc. and 35% of the energy is available at your house for electricity. This does not count the energy used in mining the coal, transporting it in trucks or trains, building the transport network, or the inefficiencies in appliances such as your electrical motors.

A refrigerator motor, for example, is typically about 60% efficient. This means that the electricity going in could be 100 watts, but only 60 watts of "shaft power" are available for the compressor. The freon cooling process is about 40% efficient, so that for those 60 watts at the compressor, only 24 watts of "cold" are created (more heat than cold is created!).

Thus the 100 watts at the power plant in coal is 35 watts at your house is 8.4 watts of "cold power", or 91.6% of the btus in that coal went to "entropy" unless there are "waste heat recovery" devices somewhere in the system. (Add to this the fact that the frost free refrigerator has heating elements in the freezer compartment wall and the outer wall to melt ice and prevent condensation, and the energy portion that actually cools your lettuce compared to that generated to cool your lettuce can be less than 2%).

You can see that efficiency is a very important subject.

Efficiency is defined as: $\frac{\text{Energy out}}{\text{Energy In}}$

100 watts out of a power plant producing 35 watts for your use at your house is 35% efficient.

Efficiency is a tricky subject and the object of many arguments by persons who see things being differently involved in a process.

For Instance: Calculations have been performed to show that the aluminum (a terrifically costly material, energy wise) in a solar collector, plus the glass, steel, copper, hydrocarbons (plastics etc.) can easily use more energy than the device would be expected

to save in its lifetime. That seems impossible. How can an energy saving device cost more in energy that it saves? The pricing of energy is not the same per btu everywhere. Gasoline has the highest price per btu of most fuels. The aluminum plant is often near a large hydroelectric dam, like the Grand Coulee in Washington, and pays a very low cost per kilowatt hour for its power, perhaps one tenth what you pay at your home.

Of course if money is your yardstick, one comparison results. If BTUs are your yardstick another comparison results.

One compares a commodity that the government can print more of at will, the other a heritage that has only a limited life on this earth, as suggested by the First Law of Thermodynamics.

One requires pocketbook comparisons, the other requires personal, morality comparisons, not done very often.

This is important in any discussion of a geothermal project for a number of reasons:

1. Geothermal energy is often used near its source and thus very efficient in terms of transportation, etc.

2. Geothermal energy often occurs in temperatures that are very close to application temperature in buildings.

3. The low temperatures of the Pinkerton Hot Springs require a great deal of attention to efficiency, since most of the heat can easily be lost and some uninsulated spot.

4. The technology developed by man for hot water heating does not include such low temperatures. The competitive marketplace being what it is, those high temperature devices are probably the most efficient through attrition, (maybe). Anything we choose to use in the CTA project will need a fresh evaluation for its efficiency.

For various thermodynamic reasons, inefficient systems wipe out temperature inefficiencies far more quickly than total heat inefficiencies. That means high grade heat is converted to low grade heat with no trouble at all.

Starting with only 95° F water makes this a difficult fact.

# NUMBERS

Before we discuss the exact particulars of this project, we need to just deluge our brains with a lot of numbers to help in comparing apples with oranges.

One Cubic Foot Water = 62.4 pounds

One Gallon Water = 8.34 pounds

7.48 Gallons Water = One Cubic Foot

One Gallon per Minute = 500 pounds per hour

1000 Watt-hours = 3412 BTUs

1 Horsepower = 746 Watts

1 BTU = 252 calories (= .252 Calories)

1 pound per square inch = 2.3 feet of water head

1 calorie = 4.19 Joules

1 dyne = Force required for fly to do one pushup

Watts = Volts x Amperes

Kilowatt-hours = Volts x Amperes x Total time (hrs)/ 1000
= Watts x Total time / 1000

1 horsepower = 550 ft-lb/ sec. = 746 Watts = 2544 BTU/hour

1 Chevrolet Corvette Engine = 400 Horsepower = 1,017,600 BTU/hour

# APPENDIX

Selected samples of CTA students reports for the assignment "write a proposal with costs for the use of the Pinkerton Hot Springs at CTA".

# ALL SEASON GREENHOUSE

USING

GEOTHERMAL RESOURCE

& BUILDING TECHNIQUE

By Brad Templin

The Spring to be used is newly located and has not been named. For convieniance sake, I will refer to it as 'Cap's Spring', in honor of Cap Allen who owns the rights to the spring.

Cap's spring is located approximately fourteen miles north of Durango Colorado and is on the west side of highway 550, about fifteen feet away from the pavement.

The average temperature of this spring is 32.22° Celcius, (hereforward refered to as C.). It discharges at an approximate (here forward referred to as ≈.), rate of 50 gpm.

In referance to an area of ground cover mesuring 400 ft.² using an underground resevoir of 1000 gallon capacity and a depth of two' ~~[illegible]~~ (width), the potential ΔT is ≈19%, relative to existing tempesature, (this figure is relative to 0°C, as the temperature increases, the figure decreases.). The point is to raise the frost line.

My proposal is to create a greenhouse that will have a minimum of heat loss, relative to the temperature of the surrounding air during the months of late fall, winter and early spring in the Animas valley.

The geothermal resource will be used to raise the frost line and heat the air directly above this point.

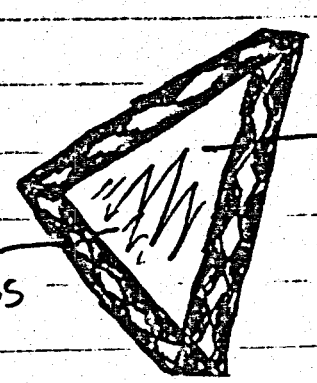
It will be ~~pumped~~ piped in an insulated, non-stick pipeline that will be closed to the outer air, to a small man made resevoir of the same material and it too will not be exposed to air. In fact, the entire system will be isolated from the air for this reason, once this spring water is exposed to air, the mineral content in it will begin to go through a chemical reaction causing it to become a solid and thus, eventually clog the pipeline.

The resevoir will ~~eventually~~ be slightly larger than the surface area of the structure that will rest above it. It will be place 16" below the ground level.

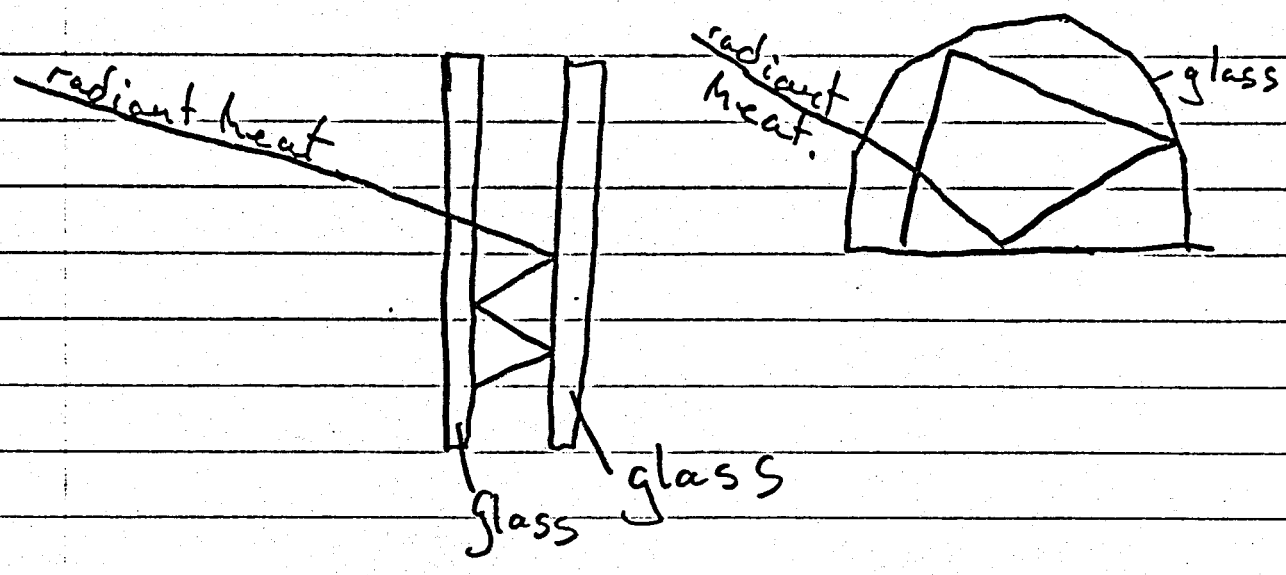
An additional air tight reservoir with a 100 gallon capacity will be placed above it. It shall be two" in width and shall be filled with alchohol. The reason that alchohol is being used is this, alchohol has a relatively high specific heat, (.581) and it will not freeze in these weather conditions.

Once the pipe is laid and the resevoirs are in place, the ground level will be lowered to where the frost line has been raised and a geodesic dome shall be built with the surface area = 400 ft$^2$.

The struts of the dome shall be made of a material with a high R-factor. The covering material shall be imperfect glass. The struts shall be ≈ six" in width, (the width will be universal), with two layers of glass, leaving an air pocket between them.



The outer layer shall be removable for the fair weather months in order to keep the heat from becoming too great within the greenhouse and to allow the heat to enter directly into the greenhouse rather than being contained within the walls.




Using this system, the temperature should not become any lower than 21.11°C.

Because of the nature of the pipe, friction will be minimal.

The excessive spring water can then be piped into an existing pool and be proclaimed a 'hot springs' and made available to the public at an admission psice. This would help with the construction

costs. Pumping is unnecessary simply because the entire length of the pipeline is downhill and because the earth is supplying all the pressure we need. The location of this project will be at Colorado Timberline Acadamy, a private boarding school directly ~~south~~east of the spring site on the opposite side of the highway.

The ≈ cost of this project will be: for 700 ft. of pipe, (400 to reservoir and 300 from reservoir to pool), with a 7" interior diameter - 2500 dollars; for one 1000 gallon reservoir - 2500 dollars; for one 100 gallon reservoir - 1000 dollars, (due to abnormal configuration); for strut material - 1500-2500 dollars; for imperfect glass - 9600 dollars; for alchohol - 700 dollars; for pool interior - 1000 dollars.

Total materials - 17,800 to 18,800 dollars.

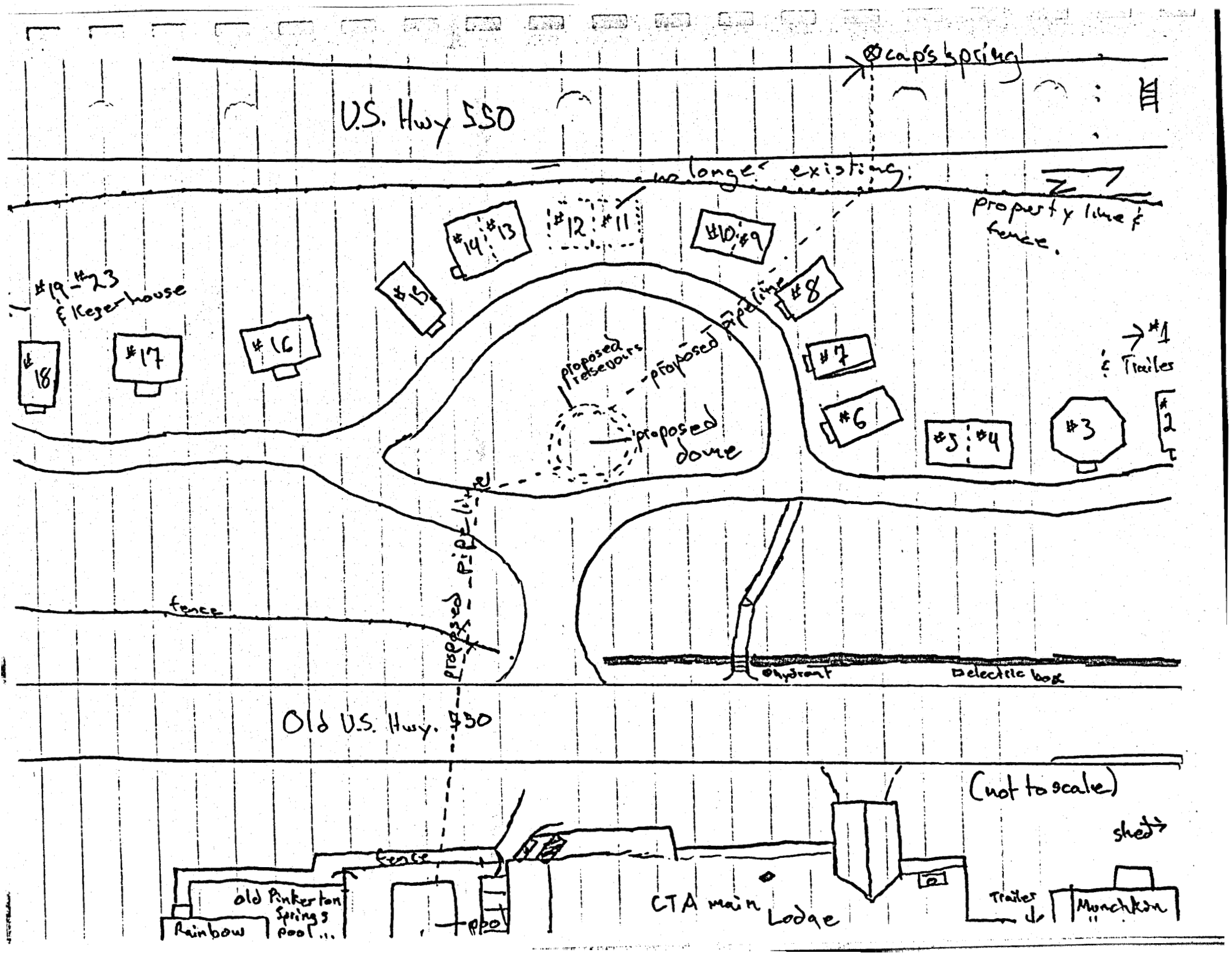
: for pipeline & reservoir labour - 2,750 dollars, (this is using C.T.A. personal for at least ½ of labour force).; for geodesic dome construction labour - 750 dollars, (this is using C.T.A. personel for at least ¾ of labour

force.); for pool restoration - 2000 dollars.
Total labour - 5,500 dollars.
Total costs - 23,300 to 24,300 dollars.
With the annual profit from produce and hot springs (visitor basis & ~~res~~ summer resort basis), this project should pay itself off in 7 to 10 years.

Alternative uses for this concept of geothermal resource:
Heating a house
Heating a livestock barn (the Knupple's should think about this one)
(i.e. heating a structure)
Thawing a road, (with the amount of hot springs in the area and the costs of road maitenence, this is especially relavant to Hwy 550).
Preliminary water heater
Heating a pool
Etc.

Brad Templin.

5/18/81


U.S. Hwy 550
cap's spring
no longer existing
property line & fence.
#19-#23 & Keg-house
#18
#17
#16
#15
#14
#13
#12
#11
#10
#9
#8
#7
#6
#5
#4
#3
#2
#1 & Trailer
proposed reservoirs
proposed pipeline
proposed dome
proposed pipeline
fence
hydrant
electric box
Old U.S. Hwy. 550
(not to scale)
shed
fence
old Pinkerton Springs pool
Rainbow
pool
CTA main Lodge
Trailer
Munchkin

Geothermal

Resources of

Colorado

Timberline

Academy

Robert
Middleton

Geothermal Resources of Colorado Timberline Academy

Identification of Resourse: Pinkerton Hot Springs A, B. Fourteen miles north of Durango along US Highway 550. Both springs are located 15 ft west of the Highway, Spring B 50 ft. South of spring A. A grant to the Department of Energy has determined that the springs should be restored to thier natural dispertion point by the Highway Department, whom altared thier coures during the construction of the new portion of H.W.Y. 550, in 1976. Spring A discharges 54 gpm at 95°F, total disolved content between 3,700/ml to 3,990/ml and the disoluents consist of sodium-calcium, chloride-bicarbonate with a high concentrate of iron. Spring B discherges 20gpm at 96°F, total disolved content was not measured, but the specific Conductance of the two springs are basically the same, So I'll say the disolved content is approximatly the same as Spring A and consists of the same disoluants.

Mound springs (300 yards north of A) have proved to be unusable, with a discharge of under 10 gpm at under 85°F, therefore are not documented.

Potential of Resource: The two springs together discharge 74 gpm at approximatly 95°F (differences of seasons). With a drop of 25°F to 70°F from 95°F there is an output of 925,740 BTU's/hr. This seems high but the volume of water is great and the degrees are few.

Proposal for Resource: I have concluded that heating a log of CTA's size to a moderate temperature is near impossible without outside energy added. I believe an efficiant method of using this costless recource is a type of water heater.

Plan: Take a large tank (10,000 gallons), heavily insulated, and run a high conductance ~~[illegible]~~ tubing, possibly 500 ft. of it, into the tank. Fresh water would run in the tubes (most likely aluminum: copper to expensive) and spring water would run in the tank. With 500 ft. of tubing I figure that 50°F water ~~[illegible]~~ in a tank of 94°F (I figure 1° would be lost in the transportation of the spring water from the discharge point to the tank) water, that the water being heated ~~[illegible]~~ could possibly reach 65°F.

There are many variables in this like the amount of water being heated, ect. But to the degree of which the water is raised, the water would go to the gas boilers to raise the water to 140°F.

Cost of Proposal: This project should cost approximatly $3500. The pipes approximatly 750, tank 2000, and 750 for miscellaneius, such as piping to tank, labor ect. This breif look into this idea for geothermal energy has been an interesting exieriance, and I shall persue it.

May 20, 1981

# PLAN FOR THE USE OF PINKERTON HOT SPRINGS SPRING A

Rain Perry
Cap Allen
Geothermal Class

My plan for Pinkerton Hot Springs Spring A, located on Raymond Knuppel's property just south of Colorado Timberline Academy, is to use it in a resaurant as a water heater for a tropical fish pond in the restaurant.

The first step in this project would be to buy or lease the hot springs and an acre around them.

The second step would be to excavate the hill where the source of the spring is so that it forms a cut away, and build a concrete vault five feet long, two feet wide and two feet high, right up against the hill.

The water from the spring, which is 91°F and comes out at a rate of 54 gpm, would run onto a funnel at the top of the vault, and be drained by a pipe at the bottom. There would be a cement trench below the drainage pipe to catch the water and bring it around to the side of the building away from it.

The concrete in the vault would be only one half foot wide for better insulation against cold air. The restaurant would be built only about two feet from the vault. Right up against the inside wall of the restaurant would be a tropical fish pond.

On the outside wall of the restaurant would be a well insulated water pump that pumps tap water (average 55°F) into a copper pipe which would go through a sealed hole in the vault into copper coils one half inch in diameter (with a two inch space in between them) that go vertically from one end of the vault to the other.

Once the water was through the coils, it would be pumped through an insulated pipe through a sealed hole in the building and empty out into a fish pond in back of the restaurant for the tourists to enjoy while eating their lobster.

The top of the vault would be removable, and the copper coils inside the vault would be held on with clamps so they could be removed about every six months to clean out the sludge at the bottom of the vault. The drain pipe would also be removable so it could be cleaned.

The water, once it has gone through the coils, the pipe into the building, emptied out through the air into the fish pond before it drains out the bottom, would be (in the fish pond) about 72°F, which is the perfect temperature for tropical fish to live in.

* * * * * * * * * * *

My estimated cost for this proposal would be:

| | |
|---|---|
| $5000 | for the land and water rights |
| 50 | copper coils |
| 200 | cement for the vault |
| 50 | insulated pipes |
| 100 | water pump |
| 1000 | concrete for fish pond |
| 1000 | drainage system for fish pond |
| 100 | cement trench |
| 1500 | tropical fish |
| 75000 | labor- excavation |
| 100000 | restaurant |
| | =$184000 |

# APPENDIX

Specific data on the Pinkerton Hot Springs

## #55 PINKERTON HOT SPRINGS

Located approximately 14 miles north of Durango along U.S. Highway 550 at the Golden Horeshoe Resort ire a group of springs known as the Pinkerton Hot Springs.

LOCATION: The location of the following springs were determined:

pring A: Latitude: 37°26'50"N.: Longitude: 107°48'17"W.; T. 37 N., R. 9 W., Sec. 25 ab, N.M.P.M.; La Plata County; Hermosa 7-1/2 minute topographic quadrangle map.

pring B: Latitude: 37°27'58"N.: Longitude: 107°48'18"W.; T. 37 N., R. 9 W., Sec. 25 a, N.M.P.M.; La Plata County; Hermosa 7-1/2 minute topographic quadrangle map.

Mound Spring: Latitude: 37°27'07"N.: Longitude: 107°48'20"W.; T. 37 N., R. 9 W., Sec. 25 ba, N.M.P.M.; La Plata County; Hermosa 7-1/2 minute topographic quadrangle map.

Little Mound Spring: Latitude: 37°27'09"N.; Longitude: 107°48'21"W.; T. 37 N., R. 9 W., Sec. 25 ba, N.M.P.M.; La Plata County; Hermosa 7-1/2 minute topographic quadrangle map.

General: Spring A (Fig. 108) is located just east of the highway right-of-way and to the south of the resort buildings. Spring B was located 900 to 1,200 ft west of Spring A in the trees and bushes. Mound Spring is located approximately 1,500 ft northwest of Spring A. As the name implies, mound spring flows from the top of a large mound approximately 100 ft above the road (Fig. 109). Little Mound Spring is located several hundred feet north of Mound Spring. The new section of U.S. 550 under construction in 1977 passes the base of Mound and Little Mound Springs. The construction of this new section of road has destroyed Spring B.

Geology and Hydrology: Spring A was sampled in the fall of 1975, January, 1976, and April 1976. The temperature remained a constant 32°C, and its discharge was 54 gpm. The dissolved solids of the waters varied from a low of 3,700 mg/l to a high of 3,990 mg/l, and the waters are a mixed sodium-calcium, chloride-bicarbonate type with a high concentration of iron.

Figure 108.--Pinkerton Hot Spring. Spring A.

Spring B was sampled only once. Its temperature was 33°C with a discharge of 20 gpm. The dissolved solids was not determined, but the field measurement of conductance was 6,000 micromhos. The waters are a sodium-bicarbonate type with a very high concentration of iron.

Mound Warm Spring: The waters of this spring have a temperature of 32°C and the discharge of the spring is 54 gpm. The waters contain approximately 3,800 mg/l of dissolved solids with a high iron content.

Little Mound Spring: The waters of this spring were not sampled for complete chemical analysis of dissolved solids. Field measurements showed that the spring had a temperature of 26°C, an estimated discharge of 2 gpm, a pH of 7.0, and a conductance of 5,500 micromhos.

Surrounding all four springs are large aprons of iron-rich sediments.

These springs are located on the south side of the La Plata Mountains and Coal Bank Hill, a pass in the La Plata Mountains. The waters emerge from colluvial and alluvial deposits overlying the Mississippian Leadville Limestone.

The La Plata Mountains and the San Juan Mounains, immediately to the east, were centers of extensive volcanic activity in middle Tertiary time. Although no volcanic rocks are found near these springs, they occur only a few miles to the north. While not shown on the accompanying geologic map (Fig. 110), the Leadville Limestone appears to be faulted in the vicinity of the springs. Moyer and others (1961) state that the waters emerge from a fault transverse to the valley. Any explanation of the occurrence of these thermal waters must explain the high concentration of dissolved iron and evaporite mineral matter in the waters. Kilgore and Clark (1961, p. 235) have shown that a thin section of early Paleozoic limestones and sandstones underlies the Pinkerton Hot Springs, none of which contain large amounts of readily soluble minerals, especially iron. However, the overlying red sandstones, shales, siltstones of the Hermosa Group do. In addition, formations within the Hermosa group contain large amounts of evaporite minerals. Contact of the thermal waters with these units would explain the origin of the mineral matter in the thermal waters.

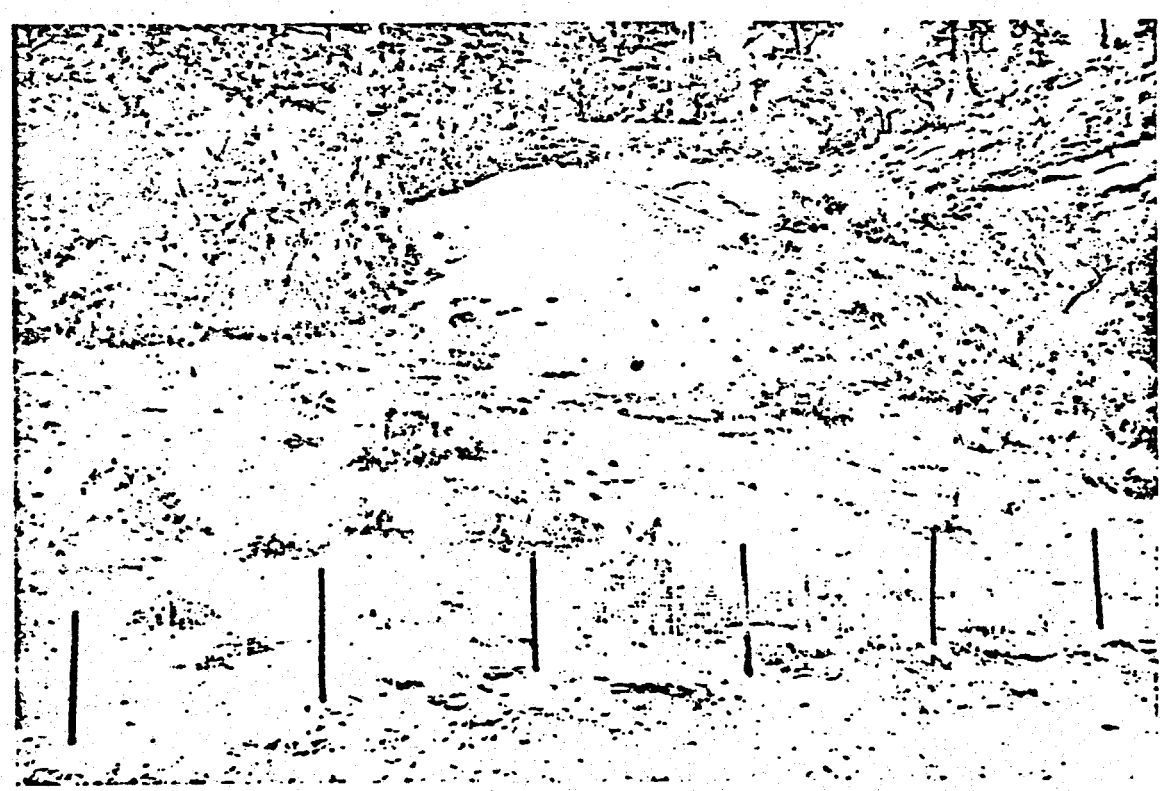


Figure 109.--Mound Spring at Pinkerton Hot Springs.

Reiter (1975) has shown this part of western Colorado to have a heat flow between 2.0 and 2.5 heat f'ow units. The source of the heat is unknown but may be related to the volcanic rocks found in the La ata and San Juan Mountains. Recharge of the thermal water is believed to occur via deep circulation along f_ult zones from the La Plata Mountains.

GEOTHERMOMETER ANALYSIS OF SPRING A AND MOUND SPRING:

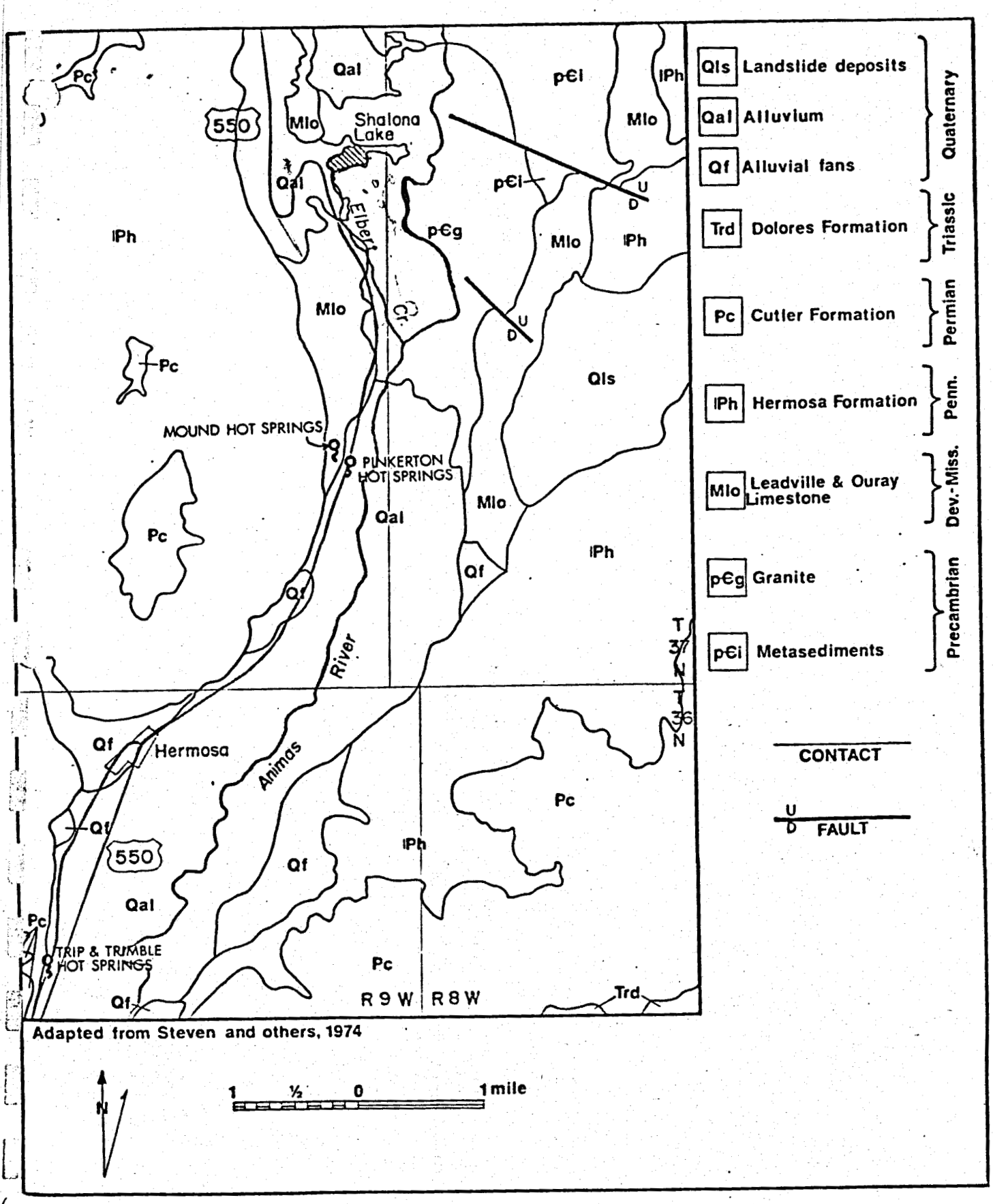
lica Geothermometer: The quartz-silica geothermometer yields an estimated temperature of 78°C for Spring A and Mound Spring.

xing Model: Since temperature-dependent equilibration between the thermal waters and quartz may control e silica content of the spring, the quartz mixing model is applicable. Use this model for Spring A yields an estimated subsurface temperature of 127°C to 133°C with a cold-water fraction of 81 to 82 percent. A temperature of 139°C with a cold-water fraction of 84 percent was estimated for Mound Spring (Table 4). ie estimated values are within the range of values that could result from normal analytical error.

Na-K and Na-K-Ca Geothermometers: The Na-K geothermometer yielded a subsurface temperature estimate of 231°C to 234°C for Spring A, and 234°C to 235°C for Mound Spring. The Na-K-Ca geothermometer yielded an stimated temperature of 202°C to 206°C for Spring A and 206°C to 207°C for Mound Spring. In both instances ie Na-K estimate is too high because the value of the term, log √Ca/Na is greater than 0.5. In addition, arge travertine and calcium carbonate deposits near the hot springs suggest that both the Na-K and Na-K-Ca geothermometer estimates are too high.

onclusion: The insignificant variation in flow, mineral content, and surface temperature of the warm spring uggests that it is not materially affected by seasonal metereological conditions. Moreover, the fluctuations of the various geothermometer model estimates are well within the range of values that could result from normal analytical errors.

Consideration of the mixing model and silica geothermometer results and mixing model precision suggests subsurface temperatures between 75° and 125°C (Table 4).




Adapted from Steven and others, 1974

Figure 110.--Geologic conditions of Pinkeron, Mound, Tripp, and Trimble Hot Springs areas.

## #56 TRIPP AND TRIMBLE WARM SPRINGS

### #56 TRIMBLE HOT SPRING

LOCATION: Latitude: 37°23'28"N.; Longitude: 107°50'52"W.; T. 36 N., R. 9 W., Sec. 15 bb, N.M.P.M.; La Plata County; Hermosa 7 1/2-minute topographic quadrangle map.

GENERAL: Trimble Hot Spring is located approximately 9.25 miles north of Durango just off U.S. Highway 550. At the present time the spring is unused and just barely flows. In the past this spring fed the large swimming pool located to the south. The spring is inside a small rock house (Fig. 111).

GEOLOGY AND HYDROLOGY: This spring had a temperature of 36°C and a discharge of less than one gpm. The waters contained 3,340 mg/l of dissolved mineral matter and are a calcium sulfate type.

The waters, although issuing from colluvial deposits at the base of the cliff, are associated with the underlying red beds of the Paradox Formation (Fig. 110).

Moyer and others (1961) have described a northeast-trending fault, downthrown on the northwest side, crossing the valley near the springs. They state that the springs emerge along this fault zone. Kilgore and Clark (1961) show this and other faults in the vicinity reaching to basement rocks. The origin of these thermal waters is unknown but may result from deep circulation and updip flow along faults in the San Juan basin.

### #56 TRIPP HOT SPRING

LOCATION: Latitude: 37°23'30"N.; Longitude: 107°50'52"W.; T. 36 N., R. 9 W., Sec. 10 cc, N.M.P.M.; La Plata County; Hermosa 7 1/2-minute topographic quadrangle map.

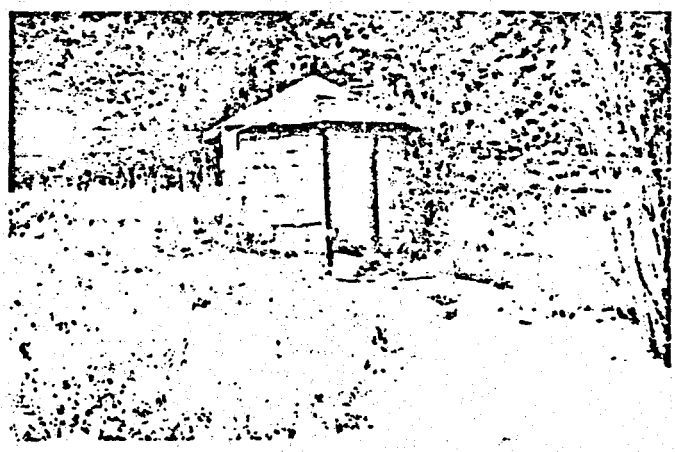


Figure 111.--Trimble Hot Springs. Spring is inside rock house.

GENERAL: This spring is located less than 200 ft north of the Trimble Hot Spring, approximately 9.25 miles north of Durango off U.S. Highway 550. The spring is located in the big tin building behind the house (Fig. 112). The spring was sampled from a concrete-lined trough in the metal building.

GEOLOGY AND HYDROLOGY: Temperature: 44°C; Discharge: not determined; Total Dissolved Solids: 3,240 mg/l; calcium-sodium sulfate type.

Like the Trimble Hot Spring waters, these waters come from colluvial deposits overlying the red beds of the Paradox Formation.

GEOTHERMOMETER ANALYSES OF TRIMBLE AND TRIPP HOT SPRINGS:

Silica Geothermometer: The silica content of these springs does not approach the solubilities of amorphous silica, chalcedony, cristobalite, or quartz. Therefore, application of any of these silica geothermometers will yield unreliable results.

Mixing Model: The amorphous silica solubility at the warm springs surface temperature (36°C to 44°C), 143 to 164 mg/l, is much higher than the silica content of the thermal water (69 to 72 mg/l). This discrepancy may be caused by mixing of the thermal water and relatively dilute groundwater.

The amorphous-silica mixing model yields a subsurface temperature estimate of 30°C to 40°C with a cold-water fraction of 39 to 47 percent of the spring flow (Table 4).

Na-K and Na-K-Ca Geothermometers: The Na-K and Na-K-Ca geothermometers yield subsurface temperature estimates of 197°C to 198°C and 97°C to 99°C, respectively (Table 4). The Na-K geothermometer estimate is too high because the term log $\sqrt{Ca}/Na$ exceeds 0.5. In addition, the low surface temperature and flow (less than 1 gpm) and the lack of substantiation of such high subsurface temperatures by the other geothermometers suggest that both the Na-K and Na-K-Ca estimates are unreliable.

CONCLUSION: Geothermometer models must be used with caution when applied to Tripp and Trimble warm springs because most of the assumptions inherent in their use are violated. Any geothermometer estimate for this area is unreliable at best; however, the subsurface temperature is probably between 45°C and 70°C (Table 4).

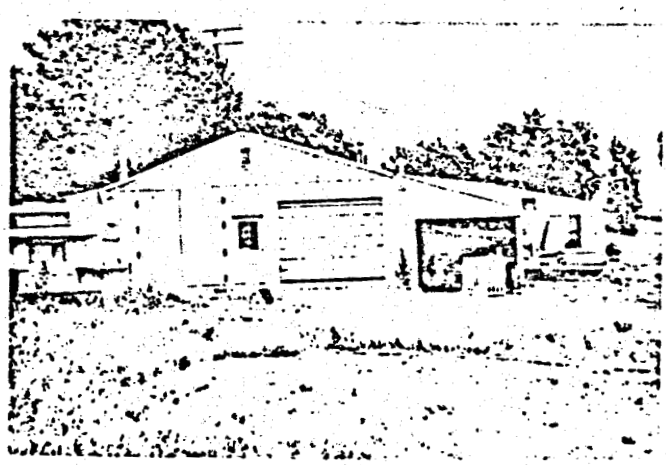


Figure 112.--Tripp Hot Springs. Spring is inside metal buildings.

Table 1. Physical Properties and Chemical Analysis of Thermal Waters in Colorado.

Pinkerton Hot Springs: Spring A

Location: 37°26'50"N. Latitude; 107°48'17"W. Longitude; T. 37 N., R. 9 W., Sec. 25 ab, N.M.P.M., La Plata County

| | Page 39 Aid Horse | Date Sampled 9/75 | 1/76 | 4/76 |
|---|---|---|---|---|
| Arsenic (As), (UG/L): | 93 | 120 | - | - |
| Boron (B), (UG/L): | 1800 | 3,000 | 2,800 | 2,800 |
| Cadium (Cd), (UG/L): | 0 | 0 | - | - |
| Calcium (Ca), (MG/L): | 250 | 510 | 560 | 530 |
| Chloride (Cl), (MG/L): | 170 | 1,000 | 1,000 | 1,000 |
| Fluoride (F), (MG/L): | 4.5 | 2.1 | 1.9 | 3.9 |
| Iron (Fe), (UG/L): | 20 | 4,400 | 4,000 | 4,500 |
| Lithium (Li), (UG/L): | 2800 | 2,500 | - | - |
| Magnesium (Mg), (MG/L): | 25 | 79 | 69 | 72 |
| Manganese (Mn), (UG/L): | 270 | 470 | 490 | 480 |
| Mercury (Hg), (UG/L): | 0 | 0 | - | - |
| Nitrogen (N), (MG/L): | .01 | 0.10 | 0.01 | 0 |
| Phosphate ($PO_4$) | | | | |
| Ortho diss. as P, (MG/L): | .05 | 0.05 | 0.01 | 0.07 |
| Ortho, (MG/L): | .15 | 0.15 | 0.03 | 0.21 |
| Potassium (K), (MG/L): | 89 | 120 | 110 | 120 |
| Selenium (Se), (UG/L): | 0 | 0 | - | - |
| Silica ($SiO_2$), (MG/L): | 52 | 28 | 28 | 29 |
| Sodium (Na), (MG/L): | 780 | 750 | 690 | 720 |
| Sulfate ($SO_4$), (MG/L): | 1500 | 690 | 610 | 540 |
| Zinc (Zn), (UG/L): | 10 | 0 | - | - |
| Alkalinity | | | | |
| As Calcium Carbonate, (MG/L): | 704 | 1,340 | 1,330 | 1,250 |
| As Bicarbonate, (MG/L): | 858 | 1,630 | 1,620 | 1,520 |
| Hardness | | | | |
| Noncarbonate, (MG/L): | 23 | 260 | 350 | 370 |
| Total, (MG/L): | 730 | 1,600 | 1,700 | 1,600 |
| Specific conductance (Micromohs): | 6300 | 5,600 | 6,060 | 5,930 |
| Total dissolved solids (TDS), (MG/L): | 3300 | 3,990 | 3,880 | 3,770 |
| pH, Field | 6.5 | - | 6.5 | 6.4 |
| Discharge (gpm): | 30 | 54 | 54 | 54 |
| Temperature (°C): | 56 | 32 | 32 | 32 |

Remarks: Located south of resort and approx. 50 feet east of U.S. 550.

Table 1. Physical Properties and Chemical Analysis of Thermal Waters in Colorado.

Pinkerton Hot Springs: Spring B

Location: 37°27'58"N. Latitude; 107°48'18"W. Longitude; T. 37 N., R. 9 W., Sec. 25 a, N.M.P.M., La Plata County

| | Date Sampled 9/75 |
|---|---|
| Arsenic (As), (UG/L): | 160 |
| Boron (B), (UG/L): | 3,000 |
| Cadium (Cd), (UG/L): | 0 |
| Calcium (Ca), (MG/L): | 530 |
| Chloride (Cl), (MG/L): | 990 |
| Fluoride (F), (MG/L): | - |
| Iron (Fe), (UG/L): | 4,400 |
| Lithium (Li), (UG/L): | 2,800 |
| Magnesium (Mg), (MG/L): | 71 |
| Manganese (Mn), (UG/L): | 530 |
| Mercury (Hg), (UG/L): | 0 |
| Nitrogen (N), (MG/L): | - |
| Phosphate ($PO_4$) | |
| Ortho diss. as P, (MG/L): | 0.01 |
| Ortho, (MG/L): | 0.04 |
| Potassium (K), (MG/L): | 120 |
| Selenium (Se), (UG/L): | 0 |
| Silica ($SiO_2$), (MG/L): | - |
| Sodium (Na), (MG/L): | 720 |
| Sulfate ($SO_4$), (MG/L): | 610 |
| Zinc (Zn), (UG/L): | 20 |
| Alkalinity | |
| As Calcium Carbonate, (MG/L): | 1,350 |
| As Bicarbonate, (MG/L): | 1,640 |
| Hardness | |
| Noncarbonate, (MG/L): | 280 |
| Total, (MG/L): | 1,600 |
| Specific conductance (Micromohs): | 6,000 |
| Total dissolved solids (TDS), (MG/L): | - |
| pH, Field | - |
| Discharge (gpm): | 20 |
| Temperature (°C): | 33 |

Remarks: Located approx. 1200 feet west of Spring A

Table 1. Physical Properties and Chemical Analysis of Thermal Waters in Colorado.

Pinkerton Hot Springs: Mound Spring

Location: 37°27'07"N. Latitude; 107°48'20"W. Longitude; T. 37 N., R. 9 W., Sec. 25 ba, N.M.P.M., La Plata County

| | Date Sampled | | |
|---|---|---|---|
| | 9/75 | 1/76 | 4/76 |
| Arsenic (As), (UG/L): | 180 | - | - |
| Boron (B), (UG/L): | 3,000 | 3,000 | 2,900 |
| Cadium (Cd), (UG/L): | 0 | - | - |
| Calcium (Ca), (MG/L): | 550 | 550 | 550 |
| Chloride (Cl), (MG/L): | 1,000 | 1,000 | 900 |
| Fluoride (F), (MG/L): | 2.1 | 1.9 | 3.0 |
| Iron (Fe), (UG/L): | 4,100 | 4,200 | 4,300 |
| Lithium (Li), (UG/L): | 2,800 | - | - |
| Magnesium (Mg), (MG/L): | 74 | 68 | 72 |
| Manganese (Mn), (UG/L): | 500 | 490 | 480 |
| Mercury (Hg), (UG/L): | 0 | - | - |
| Nitrogen (N), (MG/L): | 0.06 | 0 | 0 |
| Phosphate ($PO_4$) | | | |
| Ortho diss. as P, (MG/L): | 0.01 | 0.03 | 0 |
| Ortho, (MG/L): | 0.03 | 0.09 | 0 |
| Potassium (K), (MG/L): | 120 | 120 | 120 |
| Selenium (Se), (UG/L): | 0 | - | - |
| Silica ($SiO_2$), (MG/L): | 29 | 28 | 28 |
| Sodium (Na), (MG/L): | 730 | 710 | 710 |
| Sulfate ($SO_4$), (MG/L): | 620 | 600 | 650 |
| Zinc (Zn), (UG/L): | 10 | - | - |
| Alkalinity | | | |
| As Calcium Carbonate, (MG/L): | 1,340 | 1,320 | 1,330 |
| As Bicarbonate, (MG/L): | 1,630 | 1,610 | 1,620 |
| Hardness | | | |
| Noncarbonate, (MG/L): | 340 | 330 | 340 |
| Total, (MG/L): | 1,700 | 1,700 | 1,700 |
| Specific conductance (Micromohs): | 5,600 | 6,050 | 5,890 |
| Total dissolved solids (TDS), (MG/L): | 3,940 | 3,880 | 3,840 |
| pH, Field | - | 6.5 | 6.4 |
| Discharge (gpm): | 8E | 5E | 5E |
| Temperature (°C): | 30 | 29 | 29 |
| Remarks: | | | |

X

Table 1. Physical Properties and Chemical Analysis of Thermal Waters In Colorado.

Pinkerton Hot Springs: Little Mound Spring

Location: 37°27'09"N. Latitude; 107°48'21"W. Longitude; T. 37 N., R. 9 W., Sec. 25 ba, N.M.P.M., La Plata County

Temperature: 26°C

Discharge: 2 gpm (est.)

Specific conductance: 5,500

pH: 7.0

Table 1. Physical Properties and Chemical Analysis of Thermal Waters in Colorado.

Trimble Hot Spring

Location: 37°23'28"N. Latitude; 107°50'52"W. Longitude; T. 36 N., R. 9 W., Sec. 15 bb, N.M.P.M., La Plata County

| | Date Sampled 9/75 |
|---|---|
| Arsenic (As), (UG/L): | 17 |
| Boron (B), (UG/L): | 1,400 |
| Cadium (Cd), (UG/L): | 0 |
| Calcium (Ca), (MG/L): | 510 |
| Chloride (Cl), (MG/L): | 220 |
| Fluoride (F), (MG/L): | 2.7 |
| Iron (Fe), (UG/L): | 50 |
| Lithium (Li), (UG/L): | 1,600 |
| Magnesium (Mg), (MG/L): | 42 |
| Manganese (Mn), (UG/L): | 80 |
| Mercury (Hg), (UG/L): | 0 |
| Nitrogen (N), (MG/L): | 0.08 |
| Phosphate ($PO_4$) | |
| Ortho diss. as P, (MG/L): | 0.02 |
| Ortho, (MG/L): | 0.06 |
| Potassium (K), (MG/L): | 47 |
| Selenium (Se), (UG/L): | 0 |
| Silica ($SiO_2$), (MG/L): | 72 |
| Sodium (Na), (MG/L): | 510 |
| Sulfate ($SO_4$), (MG/L): | 1,400 |
| Zinc (Zn), (UG/L): | 10 |
| Alkalinity | |
| As Calcium Carbonate, (MG/L): | 894 |
| As Bicarbonate, (MG/L): | 1,090 |
| Hardness | |
| Noncarbonate, (MG/L): | 550 |
| Total, (MG/L): | 1,400 |
| Specific conductance (Micromohs): | 4,400 |
| Total dissolved solids (TDS), (MG/L): | 3,340 |
| pH, Field | - |
| Discharge (gpm): | 1E |
| Temperature (°C): | 36 |
| Remarks: | |

X

Table 1. Physical Properties and Chemical Analysis of Thermal Waters in Colorado.

Tripp Hot Spring

Location: 37°23'30"N. Latitude; 107°50'52"W. Longitude; T. 36 N., R. 9 W., Sec. 10 cc, N.M.P.M., La Plata County

| | Date Sampled |
|---|---|
| | 9/75 |
| Arsenic (As), (UG/L): | 17 |
| Boron (B), (UG/L): | 1,500 |
| Cadium (Cd), (UG/L): | 0 |
| Calcium (Ca), (MG/L): | 470 |
| Chloride (Cl), (MG/L): | 220 |
| Fluoride (F), (MG/L): | 2.7 |
| Iron (Fe), (UG/L): | 10 |
| Lithium (Li), (UG/L): | 1,600 |
| Magnesium (Mg), (MG/L): | 41 |
| Manganese (Mn), (UG/L): | 80 |
| Mercury (Hg), (UG/L): | 0 |
| Nitrogen (N), (MG/L): | 0.16 |
| Phosphate ($PO_4$) | |
| Ortho diss. as P, (MG/L): | 0.05 |
| Ortho, (MG/L): | 0.15 |
| Potassium (K), (MG/L): | 47 |
| Selenium (Se), (UG/L): | 0 |
| Silica ($SiO_2$), (MG/L): | 69 |
| Sodium (Na), (MG/L): | 500 |
| Sulfate ($SO_4$), (MG/L): | 1,400 |
| Zinc (Zn), (UG/L): | 20 |
| Alkalinity | |
| As Calcium Carbonate, (MG/L): | 810 |
| As Bicarbonate, (MG/L): | 988 |
| Hardness | |
| Noncarbonate, (MG/L): | 530 |
| Total, (MG/L): | 1,300 |
| Specific conductance (Micromohs): | 3,900 |
| Total dissolved solids (TDS), (MG/L): | 3,240 |
| pH, Field | - |
| Discharge (gpm): | - |
| Temperature (°C): | 44 |
| Remarks: | |

# APPENDIX

General supporting data base for the Pinkerton Hot Springs including supposed therapeutic benefits economic potential, and a description of the Pagosa Springs project.

G 34.3:11

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R. D. GEORGE, State Geologist

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BULLETIN 11

# MINERAL WATERS
## OF COLORADO

By
R. D. GEORGE, HARRY A. CURTIS,
O. C. LESTER, JAS. K. CROOK,
J. B. YEO, and others

DENVER, COLORADO
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## LETTER OF TRANSMITTAL

State Geological Survey,
University of Colorado, September 22, 1920.

*Governor Oliver H. Shoup, Chairman, and Members of the Advisory Board of the State Geological Survey.*

Gentlemen: I have the honor to transmit herewith Bulletin 11 of the Colorado Geological Survey.

Very respectfully,

R. D. George,
State Geologist.

# CONTENTS

## PART I

### GENERAL DISCUSSION OF MINERAL WATERS—R. D. GEORGE

Page
CHAPTER I. Source and geological relations of mineral waters..... 9
The source of the waters of springs..... 9
The relation of mineral waters to geological conditions..... 13
Salts and gases from sedimentary rocks..... 16
Salts and gases from igneous rocks..... 17
Thermal springs ..... 18
Historical note ..... 21
CHAPTER II. Classification of mineral waters..... 22
The German classification..... 22
The French classification..... 22
The English classification..... 23
Walton's (American) classification..... 23
Peale's classification ..... 23
Crook's classification ..... 23

## PART II

CHAPTER III. Value and uses of mineral waters—James K. Crook, adapted by R. D. George..... 30
Solid and gaseous components of mineral waters and their therapeutic uses ..... 30
Carbonic acid and alkaline carbonate and bicarbonates..... 36
CHAPTER IV. Radium as a curative agent in mineral waters. Introductory by R. D. George. Therapeutics of radioactive waters by John Satterly and R. T. Elworthy ..... 46
Therapeutics of radioactive waters..... 47
The use of the radioactive waters at Bath, England..... 48
CHAPTER V. Baths and douches and their medicinal uses. J. B. Yeo, adapted by R. D. George..... 50
General ..... 50
The cold bath ..... 51
The temperate and the tepid bath..... 54
The warm bath..... 54
The hot bath..... 56
The douche ..... 57
The vapor bath..... 59
The hot air bath..... 60
The Roman bath ..... 62
Electro-thermal and magnetic baths..... 62
The soda bath ..... 62

## CARBONIC ACID AND ALKALINE CARBONATES AND BICARBONATES

Most cold mineral springs contain carbon dioxide or carbonic-acid gas in greater or less proportion. They thus become carbonated waters unless some other ingredient is sufficiently prominent to fix its own character upon the water. Those containing an excess of this gas have an acid reaction when first drawn, and an acidulous, pungent, but very agreeable taste. It gives to water a bright and piquant sparkle, and is the gas used in charging all of our synthetic artificial waters—"seltzer," "soda," "vichy," etc. It is also present in many wines. In moderate doses carbonic acid promotes the flow of saliva, tends to allay nausea and gastric irritability, aids digestion, assists in rendering the fluids of the body alkaline, promotes diuresis, and imparts a sense of well being. The carbonic-acid waters are often better borne by the stomach than any other form of drink, and they form a pleasant medium for the administration of milk to fever patients.

*The Alkaline Carbonates* give character to the important alkaline group of mineral waters. They consist of the carbonates of calcium, iron, lithium, magnesium, potassium, and sodium. They are frequently associated with carbonic acid, which, greatly increasing their solubility, forms with them the bicarbonates. These salts have so many characters in common that it seems proper to consider them in one group, afterward observing their individual properties. Though apt to be acid in reaction when first taken from the fountain, owing to the presence of carbonic anhydride, yet their action in the system is always that of alkalies. They form a very efficacious and speedy remedy in the treatment of acid dyspepsia and flatulence. They also act as stomachics, if given before meals, by stimulating the peptic glands. Having a diuretic tendency, the alkaline carbonated waters tend to correct acidity of the urine, and are of great service in fevers, rheumatism, gout, vesical irritation, diabetes, etc. In Europe they have long held high favor in the treatment of metritis and leucorrhœa, as well as other female pelvic disorders. When combined with salines, as they often are, forming the great alkaline-saline group of waters, they are of much value in catarrhal conditions of the gastro-intestinal tract with engorgement of the portal system. They have further been found useful in obesity. When associated with iron, constituting the much-prized alkaline-chalybeate group, the range of their action is manifoldly extended (vide iron).



*Carbonate of calcium.*—The familiar "chalk mixture" of the drug stores is largely composed of this substance. It possesses several properties not observed in the other carbonates. Although alkaline in action, it is not evacuant, but in large doses is apt to cause constipation. In virtue of this action the calcic waters have been used with much success in chronic diarrhœa. There is also reason to believe that uric acid, gravel and calculi may be disintegrated and eliminated under their free use.

*Carbonate of lithium.*—The carbonate of lithium is sparingly, the bicarbonate freely, soluble in water. Solutions of lithia are alkaline. These salts are found in a considerable number of mineral waters in various proportions. Some of those most extensively advertised contain less than half a grain to the gallon, and may be regarded as practically inert so far as this substance goes. Lithia owes its virtues to the fact that it unites readily with uric acid forming the urate of lithia—a freely soluble compound which passes readily from the system. For this reason it finds its most important application in diseases characterized by the uric-acid diathesis, otherwise known as uricæmia, lithæmia, or lithiasis. It is notably useful in cases of uric-acid, sand, gravel and calculi, and in gout and rheumatoid arthritis. It is also stated to be of value in phosphatic deposits in the appendix, and in concretions, tophi, etc.

*Carbonate of magnesium.*—This is perhaps the most efficient of the antacids. It is mildly alkaline in reaction. Perhaps its best effects are observed in acid eructations, and pyrosis, and in sick headaches, especially when due to or accompanied by constipation. It is also of value in checking the formation of uric-acid gravel and calculi.

*Carbonate of potassium.*—This salt is usually found in the form of the bicarbonate. It possesses antacid, diuretic, and antilithic effects in connection with the other alkalies, but claims no individual or peculiar virtues.

*Carbonate of sodium.*—The carbonate of sodium may be taken as the standard of the alkaline carbonates found in mineral waters. This salt, or the bicarbonate, occurs with greater frequency, and, as a rule, in larger quantities than the other compounds of this character. In the body it is found in the blood and saliva, giving to these fluids their alkalinity. It also occurs in the urine, the lymph, the cephalo-rachidian fluid, and in bone. Its function in nutrition is rather accessory than essential. Waters containing

# CHAPTER IV

## RADIUM AS A CURATIVE AGENT IN MINERAL WATERS

INTRODUCTORY BY R. D. GEORGE

THERAPEUTICS OF RADIOACTIVE WATERS BY JOHN SATTERLY AND R. T. ELWORTHY

### THERAPEUTIC VALUE OF RADIOACTIVE MINERAL WATERS

Physicians, scientists and laymen freely admit that, in many instances, the curative effects of certain mineral waters cannot be explained by reference to the mineral contents of those waters as shown by the most careful chemical analyses. It is customary to refer to the change of surroundings, the restful conditions at the spas, and the psychological influence under which the patients live, as a sufficient explanation of the beneficial results which appear to be out of harmony with the medicinal value of the chemical contents of the waters. It is, however, a proven fact, apart altogether from the experiences of patients at spring resorts, that certain chemicals administered in doses of extremely small size will, in time, produce results quite out of proportion to the amount of such drug or chemical taken into the system. (See p. 34 of this report.)

The study of certain ductless glands long supposed to be functionless, and the study of certain bodies not known to be glandular in character or function have proved the extreme sensitiveness of the human system, and the fact that infinitely small amounts of certain secretions may profoundly affect the well being and functioning of the human machine. Certain foods are found to contain infinitely small quantities of certain vitally necessary ingredients (vitamines) without which the most perfect functioning of the animal system would be impossible.

Is it not possible that a part, perhaps a very important part, of the unexpected and unexplained virtues of certain mineral waters may be directly due to the subtle influence of radioactivity? The study of radium as a curative agent has proved beyond controversy its effectiveness in the treatment of certain diseases, notably cancer, and its influence upon certain bodily functions. If but a small fraction of the healing work attributed to radium by reputable physicians and surgeons is properly so credited, we are obliged



to acknowledge the great power of a very small quantity of the element, since the total amount of radium hitherto used by the entire medical profession would scarcely exceed in weight a day's dosage of certain grosser drugs for a single patient.

The following paragraphs are copied from Mineral Springs of Canada, Part I. The Radioactivity of Some Canadian Mineral Springs, by John Satterly and R. T. Elworthy, Canada Department of Mines, Mines Branch, Bull. 16, pp. 50-52, 1917.

### THE THERAPEUTICS OF RADIOACTIVE WATERS

It may be interesting to outline the main results of investigations concerning the therapeutic value of radioactive waters, although the greater part of such work has been done using artificially prepared radioactive solution, usually many times more active than naturally found solutions.

In the first place an increased activity of all the processes of nutrition and metabolism occurs. Increased oxidation is evidenced by a rise in the percentage of all urinary solids other than the chlorides, and a considerable multiplication of the red blood cells has been often observed. Difference of opinion exists as to the question of the bactericidal effects of radium and its derivatives. Some authorities have denied any such effects, yet treatment at Bath has shown an antibacterial effect in the case of gonococci. Radium emanation certainly has power to stimulate the elimination of toxins.

Under the influence of radium emanation the insoluble sodium monourate can be changed into a soluble monourate, which subsequently decomposes into ammonia and carbon dioxide. Work upon patients whose blood contained uric acid has shown that a similar process takes place in the human body when treatment in an "emanatorium" is given.

The chief agent in the therapeutic use of waters is radium emanation.

There are five ways of absorbing emanation:

1. Through the lungs.
2. Through the digestive organs.
3. Through the skin.
4. Through the medium of different forms of injection.
5. Through the employment of local applications externally.

In the first case the chief source of the emanation would be the gases which are so often evolved from springs. These gases, passed into the air of a suitable room, constitute it an "inhalatorium."

The lung is the quickest medium of absorption and discharge, and the radium emanation dissolves in the blood to a certain extent. From the blood it can enter the organs and tissue cells. The most satisfactory condition will arrive when the blood is saturated with emanation.

The second method of absorption will be adopted when waters containing radium or emanation are drunk. In this way the emanation penetrates the stomach and intestines, and diffuses into the capillaries of the lymph and portal vein, and much of the emanation imbibed reaches the arterial blood. In the case of inhalation the emanation is much more rapidly absorbed, but it is retained only as long as it is breathed, while in the drink cure emanation is introduced into the system, and solid decomposition products are deposited, which will continue to send out the radiations which are the valuable agents.

In many cases, relatively strong radium solutions are injected into patients, though such treatment hardly comes within the province of natural water therapy.

Besides inhaling radioactive air, and drinking radioactive water, a variety of baths using radioactive water have been devised, though the question of absorption by the skin is a much discussed one. The majority of authors agree that emanation does not get into the organism through the skin, but it exclusively gets into the blood through the lungs.

However, others arguing on the grounds of their experience state that if baths are taken for sufficiently long time, considerable emanation is absorbed.

## THE USE OF THE RADIOACTIVE WATERS AT BATH, ENGLAND[1]

It may be of interest to outline the various ways in which the spring waters at Bath are utilized for therapeutic treatment. Bath is the oldest and most famous health resort in the British Isles.

There are three hot springs at Bath:

(1) The King's Spring rises in the King's Bath, which is surrounded by buildings of great historic interest. Radioactive waters are served from a fountain in the famous pump room which is supplied direct from the King's Spring; (2) The Hetling spring which supplies both drinking water and swimming baths in the old Royal or Hetling baths; and (3) the Cross spring which was the fashionable bath of the seventeenth century, when Pepys bathed there.

[1] "Notes on the Therapeutics of Radium in the Bath Waters." Compiled by John Hatton, Director of the Baths.



Since Sir William Ramsay's report on the radioactivity of the Bath waters, showing that they were the most active in Great Britain, the latest methods have been employed to utilize this property.

It has been stated that radioactive waters may be used in three ways:—by inhaling the gases given off from the hot waters; by drinking the water, and by external application in the form of baths. Each one of these methods is employed at Bath.

A Radium Inhalatorium has been opened in which apparatus is installed whereby the radioactive waters of the Hot Springs may be inhaled or used for special sprays in a finely atomized form. The gases from the springs are also supplied in conjunction with the waters. The waters are atomized by steam, air, or by the gases, containing considerable amounts of emanation evolved from the springs.

Nasal sprays and douches, and ear and eye sprays are also given.

The radioactive waters are served for drinking in the grand pump room, and during the summer season at the Colonade fountain in the Institute gardens.

The Queens bath adjoining the grand pump room and the New Royal Baths, afford every convenience for all kinds of baths in the radioactive waters. The high temperature at which the water issues from the springs—49° C. or 120° F.—enables baths and douches to be given without any necessity for artificial heating.

There are deep baths with arrangements for lowering helpless patients into the waters, all kinds of reclining baths, douches, and douche-massage baths, such as are employed at Aix-les-Bains, Plombieres, and other famous European spas.

Besides these, there are large and well appointed swimming baths.

$46.00
Without
Pavement
Replacement

## XIII. LITHIUM CONTENT

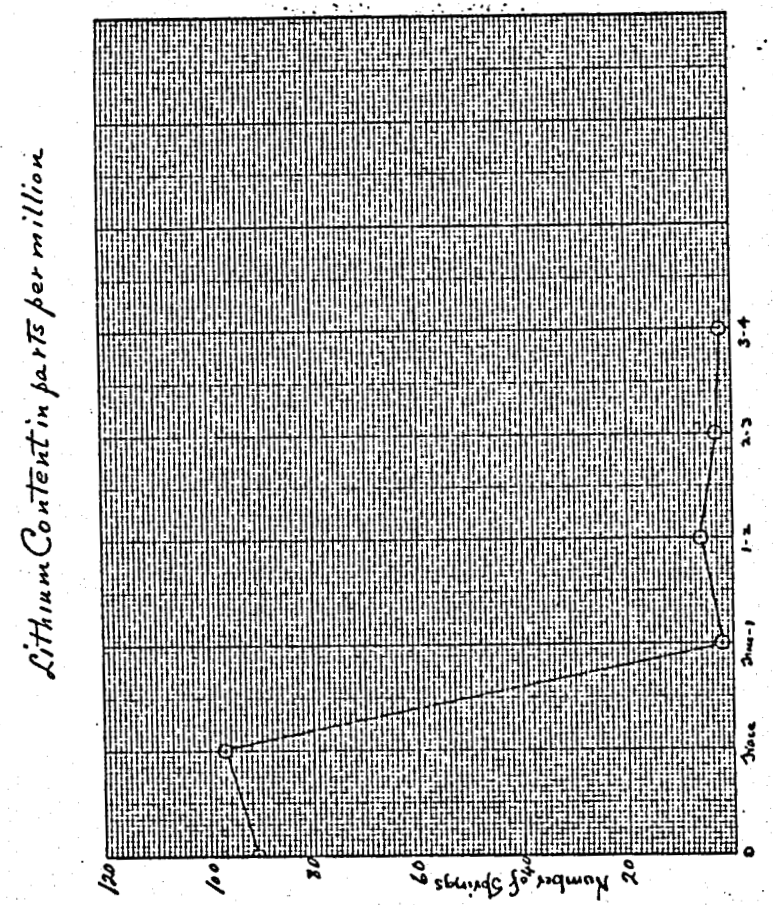
By means of the spectroscope the presence of lithium was noted in 111 of the waters analyzed. In only twelve waters, however, did the lithium spectrum appear bright enough to warrant the separation of the lithium. Since the amount separated amounted, in some cases, to less than one milligram per liter, it is safely assumed that where a trace of lithium is reported the amount present is not more than one milligram per liter.

**LITHIUM CONTENT IN PARTS PER MILLION**

| None | | Trace | | Trace-1 | 1-2 | 2-3 | 3-4 | Not det. |
|---|---|---|---|---|---|---|---|---|
| 2 | 148 | 1 | 123 | 103 | 111 | 160 | 50 | 51 |
| 6 | 149 | 3 | 124 | 106 | 157 | 162 | 165 | 1 |
| 8 | 150 | 4 | 126 | 2 | 163 | 164 | 2 | |
| 11 | 152 | 5 | 127 | | 229 | 3 | | |
| 21 | 153 | 7 | 128 | | 234 | | | |
| 29 | 154 | 9 | 129 | | 235 | | | |
| 30 | 166 | 10 | 130 | | 6 | | | |
| 31 | 167 | 12 | 131 | | | | | |
| 32 | 168 | 13 | 136 | | | | | |
| 33 | 169 | 18 | 141 | | | | | |
| 34 | 170 | 20 | 142 | | | | | |
| 38 | 173 | 21 | 144 | | | | | |
| 40 | 174 | 22 | 145 | | | | | |
| 45 | 175 | 23 | 156 | | | | | |
| 46 | 176 | 27 | 161 | | | | | |
| 52 | 177 | 28 | 171 | | | | | |
| 53 | 178 | 35 | 172 | | | | | |
| 54 | 181 | 36 | 180 | | | | | |
| 55 | 192 | 37 | 182 | | | | | |
| 56 | 193 | 39 | 183 | | | | | |
| 57 | 194 | 41 | 184 | | | | | |
| 58 | 195 | 43 | 185 | | | | | |
| 59 | 197 | 44 | 186 | | | | | |
| 60 | 205 | 65 | 187 | | | | | |
| 61 | 206 | 66 | 188 | | | | | |
| 62 | 207 | 69 | 189 | | | | | |
| 63 | 208 | 70 | 190 | | | | | |
| 67 | 209 | 71 | 191 | | | | | |
| 68 | 210 | 72 | 196 | | | | | |
| 83 | 212 | 73 | 198 | | | | | |
| 85 | 213 | 74 | 199 | | | | | |
| 86 | 214 | 75 | 200 | | | | | |
| 87 | 215 | 78 | 201 | | | | | |
| 96 | 218 | 79 | 202 | | | | | |
| 98 | 227 | 80 | 203 | | | | | |
| 99 | 232 | 81 | 204 | | | | | |
| 102 | 233 | 82 | 211 | | | | | |
| 104 | 238 | 84 | 216 | | | | | |
| 110 | 245 | 97 | 217 | | | | | |
| 115 | 246 | 100 | 219 | | | | | |
| 116 | 252 | 101 | 220 | | | | | |
| 119 | | 105 | 221 | | | | | |
| 120 | 91 | 107 | 222 | | | | | |
| 121 | | 108 | 228 | | | | | |
| 134 | | 109 | 230 | | | | | |
| 135 | | 112 | 236 | | | | | |
| 140 | | 113 | 251 | | | | | |
| 143 | | 117 | | | | | | |
| 146 | | 118 | 97 | | | | | |
| 147 | | 122 | | | | | | |

TABLE XI






Lithium Content. Fig. XI.

## SUMMARY OF GROUPINGS BY NOTABLE FEATURES

| Very Large Flow | High Temperature | High Mineralization | High in Silica | High in Sulphate |
|---|---|---|---|---|
| No. 162, Big Pagosa Spring<br>No. 102, McIntyre Spring<br>No. 45, Big Dotsero Spring<br>No. 29, Ranger's Spring on Cement Creek<br>No. 55, No. 59 } In Glenwood Group<br>No. 212, No. 214, No. 222 } In Steamboat Group<br>No. 53, Rhodes' Spring<br>No. 234, Boiling Spring at Wagon Wheel Gap<br>No. 152, No. 153 } At Orient<br>No. 252, Wellsville<br>No. 146 Hayes Spring | No. 142, Hortense Hot Springs<br>No. 246, No. 245, No. 251, No. 238 } Waunita Group<br>No. 157 at Ouray<br>No. 175, No. 176, No. 177 } Poncha Group<br>No. 162 of Pagosa Group<br>No. 215 of Steamboat Springs | No. 67 at old Colorado Salt Works, So. Park.<br>No. 55, No. 54, No. 58, No. 59, No. 60, No. 61, No. 62, No. 63 } Glenwood Group<br>No. 3, No. 4 } Near Austin<br>No. 45, No. 46 } Near Dotsero<br>No. 65, Hodges Spring | No. 160 of the Pagosa Group<br>No. 171 Scott's Spring<br>No. 199, No. 200, No. 203 } Red Creek Springs<br>No. 251 of the Waunita Group | No. 62, No. 61 } of the Glenwood Group<br>No. 67 at old Colorado Salt Works, So. Park.<br>No. 1, Golden Lithia Water.<br>No. 3, No. 4 } Near Austin |

| High in Bicarbonate | High in Chloride | High in Iron and Aluminum | High in Calcium | High in Magnesium |
|---|---|---|---|---|
| No. 4, No. 3 } Near Austin<br>No. 24 on Grape Creek<br>No. 35, east of Crisman<br>No. 65, Hodges' Spring<br>No. 211, No. 214, No. 216, No. 217, No. 220, No. 221 } In Steamboat Springs Group | No. 67 at old Colorado Salt Works, So. Park.<br>No. 54, No. 55, No. 58, No. 59, No. 60, No. 61, No. 62, No. 63 } In Glenwood Group<br>No. 4, near Austin<br>No. 45, No. 46 } Near Dotsero<br>No. 65, Hodges' Spring<br>No. 166, Strontia Springs | No. 33, Iron Spring near Crested Butte.<br>No. 205, Mineral Creek Spring near Silverton.<br>No. 96, Ironton Park Spring.<br>No. 41, on Soda Creek, near Dillon.<br>No. 157, Pavilion Spring at Ouray. | No. 166, Strontia Spgs.<br>No. 67, old Salt Works<br>No. 130 in the Manitou Group<br>No. 61, No. 62 } In Glenwood Group | No. 24 on Grape Creek<br>No. 62 of the Glenwood Group.<br>No. 65, Hodges' Spring<br>No. 66 near Guffey<br>No. 74 of the Doughty Group.<br>No. 123 of the Manitou Group<br>No. 169 on Plateau Creek<br>No. 171, Scott's Spring |

| High in Alkali Metals | High in Lithium | High in Sulphur | Miscellaneous | |
|---|---|---|---|---|
| No. 54, No. 55, No. 59, No. 61, No. 62, No. 63 } All these in the Glenwood Group<br>No. 67 at the old Colorado Salt Works in So. Park. | No. 50 in Pinkerton Group<br>No. 160, No. 162, No. 163, No. 164 } These four in the Pagosa Group<br>No. 165 at Placerville<br>No. 157 at Ouray<br>No. 111 near Leadville<br>No. 229 near Trimble<br>No. 234, No. 235 } Wagon Wheel Gap. | No. 73—61.0 mg. per L.<br>No. 74—51.1 mg. per L.<br>No. 75—59.3 mg. per L.<br>The above three are all from the Doughty Group.<br>No. 84—61.09 mg. per L. Near Hygiene.<br>No. 105—77.95 mg. per L. Mack Spring. | | |

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*Note*

I wished to comply with the request of Professor Curtis that he be permitted to read the proof of his part of the report, but I regret that the urgency for immediate action in the printing of the report made this impossible.

R. D. GEORGE.

## DURANGO, LA PLATA COUNTY

47-51. These warm springs are on the Pinkerton ranch in the Las Animas Valley, about half way between Trimble and Rockwood. They are west of the wagon road, and are convenient to the Denver and Rio Grande Railway.

The rock formations of the immediate neighborhood are of Paleozoic age, but pre-Cambrian rocks outcrop a short distance to the north. The elevation is about 7,500 feet.

The group includes five large springs and several smaller ones, all issuing from a sandstone formation. The waters of only two of the springs were analyzed, but radioactivity tests were made on those of five springs. The two waters analyzed are similar in most respects, but the north spring contains 20 parts of lithium chloride per million, and in this respect is one of the three highest in the State.

Practically nothing has been done to develop the springs for health or pleasure resort purposes.

## ELDORADO SPRINGS, BOULDER COUNTY

52. There are several cold springs and one warm spring which is weakly mineralized. The rocks are the upturned sandstones and shales of the Carboniferous formations. The warm spring has a flow of about 12 gallons per minute. The waters are used in a large swimming pool. The springs are developed by a good hotel, swimming pools, bath houses, pleasure ground and cottages.

## FAIRPLAY, PARK COUNTY

53. *Warm Spring.* South and southwest of the town of Fairplay, Park County, there stretches a broad alluvial area on both sides of Fourmile Creek, a tributary of the South Platte. The surface of the alluvial plain is somewhat hilly and in places is cut by ravines. The spring comes from a side hill in a small gulch. The flow is estimated at 250 to 300 gallons per minute. The water is but weakly mineralized, and has a temperature of 79° F.

## GLENWOOD SPRINGS, GARFIELD COUNTY

54-64. The Glenwood Springs are located toward the eastern end of Garfield County on both sides of the Grand River, both above and below the mouth of Roaring Fork. They are among the most highly mineralized waters of the State, and are well charged with gases. Carbon dioxide occurs in considerable excess and hydrogen sulphide is present in all the spring waters. The temperatures of

## NUMBER 47

### PINKERTON SPRINGS—N. W. PINKERTON SPRING

Location—On Pinkerton Ranch, 4½ miles north of Trimble.

#### Radioactivity

Curies Ra Emanation per liter x $10^{-10}$, Water, 0.73.

Mache Units per liter, Water, 0.2.

## NUMBER 48

### PINKERTON SPRINGS, POOL SPRING

Location—Durango.

#### Radioactivity

Curies Ra Emanation per liter x $10^{-10}$, Water, 0.27.

Mache Units per liter, Water, 0.07.

## NUMBER 49

### PINKERTON SPRINGS, CEDAR SPRING

Location—Durango.

#### Radioactivity

Curies Ra Emanation per liter x $10^{-10}$, Water, 10.10.

Mache units per liter, Water, 2.73.



## NUMBER 50

### NORTH PINKERTON SPRING

Location—Between Trimble and Rockwood.

Rate of Flow—4 to 8 and 7 to 8 gal. per min. Temperature—87° F.

Class of Water—Sodic, calcic, bicarbonated, muriated, alkaline-saline, lithic, (carbondioxated).

| Constituents | Formula | Milligrams per liter Approximately parts per million | Reacting value percentage |
|---|---|---|---|
| Silica | $SiO_2$ | 35.3 | ..... |
| Sulphate | $SO_4$ | 634.3 | 10.80 |
| Bicarbonate | $HCO_3$ | 1310.4 | 17.60 |
| Carbonate | $CO_3$ | None | ..... |
| Phosphate | $PO_4$ | Trace | ..... |
| Chloride | Cl | 935.8 | 21.60 |
| Iron | Fe | ..... | ..... |
| Aluminum | Al | ..... | ..... |
| Iron oxide | $Fe_2O_3$ | Trace | ..... |
| Aluminum oxide | $Al_2O_3$ | | |
| Manganese | Mn | None | ..... |
| Calcium | Ca | 537.5 | 21.94 |
| Magnesium | Mg | 37.2 | 2.51 |
| Potassium | K | 120 | 2.51 |
| Sodium | Na | 636.1 | 22.64 |
| Lithium | Li | 3.4 | .40 |
| | Total | 4250.0 | 100.00 |

| | | | |
|---|---|---|---|
| Concentration value | 122.20 | Excess carbon dioxide | 472.5 |
| Hydrogen sulphide, $H_2S$ | None | Iron precipitated | Trace |
| Arsenic, As | ..... | Evaporation solids | 3829 |
| Strontium, Sr | ..... | Oxygen consuming capacity | 4.68 |

#### Hypothetical Combinations

Milligrams per liter, approximately parts per million

| | | | |
|---|---|---|---|
| Lith. chlor., LiCl | 20.4 | Calc. bicarb., $Ca(HCO_3)_2$ | 1741.0 |
| Pot. chlor., KCl | 228.8 | Iron and aluminum oxides, $Fe_2O_3$, $Al_2O_3$ | ..... |
| Sod. chlor., NaCl | 1335.4 | Calc. silicate, $CaSiO_3$ | ..... |
| Sod. sulph., $Na_2SO_4$ | 341.8 | Silica, $SiO_2$ | 35.3 |
| Mag. sulph., $MgSO_4$ | 184.2 | Mang. oxide, $Mn_2O_4$ | ..... |
| Calc. sulph., $CaSO_4$ | 363.1 | Mag. bicarb., $Mg(HCO_3)_2$ | ..... |
| Calc. carb., $CaCO_3$ | ..... | Sod. bicarb., $NaHCO_3$ | ..... |
| Ferrous bicarb., $Fe(HCO_3)_2$ | ..... | | |
| Total | | | 4250.0 |

#### Properties of Reaction in Per Cent

| | | | |
|---|---|---|---|
| Primary salinity | 51.10 | Primary alkalinity | ..... |
| Secondary salinity | 13.70 | Secondary alkalinity | 35.20 |
| Tertiary salinity | ..... | Tertiary alkalinity | ..... |

## NUMBER 51

## SOUTHEAST PINKERTON SPRING

Location—Durango.

Rate of Flow—3 gal. per minute. Temperature—.....

Class of Water—Sodic, calcic, bicarbonated, muriated, sulphated, alkaline-saline, ferruginous, carbondioxated.

| Constituents | Formula | Milligrams per liter Approximately parts per million | Reacting value percentage |
|---|---|---|---|
| Silica | $SiO_2$ | 38.0 | ..... |
| Sulphate | $SO_4$ | 638.2 | 11.08 |
| Bicarbonate | $HCO_3$ | 1200 | 16.40 |
| Carbonate | $CO_3$ | None | ..... |
| Phosphate | $PO_4$ | Trace | ..... |
| Chloride | Cl | 957.6 | 22.52 |
| Iron | Fe | ..... | .29 |
| Aluminum | Al | ..... | ..... |
| Iron oxide | $Fe_2O_3$ | 14.1 | ..... |
| Aluminum oxide | $Al_2O_3$ | | |
| Manganese | Mn | None | ..... |
| Calcium | Ca | 488.2 | 20.34 |
| Magnesium | Mg | 36.6 | 2.51 |
| Potassium | K | 80 | 1.71 |
| Sodium | Na | 694.5 | 25.15 |
| Lithium | Li | Not run | ..... |
| | | 4147.2 | 100.00 |
| Oxygen in $Fe_2O_3$ | | 4.2 | |
| | Total | 4143.0 | |

| | | | |
|---|---|---|---|
| Concentration value | 120.00 | Excess carbon dioxide | 432.7 |
| Hydrogen sulphide, $H_2S$ | None | Iron precipitated | Trace |
| Arsenic, As | ..... | Evaporation solids | 3786 |
| Strontium, Sr | ..... | Oxygen consuming capacity | 2.14 |

### Hypothetical Combinations

Milligrams per liter, approximately parts per million

| | | | |
|---|---|---|---|
| Lith. chlor., LiCl | .... | Calc. bicarb., $Ca(HCO_3)_2$ | 1243.4 |
| Pot. chlor., KCl | 152.6 | Iron and alum. oxides, $Fe_2O_3$, $Al_2O_3$ | .... |
| Sod. chlor., NaCl | 1459.0 | Calc. silicate, $CaSiO_3$ | .... |
| Sod. sulph., $Na_2SO_4$ | 89.6 | Silica, $SiO_2$ | 38.0 |
| Mag. sulph., $MgSO_4$ | 181.2 | Mang. oxide, $Mn_3O_4$ | .... |
| Calc. sulph., $CaSO_4$ | 613.7 | Mag. bicarb., $Mg(HCO_3)_2$ | ..... |
| Calc. carb., $CaCO_3$ | ..... | Sod. bicarb., $NaHCO_3$ | 334.1 |
| Ferrous bicarb., $Fe(HCO_3)_2$ | 31.4 | | |
| Total | | | 4143.0 |

### Properties of Reaction in Per Cent

| | | | |
|---|---|---|---|
| Primary salinity | 53.72 | Primary alkalinity | .... |
| Secondary salinity | 13.48 | Secondary alkalinity | 32.22 |
| Tertiary salinity | .... | Tertiary alkalinity | .58 |

Vagosa Preliminary

Before discussing the preliminary design, it would be worthwhile to point out the major differences between the original proposal and the current design. These differences are the major reasons for the increase in estimated cost of the heating system. These have also created several problems which were not anticipated at the start.

1) Originally it had been planned that existing wells and the new well drilled by the Colorado Geological Survey would be used in the heating system. Several factors have combined to eliminate this possibility. The first well drilled by the Colorado Geological Survey, O-2, produces geothermal water at about 120°F which is too cool for practical use. Additionally, this well has developed a significant leak due to what appears to be problems in completion; if it were to be used, the cost of repairs would have to be determined. The second well, P-1, drilled by the State, produces small quantities of cool water, at 112°F, and is therefore also impractical for the proposed heating system. It may be possible to perforate this well at a depth closer to the surface, to produce water at a sufficient flow rate and temperature; the cost of this operation is being investigated. The existing County Courthouse well produces water at 140°F, which is of high enough temperature; however, the limited flow rate of 250 gpm is insufficient. The other wells available for use are of questionable value due to their extended age and their uncertain physical condition, and due to a lack of knowledge as to the producing zone within which they are completed. Therefore, a new hot water well or wells may be required.

2) The original proposal had called for the direct utilization of the geothermal fluids for the heating medium. However, the decision was made by the advisory committee that a clean circulating fluid

should be used. Thus a close loop heating system has been designed utilizing supplementary heat exchange equipment. This equipment was not expected to be necessary when the proposal was prepared and its costs were not included.

3) The number of users has increased significantly and the heating load for the system has very close to doubled. Thus the pipeline size has increased to accommodate the additional flow. Table 1 shows the differences in number of users, design flow rate, and annual heat load between the proposal and the present design. For reference purposes, Tables 2, 3, and 4 have been included to document the flow requirements of all users.

The increase in cost of the project is due primarily ~~with~~ the decision to go with a closed loop heating system and the significant number of new users. Additionally, the wells drilled by the Colorado Geological Survey and those available to project are insufficient for the system needs.

The additional costs can be attributed to the need for heat exchange equipment and new geothermal production wells. However, these costs are partially offset by the money originally allocated for a reinjection well and the reduction in the cost estimate for the pipeline. The following table shows the cost breakdown from the original proposal and current design.

Cost Breakdown for the Project

| | Proposal | Current Design |
|---|---|---|
| Pipeline | $399,000 | $334,100* |
| Injection Well | 95,000 | -0- |
| Production Well | -0- | 80,000 |
| Pumps and Instrumentation | 49,800 | 50,000 |
| Heat Exchange Equipment | -0- | 121,000 |
| | $543,800 | $585,100 |

* The current design is based on using an uninsulated return line as opposed to an insulated line as planned in the proposal.

It should be pointed out that only $547,000 has been allocated by DOE for the construction of this portion of the project. It is possible to reduce the above costs in several areas which may prove acceptable. For instance, the heat exchanger cost given is based on the design flow rate of 1800 gpm needed in the future; this cost can be reduced to $73,500 if the design flow rate is reduced to the 1000 gpm that is expected to be needed for the first years. Then, the additional heat exchangers could be purchased as needed. In the same manner, the $80,000 estimated cost for the production well is based on future needs; a savings of between $20,000 to $40,000 could be obtained if only the necessary production wells are drilled at this time.

Table 1. Differences Between Proposal And Present Design

NUMBER OF USERS

| | Proposal | Present Design |
|---|---|---|
| Public Buildings | 12 | 10 |
| Businesses | 22 | 54 |
| Residential | 23 | 63 |

DESIGN FLOW RATE IN GALLONS PER MINUTE Peak Design

| | Proposal | Present Design |
|---|---|---|
| Public Buildings | 392 | 379 |
| Businesses | 372 | 1055* |
| Residential | 138 | 378 |
| TOTALS | 902 | 1812 |

* Includes an additional 100 gpm not accounted for in survey

ANNUAL HEAT LOAD IN $10^6$ BTU/YR

| | Proposal | Present Design |
|---|---|---|
| Public Buildings | 12,400 | 11,900 |
| Businesses | 11,900 | 33,000 |
| Residential | 4,300 | 11,800 |
| TOTALS | 28,600 | 56,700 |

Table 2.

HEATING LOAD FOR PUBLIC BUILDINGS

| Business | Code No. on Map | Proposal: Annual Heat Load $10^6$ Btu/yr | Proposal: Average Flow Rate GPM | Proposal: Peak Flow Rate GPM | New Estimate: Annual Heat Load $10^6$ Btu/yr | New Estimate: Average Flow Rate GPM | New Estimate: Peak Flow Rate GPM | Comments |
|---|---|---|---|---|---|---|---|---|
| Museum | 10 | 93 | .85 | 3.0 | 313 | 2.9 | 10 | |
| Forest Service | 25,34 | 486 | 4.5 | 13.5 | 663 | 6 | 21 | Two buildings: different heating costs from first time |
| Jr. High School<br>Sr. High School<br>Elementary<br>Bus Garage | 92,93<br>94<br><br>157 | 6363 | 58.0 | 203.0 | 6669 | 61 | 213 | |
| Courthouse | 132 | 256 | 2.3 | 8.0 | 2661 | 24.3 | 85 | Old figure was for only 12% of building heating |
| Town Hall | 112 | 617 | 5.6 | 19.6 | 626 | 5.7 | 20 | |
| Housing Corp. | - | 3227 | 29.4 | 102.9 | | | | Not now included |
| County Shop | 145 | 672 | 6.1 | 21.35 | 939 | 8.6 | 30 | |
| Town Shop | - | 652 | 5.9 | 20.65 | | | | Not now included |
| TOTALS | | 12,366 | 112.65 | 392.0 | 11,871 | 108.5 | 379 | |

Table 3

BUSINESSES ON ORIGINAL PROPOSAL

| Business | Code No. on Map | Proposal Annual Heat Load $10^6$ Btu/yr | Proposal Average Flow Rate GPM | Proposal Peak Flow Rate GPM | New Estimate Annual Heat Load $10^6$ Btu/yr | New Estimate Average Flow Rate GPM | New Estimate Peak Flow Rate GPM | Comments |
|---|---|---|---|---|---|---|---|---|
| Silver Dollar | 4 | 89 | .81 | 2.8 | 125 | 1.14 | 4 | |
| J's Mart | 6 | 244 | 2.2 | 7.7 | 1001 | 9.1 | 32 | |
| Circle K | 1 | 159 | 1.5 | 5.25 | 159 | 1.4 | 5 | |
| Al's Cafe | 8 | 75 | .7 | 2.45 | 313 | 2.86 | 10 | |
| San Juan Motel | 2 | 3181 | 29.0 | 101.5 | 2348 | 21.4 | 75 | |
| Dr. Davis | 26 | 318 | 2.9 | 10.1 | 188 | 1.71 | 6 | |
| Jo Ge's | 27 | 222 | 2.0 | 7.0 | 94 | 0.86 | 3 | |
| Harvey's Motel | 28-30 | 909 | 8.3 | 29.0 | 1315 | 12 | 42 | |
| Pioneer West | 31 | 91 | .83 | 2.9 | 94 | 0.86 | 3 | |
| Trading Post | 32 | 44 | .41 | 1.4 | 125 | 1.14 | 4 | |
| Solar Mall | 33 | 227 | 2.07 | 7.2 | 1722 | 15.7 | 55 | |
| United Farm | 64 | 125 | 1.14 | 4.0 | 188 | 1.71 | 6 | |
| Goodmans | 95 | 409 | 3.73 | 13.1 | 470 | 4.3 | 15 | |
| Jackish Drugs | 125 | 227 | 2.07 | 7.2 | | | | |
| Total Sports | 119 | 333 | 3.03 | 10.6 | 940 | 8.6 | 30 | |
| La Canting | 118 | 363 | 3.31 | 11.6 | 282 | 2.6 | 9 | |
| Universal Phone | 105 | 227 | 2.07 | 7.25 | | | | |
| Methodist Church | 158 | | | | 782 | 7.1 | 25 | |
| Alley's | 160 | 181 | 1.65 | 5.8 | 188 | 1.7 | 6 | |
| Johnson Chevrolet | 136 | 1818 | 16.6 | 58.1 | 2473 | 22.6 | 79 | |
| Gambles & Groc. | 137 | 1363 | 12.4 | 43.4 | 1566 | 14.3 | 50 | |
| Conoco Service Station | 142 | 327 | 3.0 | 10.5 | 1753 | 16 | 56 | |
| Pagosa Hotel Bldg. | | 545 | 4.97 | 8.47 | | | | |
| Spa Motel | | 444 | 4.05 | 14.2 | | | | |
| TOTALS | | 11,921 | 108.74 | 372.0 | 16,126 | 147 | 515 | |

Table 4

BUSINESSES NOT INCLUDED ON PROPOSAL SURVEY

| Business | Code No. on Map | Annual Heat Load $10^6$ Btu/yr | Flow Rate (GPM) Average | Flow Rate (GPM) Peak |
|---|---|---|---|---|
| Griffits | 3, 5 | | | |
| River Center | 7 | | | |
| Colo. Can Sports | 9 | | | |
| San Juan Chevron | 18 | 391 | 3.4 | 12 |
| New Horizon Book | 22 | 187 | 1.71 | 6 |
| Biggins | 23 | 187 | 1.71 | 6 |
| Pagosa Lodge, Masons | 38 | 341 | 3.11 | 11 |
| Church of Christ | 45 | | | |
| Bakery | 51 | 778 | 7.1 | 25 |
| Larson Law Office | 96 | 187 | 1.71 | 6 |
| Roys Hair Care | 104 | 187 | 1.71 | 6 |
| Mortuary | 106 | 187 | 1.71 | 6 |
| Parish Hall | 107 | | | |
| Rectory | 108 | 1001 | 9.14 | 32 |
| Catholic Church | 109 | | | |
| Natural Gas Office | 110 | 125 | 1.14 | 4 |
| Adobe | 111 | 1589 | 14.5 | 51 |
| Bank | 114 | 137 | 1.25 | 5 |
| Pagosa Bar | 117 | 313 | 2.86 | 10 |
| Barber Shop | 120 | 156 | 1.43 | 5 |
| TV Repair | 121 | 150 | 1.43 | 5 |
| Montoya | 122 | 498 | 4.5 | 16 |
| Hardware | 124 | | | |
| Lester Building (Pagosa Hotel) | 126 | 1941 | 17.1 | 62 |
| Sears | 128 | 150 | 1.4 | 5 |
| Hub | 130 | 471 | 4.3 | 15 |
| Mesa Verde | 131 | 471 | 4.3 | 15 |
| Poma Building | 135 | 939 | 8.6 | 30 |
| Taxidermy | 141 | 142 | 1.3 | 5 |
| Pagosa Plaza | 146 | 2504 | 22.85 | 80 |
| Middle Earth Deli | 140 | 219 | 2 | 7 |
| Post Office | 103 | 470 | 4.3 | 15 |
| TOTALS | | 13,721 | 124.56 | 440 |

# PRELIMINARY DESIGN, PAGOSA SPRINGS GEOTHERMAL PROJECT

## General

For the proposed closed distribution system, two independent loops have been identified. These are shown in Figure 1. The first loop is to eventually carry 500 GPM and will extend west from the Courthouse, in an existing easement, to the Elementary School. The second loop will eventually carry 1300 GPM east from the Courthouse. This line will be ~~south~~ north of Pagosa Street in an existing easement in the alley. At the Museum the line will turn south and cross Highway U.S. 160, where it will branch into a line about 700 feet long heading west and a line about 1,400 feet long heading east.

## Pipe

Two types of pipe have been considered. The first is an asbestos-cement (A-C) type pipe and the second is a fiberglass type pipe. The estimated purchase costs of each are as follows:

| Diameter | Insulated | Uninsulated |
|---|---|---|
| **Asbestos-Cement** | | |
| 6-inch | $ 9.21/LF | $3.00/LF |
| 8-inch | $14.23/LF | $4.00/LF |
| 10-inch | $18.25/LF | $6.00/LF |
| 12-inch | $24.33/LF | $8.50/LF |
| **Fiberglass** | | |
| 6-inch | $11.27/LF | $4.37/LF |
| 8-inch | $17.77/LF | $8.31?LF |
| 10-inch | $24.71/LF | $11.27/LF |
| 12-inch | $30.59/LF | $14.58/LF |

The lengths and diameters required for each loop, which are designed to allow for future expansion of the system, are as follows:

| | | |
|---|---|---|
| **West Loop** | | |
| 10-inch | 1,650 feet | 1,650 feet |
| 8-inch | 1,000 feet | 1,000 feet |
| **East Loop** | | |
| 12-inch | 1,000 feet | 1,000 feet |
| 10-inch | 2,850 feet | 2,850 feet |
| 8-inch | 200 feet | 200 feet |
| 6-inch | 2,100 feet | 2,100 feet. |

Figure 1

FIGU

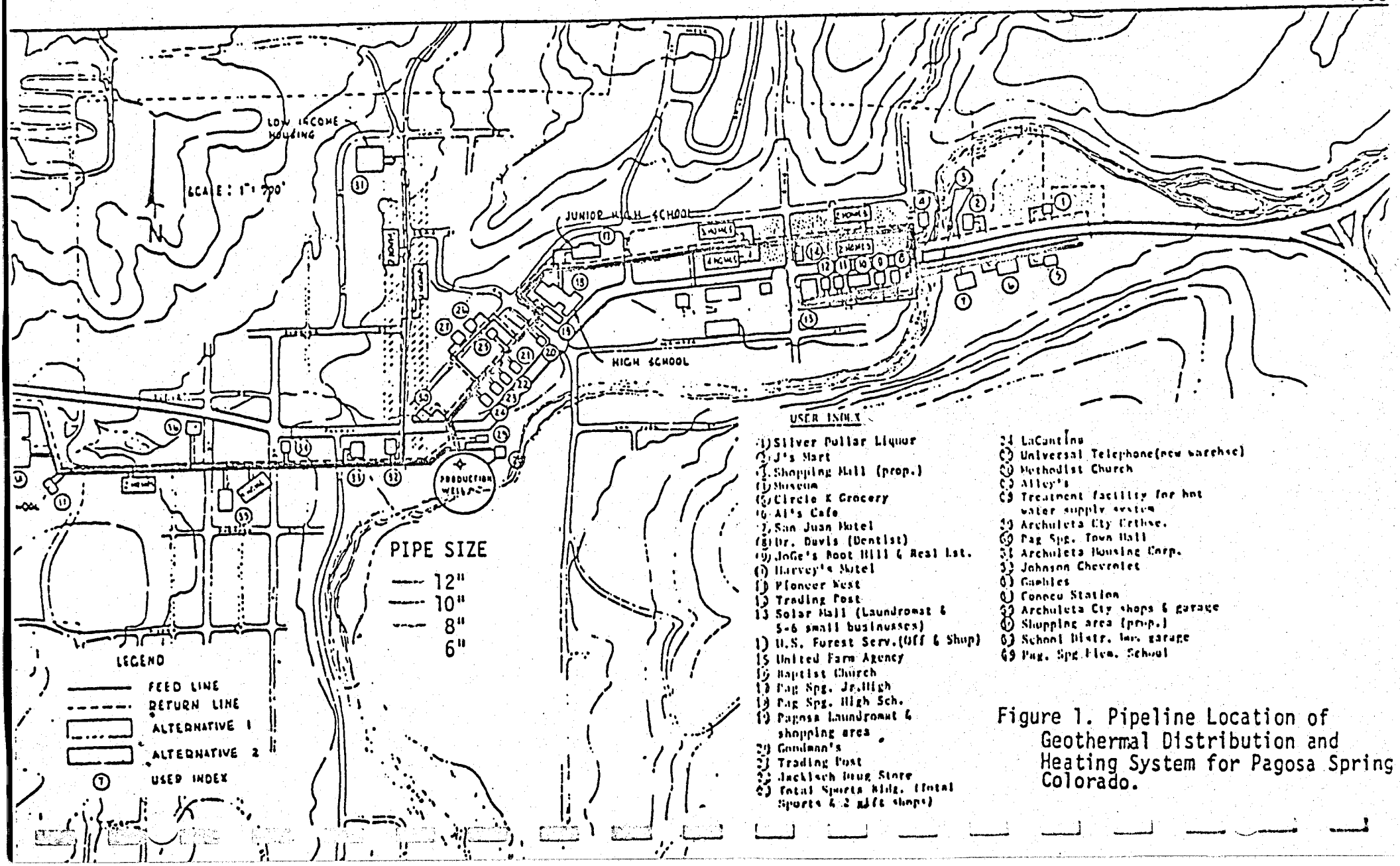


Figure 1. Pipeline Location of Geothermal Distribution and Heating System for Pagosa Spring Colorado.

Based on insulating only the hot line, and leaving the return line uninsulated, the total cost of the asbestos-cement type pipe would be about $190,000 and the cost of the fiberglass type pipe would be about $270,000.

The insulated pipe is an A-C pipe lined with a smooth epoxy core, all of which is surrounded by polyurethane foam and encased in a larger A-C pipe. Information, provided by Johns-Manville, indicates the pipe will be acceptable for meeting the permissible temperature loss criteria.

The pipe installation would consist of laying the supply and return line, separated by about a foot, in the same trench. The pipe need only be buried 2 to 3 feet deep. Anticipated installation costs could be expected to be about 75 percent of the pipe cost. This cost for the A-C type pipe could be about $140,000.

The following assumptions were made in calculating the heat loss through the pipeline for the design case:

| | |
|---|---|
| Soil temperature: | 20°F |
| Soil conductivity: | 12 Btu/hr-in |
| Return and supply pipe separation: | 1 foot |
| Supply temperature: | 137°F |
| Return temperature | 110°F |

The following is the heat loss with these assumptions. These assumptions would have to be considered worst case; therefore the heat loss will in all probability be less. These values are for the concrete asbestos; the fiberglass values would be comparable.

Concrete-Asbestos Pipe

| Pipe Diameter | Insulated (Supply) | Uninsulated (Return) |
|---|---|---|
| 6-inch | 24 Btu/hr/ft | 138 Btu/hr/ft |
| 8-inch | 23 Btu/hr/ft | 154 Btu/hr/ft |
| 10-inch | 33 Btu/hr/ft | 162 Btu/hr/ft |
| 20-inch | 42 Btu/hr/ft | 171 Btu/hr/ft |

## Fiberglass Pipe

| Pipe Diameter | Insulated Supply | Insulated Return |
|---|---|---|
| 6-inch | 29 Btu/hr/ft | 21 Btu/hr/ft |
| 8-inch | 28 Btu/hr/ft | 20 Btu/hr/ft |
| 10-inch | 41 Btu/hr/ft | 29 Btu/hr/ft |
| 12-inch | 51 Btu/hr/ft | 36 Btu/hr/ft |

The conclusions reached from utilizing these values indicate that the supply temperature will drop less than $1^{o}F$. However, the temperature of water in the return portion of the pipeline could be lowered by $6^{o}F$ if an uninsulated pipe is used. If the return pipe is insulated, the temperature loss is less than $1^{o}F$.

The potential heat saving by insulating the return pipeline is $11.200 \times 10^{6}$ Btu/yr, equivalent to 20 percent of the entire heat load of the system. If this heat could be utilized it would be valued at over $24,000/year. The real potential benefit in insulating the return pipeline, however, will be in the conservation of the geothermal resource, since the annual flow rate from the geothermal reservoir could then be reduced by 10 to 20 percent. The exact value of the change in the reservoir flow rate will be dependent upon the pumping scheme and the heat exchange equipment.

## Pumps

Total maximum flow of water in the full-size system is anticipated to be 1800 GPM. One set of pumps servicing both loops could be used. There should be a standby pump to allow for some maintenance flexibility. Three 900 GPM pumps could be used with one or two operating as needed and the third one as a standby. For more pumping flexibility, four 600 GPM pumps could be used with up to three operating simultaneously and the remaining one to be used for standby.

Preliminary analysis indicates that the required pumping head will be about 120 feet. Typical pump purchase costs, including motors, would be:

4-600 GPM - 30 H.P. @ $1,500/each = $6,000
3-900 GPM - 40 H.P. @ $1,800/each = $5,400

Pump controls will also be required. The simplest control would be a set of limit switches to turn the pumps on or off as required by the demand.

Variable speed pumps would provide some advantages, but have not been thoroughly examined. However, they will require a more costly and sophisticated control system.

## System Operation

Briefly, the system will operate as follows: Figure 2 is a schematic diagram of the system.

A. Clean water in the closed loop will be heated by geothermal water, via the heat exchangers. The geothermal water will be discharged into the river after it leaves the heat exchanger.

B. The clean water will be continuously circulated in the loop, by means of the pumps. The amount being circulated is determined by demand.

C. At the terminal point of the supply line, a pressure drop will be induced, creating a pressure differential between supply and return line.

D. The users will have a thermostatically controlled solenoid valve in line with their unit inside of their own buildings.

E. The pressure drop between the supply and return line will allow a constant flow through the user's system. A small, manually operated globe valve could control the rate of flow to each user, or a more costly flow regulator could be placed in the user's line.

F. A meter in the line would record usage and serve as a basis for billing. Figure 3 is a schematic diagram of the anticipated control and metering of the geothermal fluid. The cost of this method is shown in Table 6.

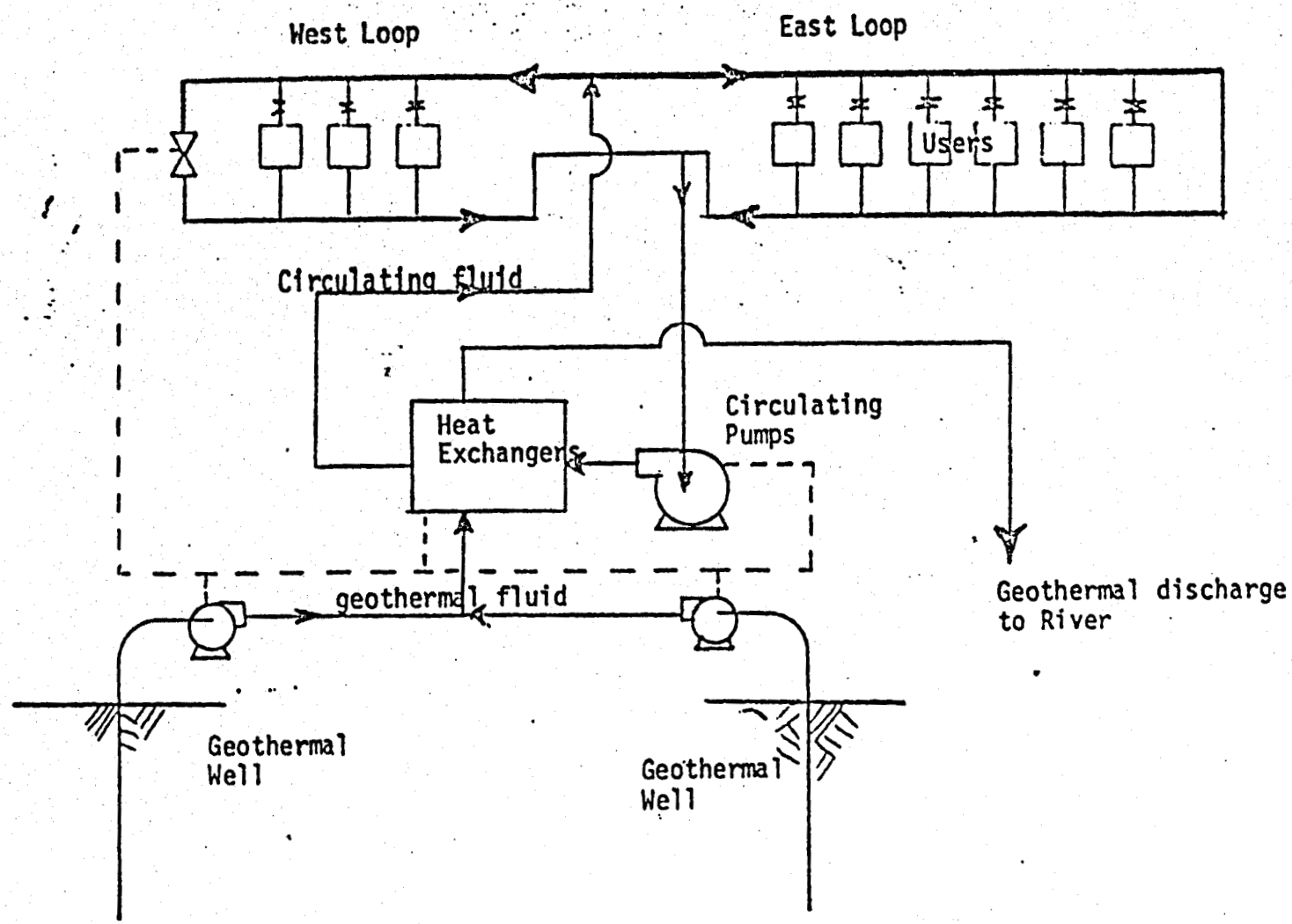


Figure 2. Schematic Diagram of Heating System

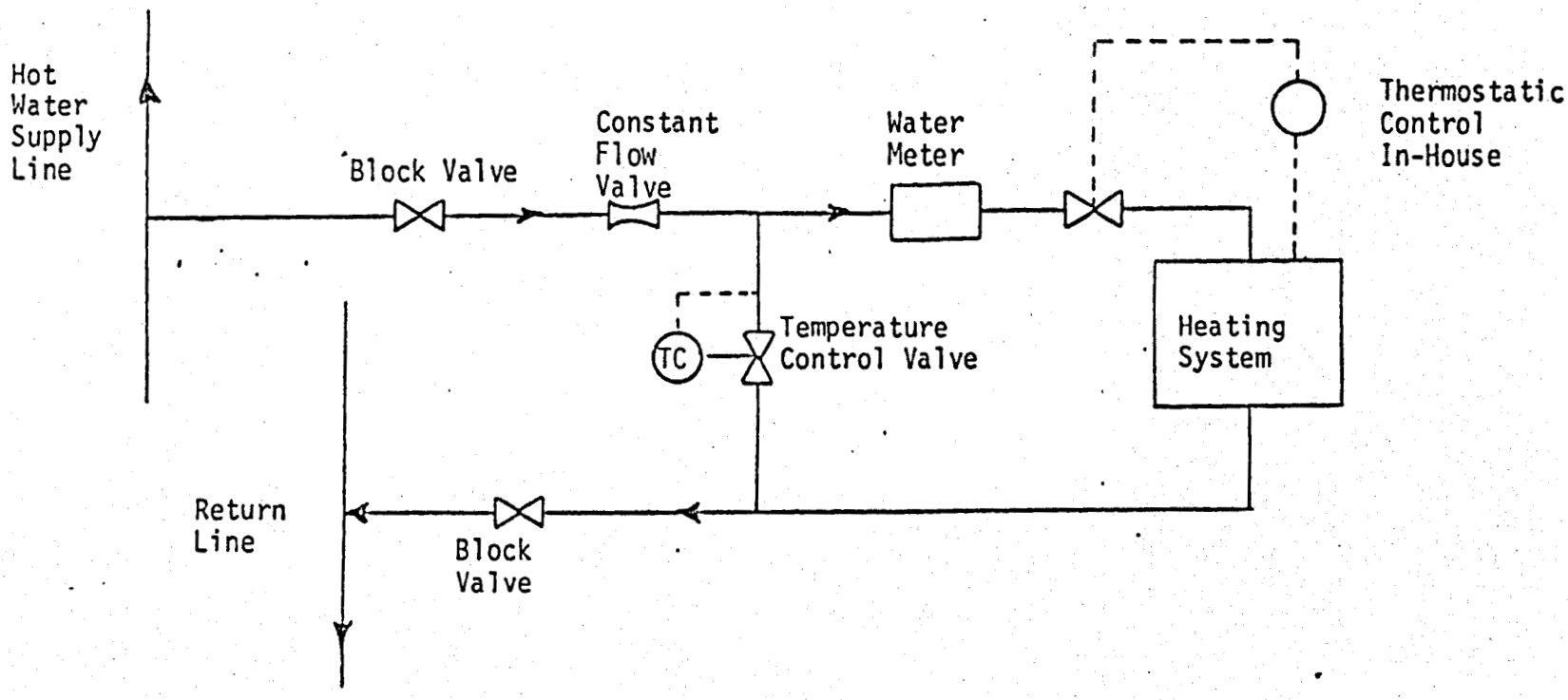


Figure 3. Schematic Diagram of Flow Metering System

Table 6

Estimated Cost of Metering System and ~~Tap Fee~~ Service Lines

| Item | Cost | |
|---|---|---|
| Block Valve | $ 28.00 | |
| Constant Flow Valve | 33.00 | |
| Temperature Control Valve | 75.00 | |
| Water Meter | 60.00 | |
| Thermostatic Control* | -0- | |
| Block Valve | 28.00 | |
| | | $224.00 |
| Piping to and From House, 140'** | 210.00 | |
| Trenching | 200.00 | |
| | | $410.00 |
| Total Costs | | $634.00 |

* This item and associated shutoff valve will be part of the individual heating system.

** 1-inch Copper Pipe @ $1.51/ft.

would have to add labor for installing meters

RETROFITTING REQUIREMENTS FOR RESIDENCES

There are four basic approaches, outlined below, for retrofitting the private residences. The particular heating system to be used will be determined on an individual basis. The estimated retrofitting cost for each heating scheme is also presented. The costs presented exclude the cost for flow control and metering requirements.

1. Heating coil in existing forced-air system

| | | |
|---|---|---|
| Coil cost | $170 | |
| Piping | 50 | |
| Thermostatic Control | 100 | |
| Labor | 200 | |
| TOTAL | $520 | |

2. Baseboard Radiators

These designs for 1500 ft² bldg.

| | | |
|---|---|---|
| Radiator cost | $2220 | $9.58/ft X 232 ft |
| Piping | 50 | |
| Thermostatic Control | 100 | |
| Labor | 700 | |
| TOTAL | $3070 | |

3. Cabinet Convector

| | | |
|---|---|---|
| Heating Units | $1850 | |
| Piping | 150 | |
| Thermostatic Control | 100 | |
| Labor | 800 | |
| TOTAL | $2900 | |

4. Installation of new Forced-Air Heating System

| | | |
|---|---|---|
| Heating system | | |
| Materials and labor | $1200 | $1/ft$^2$ |
| Piping | 50 | |
| Thermostatic Controls | 100 | |
| Heating Cost | 170 | |
| TOTAL | $1520 | |

| PIPE DIAMETER IN | FLUID TEMP. °F °F | INSULATION INSTALLED (YES/NO) | HEAT LOSS JM BTU/HR-FT (1) | HEAT LOSS $S_c$ BTU/HR-FT (2) | PIPE LENGTH FT | ANNUAL LOSS MMBTU (3) | ENERGY SAVED MMBTU | INSULATION COST $ | SIR (4) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 112 | NO | 142 | 182 | 2100 | 2547 | 2239 | 13,041 | 10.0 |
| 6 | 112 | YES | 22 | ... | 2100 | 308 | | | |
| 6 | 137 | NO | ... | 231 | 2100 | 3457 | 3024 | 13,041 | 13.5 |
| 6 | 137 | YES | 29 | ... | 2100 | 433 | | | |
| 8 | 112 | NO | 158 | 200 | 1200 | 1601 | 1433 | 12,276 | 6.8 |
| 8 | 112 | YES | 21 | ... | 1200 | 168 | | | |
| 8 | 137 | NO | ... | 255 | 1200 | 2173 | 1934 | 12,276 | 9.2 |
| 8 | 137 | YES | 28 | ... | 1200 | 239 | | | |
| 10 | 112 | NO | 167 | 217 | 4500 | 6512 | 5612 | 55,125 | 5.9 |
| 10 | 112 | YES | 30 | ... | 4500 | 900 | | | |
| 10 | 137 | NO | ... | 276 | 4500 | 8838 | 7529 | 55,125 | 7.8 |
| 10 | 137 | YES | 41 | ... | 4500 | 1309 | | | |
| 12 | 112 | NO | 176 | 233 | 1000 | 1555 | 1308 | 15,830 | 4.8 |
| 12 | 112 | YES | 37 | ... | 1000 | 247 | | | |
| 12 | 137 | NO | ... | 297 | 1000 | 2110 | 1748 | 15,830 | 6.4 |
| 12 | 137 | YES | 51 | ... | 1000 | 362 | | | |

(1) Conditions as presented in preliminary plan

(2) Same conditions as (1). Computed from shape factor S = 2 x Pi / (arccosh(2 x Depth / Diameter))

(3) Uses annual average temperature of 42 °F

(4) Computed per NBS BSS 113 using natural gas as the displaced fossil fuel @ $3.85/MMBTU delivered and a discount rate of 10% along with a fuel escalation rate of 7%. Other costs as stated

CONCLUSION: PIPING TO BE INSULATED SHOULD BE 6" SUPPLY AND RETURN ALONG WITH 8" and 10" SUPPLIES FOR A COST OF $93483 AND AN ANNUAL SAVINGS OF 14726 MMBTU

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## ACKNOWLEDGMENTS

Many thanks to those residents, officials and business people of Durango, Glenwood Springs, Idaho Springs and Ouray, who so willingly provided information for this report. Although they were so numerous as to preclude naming them all here, their help is most appreciated. We hope that the report accurately reflects the conditions and goals at the four sites. If it does, it is primarily because of the assistance or the help of the people in those areas, who know it best.

## INTRODUCTION

The State of Colorado seems to have significant geothermal energy potential. Geothermal energy use can help conserve other resources.

In order to more accurately define what the geothermal potential is, a detailed analysis of specific sites was considered to be necessary. Furthermore, such analyses can provide ideas and information to potential users, developers and others in the development process to help stimulate geothermal development. Additionally, geothermal energy offers opportunities for economic development, particularly as energy becomes an ever larger and more important part of businesses' operating costs. The analyses can also help identify constraints to geothermal energy development and subsequently suggest solutions. Finally, information about the potential and the limitations to development can help federal and state governments design and implement programs that help increase goethermal energy use.

### Scope of Report

This study, conducted by the Colorado Geological Survey under contract with the U.S. Department of Energy, has analyzed the potential of four prospective geothermal development sites in Colorado and prepared hypothetical plans for their development. These plans are certainly not the only possible ones, but are meant to serve primarily as examples. Since these plans have, however, been prepared using information and ideas derived largely from residents and officials at those sites, as well as published reports, it is believed they are reasonably realistic and in tune with local conditions.

The study has included the investigation of several broad areas for each site. The first area of investigation was the site itself: its geographic, population, economic, energy demand characteristics and the attitudes of its residents relative to geothermal development potential. Secondly, the resource potential was described, to the extent it was known, along with information concerning any exploration or development that has been conducted. The third item investigated was the process required for development. There are financial, institutional, environmental, technological and economic criteria for development that must be known in order to realistically gauge the possible development. Using that information, the next concern, the geothermal energy potential, was then addressed. Planned, proposed and potential development are all described, along with a possible schedule for that development. An assessment of the development opportunities and constraints are included.

The summary section describes the findings of all four complete site analyses. Technical methodologies are described in the Appendix.

## A. DURANGO SITE

### Site Description

The site for this study is located in La Plata County in Southwest Colorado (Fig. A-1). It includes the area from the Purgatory Ski area north of the City of Durango to just south of the Bodo Industrial Park. The Animas River, "River Of Souls," flows through the Valley and provides water for irrigation, industry and domestic use. The terrain varies from the rugged San Juan Mountains on the north to the mesas on the south. The elevation ranges ranges from 6400 to 9400 feet. About 20 miles south of the site is the Southern Ute Indian Reservation and beyond that, the New Mexico State line.

Access to the north, east and west is obstructed by mountain passes that are prone to blizzards, slides and icy roads in winter (two-lane Highways 550 and 160 serve the area). To the south, where the terrain flattens, access is easier.

The City of Durango has an average 8214 annual degree days and an average low temperature of 11°F (Cuniff, et al, 1979). The growing season averages 117 days and is about 90 - 120 days for apple and pears and other fruit crops grown in the northern part of the study area and about 150 days for more frost-resistant crops such as alfalfa and potatoes (Cap Allen, pers. comm., 1979). The mean annual precipitation of the City of Durango is 19 inches and the mean annual temperature is 28°F in January, 67° in July (Division of Commerce and Development, 1974).

Land Use and Ownership - The fertile valley just north of the City of Durango was once primarily agricultural but is now low-density residential with a few scattered commercial establishments. Further north to the Purgatory Ski resort is some very low density residential development, a year-round luxury recreation resort and a few restaurants, lodges, a ski-rental shop and a private boarding school.

The City of Durango covers about 2,182 acres of land. South of the City, the Bodo Industrial Park contains about 240 acres. The valley north of the City has about 3500 acres of developable land (Dallas Reynolds, per. comm., 1979). Much of the land adjoining the study area at the north is National Forest Land, as shown in Figure A-2. County-wide, only about 40 percent of the land is privately owned (Table A-1.) Within the study area, much of the undeveloped land is undevelopable, either steep slopes or flood plain. The ownership restraints and geological conditions restrict the land available for expansion.

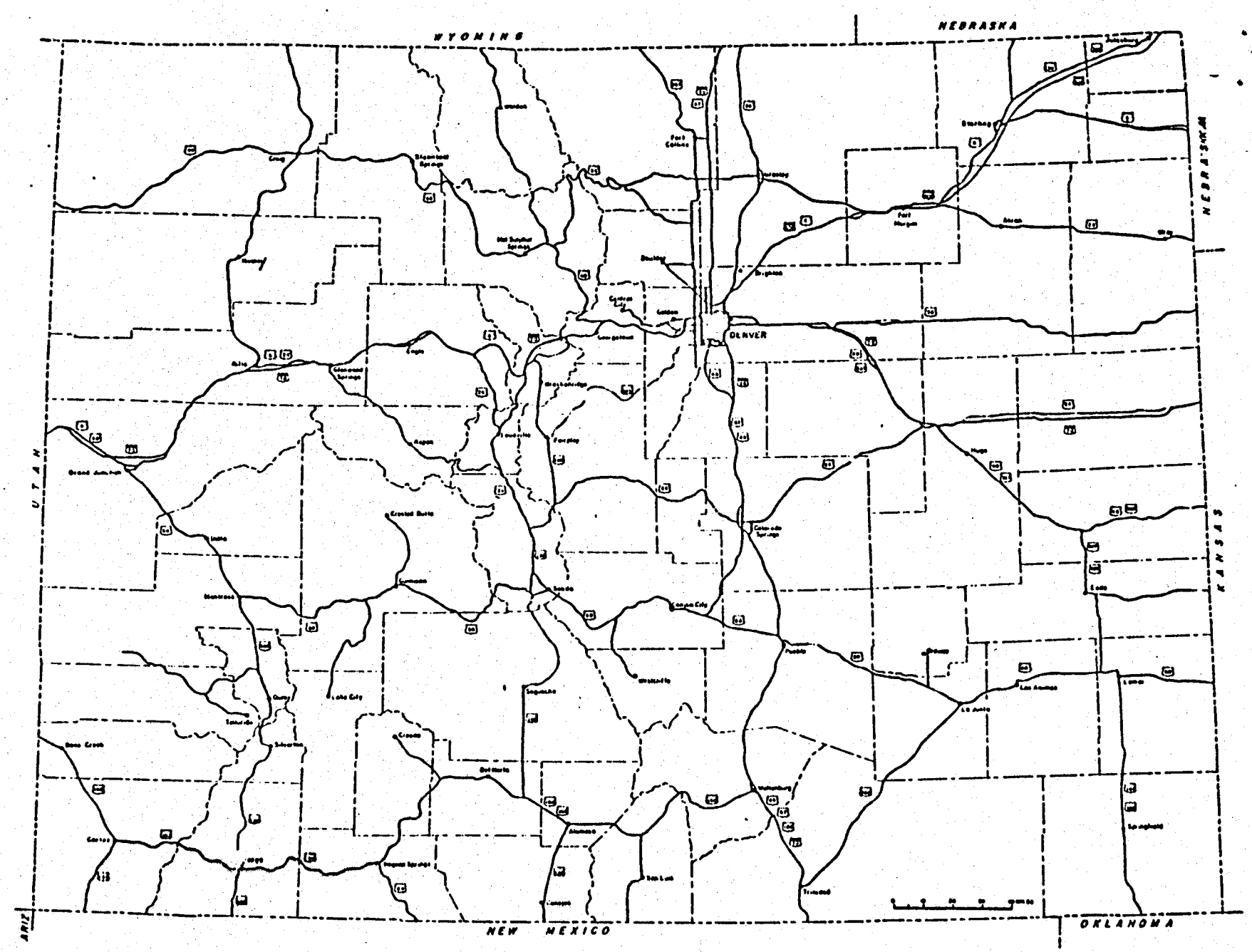
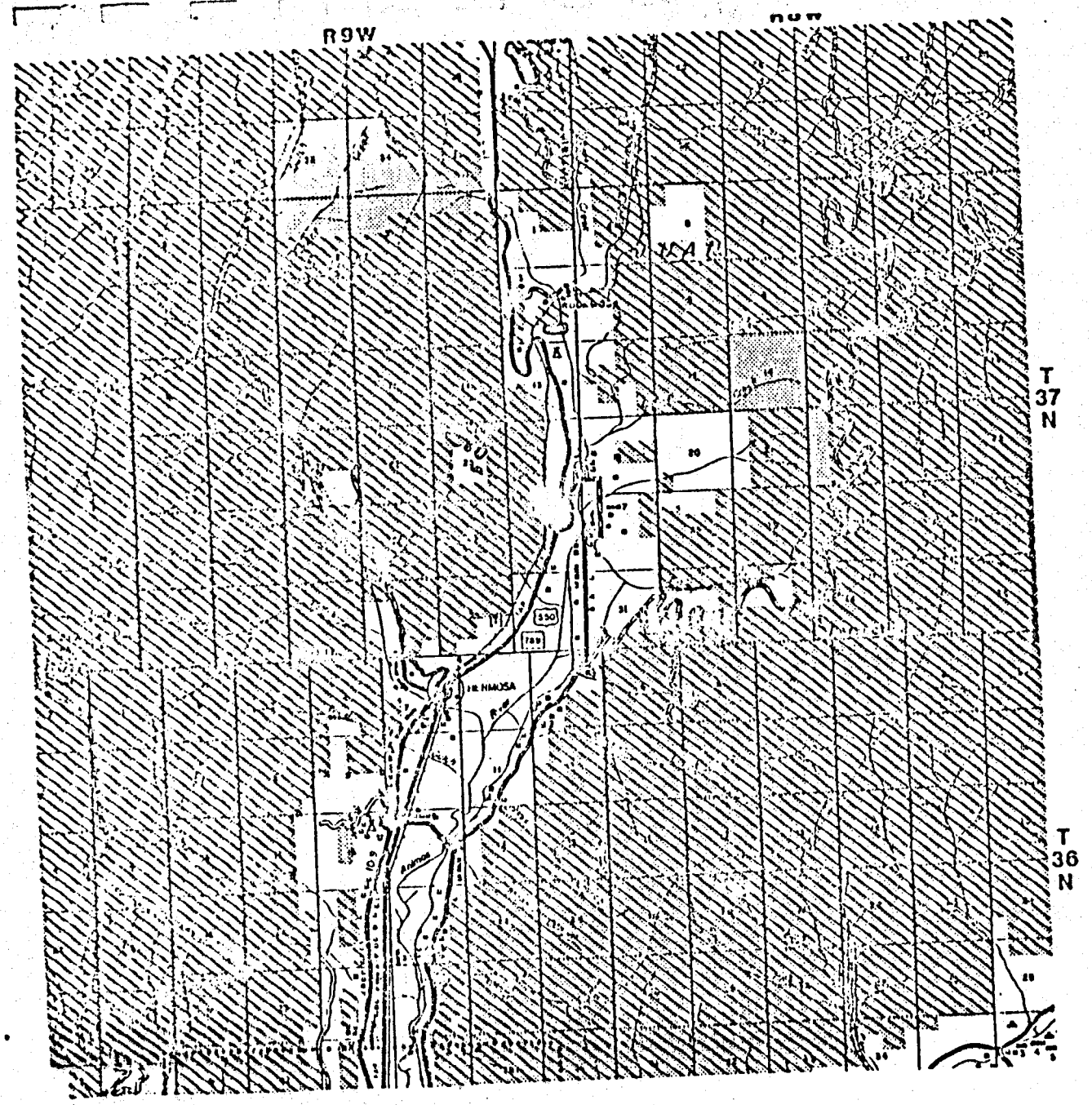



Figure A-1. Location of Durango Site




Base from Colo Dept of Highway

LAND AND MINERAL OWNERSHIP OF UPPER ANIMAS VALLEY AREA

Figure A-2.

TABLE A-1

LAND OWNERSHIP
LA PLATA COUNTY

Number of Acres and Percent of County

| TOTAL | PRIVATE | U.S.F.S. | B.L.M. | UTE TRIBAL LANDS | STATE | MUNICIPAL |
|---|---|---|---|---|---|---|
| 1,066,366 | 421,312 | 394,537 | 29,344 | 202,953 | 14,980 | 3,240 |
| 100% | 39.5% | 37% | 2.8% | 18.8% | 1.4% | .3% |

Source: Del Duca, et al, 1975

Population - The population of La Plata County is growing. The 1970 population of 19,199 grew to an estimated 27,500 in 1977, an increase of 43 perecent (Johnson, 1979). Within the City of Durango, the population grew from 10,333 to an estimated 12,240, an increase of 25.8 percent (Division of Commerce and Development, 1978). About 16,500 or 60 percent of the counties population is estimated to be located in Durango and the urbanizing (Johnson, 1979).

About 4447 dwelling units are estimated to be in the city, with 2829 of these single-family homes, 192 mobile homes, 806 apartments, and 620 rooms. About 850 units, nearly all single-family, are located in the northern part of the study area (Phillips, Brandt, Reddick, 1979). The population in Durango is expected to grow to 21,460 by the year 2000. The northern study area is forecast to ultimately support a total of 1,760 dwelling units (Phillips, Brandt, Reddick, 1979). Extrapolating to the year 2020 indicates a total of 41,410 persons within the study area.

Economy - The economy of La Plata County is diverse, including tourism and recreation, agriculture, wood products and other manufacturing, construction, government and mining (San Juan Regional Commission, 1978). The mining activity that brought the first permanent settlers into the area has, however, declined (Division of Business Research, Univ. of Colorado, 1978). Only two coal mines and no hard rock mines are currently producing (San Juan Regional Commission, 1978). An abundance of high quality coal in the county could encourage significant mining, but is constrained by the lack of a rail system and the high cost of trucking coal (Janet Schultz, pers. comm., 1979). Development of gold, silver, copper, natural gas, and coal resources primarily under Federal ownership offers potential but is determined by Federal leasing and permitting policies.

Light manufacturing is encouraged as a way to diversify the economy. Table A-2 shows the manufacturers currently in the area. The types and magnitude of manufacturing activities are limited by the remoteness of the area from large population centers and the lack of rail transportation. There is, however, a large rural market including four Indian reservations, five counties, and ten municipalities.

In La Plata County and surrounding counties, agriculture is a significant part of the economy, contributing about 10.9 percent of the regional income in 1970.

Dry beans, hay, wheat, and corn for grain and silage are the primary field crops. Small amounts of rye, beer barley, potatoes, oats, broomcorn, seeds, fruits, vegetables, and sugar beets are also grown (Division of Business Research, University of Colorado, 1975). Most crops are exported. Within the study area are cherry, pear, and apple orchards. A planned irrigation project, the Animas-La Plata project, would enhance the agricultural production, but is being met with significant opposition (Ron Short, pers. comm., 1979).

Livestock production in the region includes cattle, pigs, and sheep, with sales contributing about 5.5 percent of the Region's 1970 income (Division of Business Research, Univ. of Colorado, 1975). Most of the livestock is exported to feedlots or markets outside the region. Agriculture has been declining, presumably because of declining product prices and increasing land costs, with land in great demand for subdivisions (San Juan Regional Commission, 1978).

Timber has historically been a significant segment of the region's economy, with most of the timber on public land (Division of Business Research, Univ. of Colorado, 1975), but roadless area studies and wilderness designations have limited the availability of timber from these federal lands. Wood products manufactured in La Plata County are used mainly in the active local construction industry (San Juan Regional Commission, 1978).

Government, wholesale and retail trades and services are the largest sources of jobs in the Region. The City of Durango is the center of the Region's tourist activity, as well as its service center and La Plata County seat. Scenic and historical attractions such as the Mesa Verde Indian Ruins, the Narrow Gauge Railroad, old mining towns, the Purgatory ski resort, the Tamarron resort development and spectacular mountain vistas encourage some 1 million visitors to the area each year (Phillips, Brandt, Reddick, 1978). Conventions and skiers are attracted by scheduled jet service to La Plata airport. Ski buses bring skiers from all around the Southwest. About 658 commercial establishments were located in La Plata County in 1975, with 502 of those wholesale and retail trade and services as shown on Table A-3 (U.S. Bureau of the Census, 1977). In 1974, there were 47 hotels and motels in the City of Durango (Division of Business Research, Univ. of Colorado, 1975), along with numerous restaurants.

The Ft. Lewis College at Durango is another facility that is important to the economy of the area, with students contributing to the area's economy and increasing the attractiveness of the area by adding to the educational and cultural opportunities for residents. San Juan Basin Vo-Tech School, about 30 miles west of Durango, a vocational-technical school, attracts students from the study area and provides a trained labor force to the region in many tecnnical fields.

TABLE A-2

INDUSTRIES
DURANGO STUDY AREA
1977

| Manufacturer | SIC Code | Temperature Required °C | No. of Employees |
|---|---|---|---|
| Basin Co-op Inc. | 2048 | 274 | 15 |
| Basin Packing Co. | 2011 | 177 | 5 |
| | 2752 | 149 | 5 |
| | 2791 | 149 | |
| Burnett Construction Co. | 3273 | 66 | 35 |
| Cabinets by Ralph Thomas | 2434 | 0 | 5 |
| City Market Bakery | 2051 | 232 | 175 |
| Coca-Cola Bottling Co. | 2086 | 77 | 35 |
| Cooper Publications Inc. | 2721 | 149 | 5 |
| Culhane Inc. | 2099 | 150 | 5 |
| Design III | 2499 | 93 | 5 |
| Double Eagle Ranch Inc. | 3961 | 93 | 5 |
| Durango Coca-Cola Bottling Co. | 2086 | 77 | 35 |
| Durango Herald Inc. | 2711 | 149 | 35 |
| | 2751 | 149 | |
| Durango Ornamental Iron Inc. | 3446 | 0 | 5 |
| | 3444 | 93 | |
| Durango U.S.A. | 3949 | 93 | 5 |
| Eagle Block Co. | 3271 | 204 | 5 |
| Graden Elevator & Feed | 2048 | 274 | 5 |
| | 2047 | 121 | |
| Jackson-David Bottling Co. | 2086 | 77 | 35 |
| Las Animas Wood Products | 2431 | 93 | 5 |
| Mesa Paving Co. | 2951 | 260 | 35 |
| Oliger Sheet Metals | 3444 | 93 | 5 |
| | 3448 | 0 | |
| | 3449 | 93 | |
| Print Shop The | 2752 | 149 | 5 |
| | 2761 | 149 | |
| Redfield Co. Durango Optics | 3832 | 0 | 175 |
| Rocky Mountain Doll House Co. | 3944 | 0 | 5 |
| Rocky Mountain Glassware | 3231 | 649 | 5 |
| | 3229 | 1427 | |
| San Juan Lumber Co. | 2421 | 93 | 175 |
| Telluride Iron Works | 3532 | 0 | 35 |
| Townsend Enterprises | 3589 | 1371 | 5 |
| Treasure Tunnel | 3911 | 93 | 5 |
| | 3915 | 0 | |
| | 3999 | 93 | |

TABLE A-2 CONT.

| Manufacturer | Sic Code | Temperature Required °C | No. of Employees |
|---|---|---|---|
| Tri-State Printing & | 2751 | 149 | 5 |
| & Basin Office Supply | 2761 | 149 | |
| Tritec Solar Industries Inc. | 3433 | 93 | 5 |
| | 3564 | 0 | |
| | 3822 | 93 | |
| United Stationery & Confectionery Co. | 3065 | 93 | 5 |
| Watts Jewelry Co. | 3911 | 93 | 5 |

Source: Cuniff, et al, 1979

TABLE A-3

Number of Business Establishments by Industry in La Plata County 1975

| | |
|---|---|
| Agricultural Services | 6 |
| Mining | 8 |
| Contract Construction | 62 |
| Manufacturing | 20 |
| Transportation and Other Public Utilities | 22 |
| Wholesale Trade | 32 |
| Retail Trade | 192 |
| Finance, Insurance and Real Estate Services | 62 |
| Nonclassifiable Establishments | 206 |
| | 49 |
| TOTALS | 658 |

Source: U.S. Bureau of the Census
County Business Patterns, 1975, Colorado
Washington, D.C., 1977.

The construction industry is active, with housing construction at an all-time high. However, because seasonal or vacation homes are such a significant part of the homes being built, year-round housing shortages are a serious problem. Housing projects in process or proposed include 180 units on 90 acres in the northern Animas Valley being developed by Mennen Shaving Cream Corp., Rockwood Estates being developed adjacent to the Tamarron Resort and an 80-acre development in the northern Animas Valley. A new shopping center is planned to be located near the Industrial Park and intensive commercial development for the riverfront area within the City of Durango is being proposed by the City (Dallas Reynolds, pers. comm., 1979).

Within the commuting area, or all of La Plata County and that part of Montezuma County extending about 30 miles west, a total of 7,537 persons were in the labor force in 1970. Of those, 5.8 percent were unemployed. As shown in Table A-4, 20 percent were in retail trade and 13.3 percent were in services and miscellaneous (Colorado Division of Commerce and Development, 1978). The major employers in the commuting area, are all located within the study area.

Energy Demand - The natural gas consumption in the study area was investigated. As shown on Table A-5, the 3,417 Durango residential customers averaged about 150 MCF of natural gas for residential use per customer per year, or about 292 MCF of natural gas or 155 million Btu's per residence for both residential and commercial space and hot water heat. The total commercial energy consumed was about .93 of the total residential consumption. The average cost for residential consumption of natural gas is $2.80 per million Btu and about $10.00 per million Btu for electricity (Colorado Public Utilities Commission, 1979). The forecast demand, based on consumption, is $2.12 \times 10^{12}$ Btu's by the year 2020 for residential and commercial uses.

The actual industrial energy consumption is more than the reported industrial natural gas sales because small industrial users are classified by the natural gas supplier as "commercial" and because industrial users may be using additional fuels.

In some parts of the study area, natural gas is not available. An example is the northern part of the valley where electricity or propane are used for heat. To account for the supplemental or alternative use of fuels other than natural gas, the thermal energy demand was calculated based on heating degree days and extreme low temperatures. These estimates indicate that about $1.67 \times 10^{12}$ Btu's of thermal energy would be required by the year 1984 and about $2.55 \times 10^{12}$ Btu's would be required by the year 2000, for all uses. The Tamarron Resort energy demand was assessed independently because it is a major energy market that is very near the geothermal resource area and is, furthermore, reliant upon electricity for heat. The energy demand for Tamaron was estimated to be $.037 \times 10^{12}$ Btu's by 1984 and $.108 \times 10^{12}$ Btu's by the year 2000 (Cuniff, et al, 1979)

Public Issues - The attitudes and goals of the residents of an area play a large part in the events that occur there. In this area, the northern part is the area most proximate to surface manifestations of hydrothermal activity. Although once an agricultural valley, the development now is predominantly low-density residential, with some scattered, but large, energy-consuming commercial establishments. The southern part of the study area, that part furthest removed from geothermal resources, is industrial. New industry is

TABLE A-4

LABOR DATA FOR COMMUTING AREA

| Employment Category | 1970 No. | 1970 Percent | 1977 Estimate No. | 1977 Estimate Percent |
|---|---|---|---|---|
| Agriculture | 760 | 10.1 | 766 | 6.5 |
| Mining | 140 | 1.9 | 65 | 0.6 |
| Contract Construction | 518 | 6.9 | 594 | 5.0 |
| Manufacturing | 372 | 4.9 | 666 | 5.6 |
| Transportation & Public Utilities | 463 | 6.1 | 434 | 3.7 |
| Wholesale Trade | 157 | 2.1 | 282 | 2.4 |
| Retail Trade | 1,577 | 20.9 | 1,093 | 17.7 |
| Financial, Insurance and Real Estate | 258 | 3.4 | 336 | 2.9 |
| Services and Miscellaneous | 1,000 | 13.3 | 2,749 | 23.3 |
| Government (Federal, State and Local) | 1,189 | 15.8 | 1,768 | 15.0 |
| TOTAL EMPLOYMENT | 7,101 | 94.2 | 11,108 | 94.1 |
| UNEMPLOYMENT | 436 | 5.8 | 700 | 5.9 |
| TOTAL LABOR FORCE | 7,537 | 100.0 | 11,808 | 100.0 |

Source: Division of Commerce and Development, State of Colorado, Department of Local Affairs, 1978.

TABLE A-5

NATURAL GAS SALES
DURANGO
1977

| Total Customers | Residential Mcf | Residential No. Customers | Commercial Mcf | Commercial No. Customers | Industrial Mcf | Industrial No. Customers |
|---|---|---|---|---|---|---|
| 3,905 | 513,783 | 3,417 | 482,803 | 472 | 90,158 | 16 |

Source: People's Natural Gas Co., Durango, Colo., 1979

being encouraged to locate there in preference to other area. The middle portion is the City of Durango, with primarily commercial and residential uses.

No drastic changes are anticipated, since these patterns are deliberate. Light manufacturing is being encouraged in order to diversify the economy. A strong desire to preserve the quality of life in the area, without significant population growth, is apparent. This desire, combined with the previously-established economic patterns, seems likely to assure the continuation of the recreation and tourism focus. A continuation, therefore, of current development patterns and land use policies can be anticipated. This includes a sparse residential development and some new commercial facilities in the northern section, the limitation of industrial sites to the industrial park, and some increase density within Durango.

## Geothermal Resource Evaluation

Pinkerton, Trimble and Tripp Hot Springs are the surface expressions of the geothermal resource for this development site. The characteristics of the springs that were identified by the Colorado Geological Survey in resource assessment work (Barrett and Pearl, 1976 and Pearl, 1979) are shown on Tables A-6, A-7 and A-8. Since that inventory was conducted, a highway cut has severed the spring conduit at Pinkerton Hot Springs, changing the location of the discharge. Analyses that were performed by the Colorado Geol. Survey indicated high enough temperatures for space heating and other uses requiring similar temperatures and about .04-.05 x $10^{12}$ Btu's of usable energy (Pearl, 1979). However, these estimates cannot be confirmed without additional information. Some additional exploration work was preformed by the Colorado Geol. Survey in the summer of 1980 and the data are being evaluated (R.H. Pearl, per. comm., 1980).

Current Uses of Geothermal Energy - There is apparently no geothermal energy currently in use in this area. At one time, Pinkerton Hot Springs and Trimble Hot Springs supplied water to swimming pools that were popular with residents and visitors in the area. A home heating system and a greenhouse were constructed at Tripp Hot Springs to use geothermal fluid but were not used. A system has been designed for Timberline Academy at Pinkerton Hot Springs to use geothermal heat. A grant was awarded by the U.S. Department of Energy for constructing such a system as soon as the State Highway Department restores the spring flow (Cap Allen, pers. comm., 1979). The owner of the Trimble Hot Springs has also indicated he will construct a geothermally-heated resort and is also well aware of the potential for extensive use of the geothermal energy throughout the area (Rudy Baer, pers. comm., 1979).

TABLE A-6

GEOTHERMAL RESOURCE CHARACTERISTICS
TRIPP/TRIMBLE/PINKERTON/MOUND

| Spring or Wells | Location | Total Dissolved Solids mg/L | Surface Temperature C° | Total Current Discharge gpm |
|---|---|---|---|---|
| Trimble | 36N,9W,Sec. 15 | 3340 | 36 | <1 |
| Tripp | 36N,9W,Sec. 10 | 3240 | 44 | NA |
| Pinkerton A | 37N,9W,Sec. 25 | 3700-3980 | 32 | 54 |
| B | 37N,9W,Sec. 25 | NA | 33 | 20 |
| Mound | 37N,9W,Sec. 25 | 3800 | 32 | 54 |
| Little Mound | 37N,9W,Sec. 25 | NA | 26 | 2 |

Source: Barrett and Pearl, 1976

TABLE A-7

GEOTHERMAL RESERVOIR CHARACTERISTICS
TRIPP/TRIMBLE/PINKERTON/MOUND

| Reservoir Type | Estimated Areal Extent $mi^2$ | Estimated Thickness ft | Estimated Subsurface Temperature °C | Estimated Total Btu's $10^{15}$ |
|---|---|---|---|---|
| Tripp/Trimble | | | | |
| Fracture | 1 | 1000 | 58°C | .0357-.0357 |
| Pinkerton | | | | |
| Fracture | 1.2 | 1000 | 50°C | .0099-.0209 |
| | | | | .0446-.0566 |

Source: Pearl, 1979

TABLE A-8

Dissolved Mineral Content of Thermal Waters in Study Area

| | Pinkerton Hot Springs | Trimble Hot Springs | Tripp Hot Springs |
|---|---|---|---|
| Arsenic (ug/l) | 120.0 | 17.0 | 17.0 |
| Boron (ug/l) | 3,000.0 | 1,400.0 | 1,500.0 |
| Cadium (ug/l) | 0.0 | 0.0 | 0.0 |
| Calcium (mg/l) | 510.0 | 510.0 | 470.0 |
| Chloride (mg/l) | 1,000.0 | 220.0 | 220.0 |
| Fluoride (mg/l) | 2.1 | 2.7 | 2.7 |
| Iron (ug/l) | 4,400.0 | 50.0 | 10.0 |
| Lithium (ug/l) | 2,500.0 | 1,600.0 | 1,600.0 |
| Magnesium (mg/l) | 79.0 | 42.0 | 41.0 |
| Manganese (mg/l) | 470.0 | 80.0 | 80.0 |
| Mercury (ug/l) | 0.0 | 0.0 | 0.0 |
| Nitrogen (mg/l) | 0.10 | 0.08 | 0.16 |
| Phosphate (mg/l) | 0.05 | 0.02 | 0.05 |
| Potassium (mg/l) | 120.0 | 47.0 | 47.0 |
| Selenium (mg/l) | 0 | 0 | 0 |
| Silica (mg/l) | 28.0 | 72.0 | 69.0 |
| Sodium (mg/l) | 750.0 | 510.0 | 500.0 |
| Sulfate (mg/l) | 690.0 | 1,400.0 | 1,400.0 |
| Zinc (ug/l) | 0 | 10.0 | 20.0 |
| Alkalinity | | | |
| as Calcium Carbonate (mg/l) | 1,340.0 | 894.0 | 810.0 |
| as Bicarbonate (mg/l) | 1,630.0 | 1,090.0 | 988.0 |
| Hardness | | | |
| Noncarbonate (mg/l) | 260.0 | 550.0 | 530.0 |
| Total (mg/l) | 1,600.0 | 1,400.0 | 1,300.0 |
| Specific Conductance | 5,600 | 4,400 | 3,900 |
| Total Diss. Solids (mg/l) | 3,990 | 3,340 | 3,240 |
| Ph, Field | 6.5 | - | - |
| Discharge (gpm) | 54.0 | 1E | - |
| Temperature (C) | 32 | 36 | 44 |
| Date Sampled | 9/75 | 9/75 | 9/75 |

Source: Barrett and Pearl, 1976

## Geothermal Development Process

The manner in which geothermal energy can be developed is dependent upon conditions at the specific site. The most influential of these are described below.

Financial - To finance the federal geothermal projects, several avenues are possible. Some grants have been available such as the one Timberline Academy will receive to develop a simple geothermal heating system for the main school facilities. Since the Trimble project is not imminent, no financing arrangements have as yet been indicated, but presumably, the project will be financed with private funds. As another alternative, to develop and manage these and other projects in lieu of an interested private energy developer, a special district or cooperative could be established among potential users. Levies could be assessed, revenue bonds issued, or grant funds or loans, private or government, obtained.

Although U.S. Dept. of Energy grants for development are not currently widely available, other federal sources may be tapped, where their mandates coincide with the proposed geothermal energy development. For example, areas impacted by energy development as well as economically depressed areas are target areas for Federal agencies such as the U.S. Housing and Urban Development Department and the Farm Home Administration under the U.S. Department of Agriculture.

Leasing and Permitting - To establish the right to develop the energy, a prospective developer must either own or lease the geothermal rights and the land surface to be used and must have rights to the water containing the heat if the water is to be consumed. No leases on public land within the study area have been issued. To drill a well requires State permits (Coe and Forman, 1979).

Approval by La Plata County would also be required for a geothermal development outside Durango city limits and by the building department if within the City. Depending upon the size, magnitude of impacts and consistency of use, approval may require from a week to six months. A significant land development review begins with a sketch plan for preliminary review. It is submitted to certain State agencies and to the planning commission for their review, is discussed at a public hearing and then is considered by the Board of County Commissioners. In La Plata County, residents prepare their own land and resource management program. Thus, any new development would have to conform to the goals of the current residents in that region (Dallas Reynolds, pers. comm., 1979).

Technological Requirements - The procedure for exploring for geothermal energy is aimed toward learning more about the magnitude of heat, the size of the reservoir, possible reservoir depths, and suitable well locations. It would usually begin with a preliminary exploration program including geologic evaluation, seismic tests, possibly more geochemical analyses and drilling and analyzing gradient holes. A feasibility study is usually conducted to determine whether the investment seems to be warranted and finally a test well (or wells) is drilled and tested. Depending upon the magnitude of the energy demand and the production of the well, the test well may be used as a production well and/or additional wells may be drilled.

Too little is known about the geothermal resources in this area to conjecture

about specific technical requirements or engineering design. Since the dissolved solids content is not particularly high, no exotic treatment is indicated so far. The key question is whether the water is hot enough to use as an independent source of heat (about 60°C (140°F) is generally required). If the water produced is not near the 60°C temperature, it could still be a valuable resource by using heat pumps or boilers to boost the heat produced.

Disposal of the fluid in a manner to protect ground and surface water quality may be either by reinjection into another well, surface disposal or use of the geothermal fluid, depending upon the quality of the fluid, the standards of the stream or underground aquifer, as determined by the Water Quality Control Division. Or a downhole heat exhcanger that would extract the heat from inside the well might be suitable.

Environmental Considerations - Pending a detailed study, environmental effects of geothermal development are not definable. Reports do indicate that the existing spring discharge has damaged trees (Cap Allen, pers. comm., 1979). This implies that careful handling of the resource would be needed if the fluid recovered exhibited characteristics similar to those of the spring. This also implies that by properly controlling the fluid with a well, further environmental damage could be avoided. In any case, the State's permitting system is designed to assure that neither the groundwater sources or surface water sources will be degraded.

Other environmental concerns include soil, wildlife, wildlife habitat, plant life, land disturbance, damage to the ecosystem as a whole and socio-economic impacts. Air pollution is another matter of high concern for geothermal develoment. Noxious gases must be precluded from polluting the air. The Colorado Air Quality Control Division is charged with assuring that standards are met and with issuing permits for discharging air pollutants, where appropriate. Development of geothermal energy, if properly done, is relatively environmentally benign. Most direct negative impacts can be avoided.

Indirectly, geothermal development could effect environmental damage by encouraging economic development and population growth in locations where the energy is available. So far, the availability of geothermal energy is not a primary determinant for industrial location decisions and should not attract massive and rapid growth in the foreseeable future. Further, the City and County have established the mechanism for prevention of development in hazardous areas and for review and control of new development.

Since according to the Colorado Division of Water Resources the water in the Animas River has not been completely allocated, some water is probably available for development. If the geothermal reservoir is a tributary to the river, obtaining some of these water rights would assure control of the geothermal fluid. If the geothermal reservoir is not tributary, only 1/100th of the estimated water underlying the land controlled by the developer could be extracted in any one year. Water rights might also be purchased, and a plan of augmentation filed to substitute water for the geothermal fluid, or the water could be reinjected in a reinjection well after removing the heat.

Economic Considerations - According to studies by the New Mexico Energy Institute, the cost to develop geothermal for the entire town of Durango would be competitive with natural gas in the very near future. When transmission costs are reduced, when retrofitting costs are eliminated (as in new structures) and when geothermal energy is compared with the cost of electricity or propane, the geothermal energy is considerably more economical. Analyses indicated that a large energy user such as the Tamarron Resort, which is only about 2 miles from the resource, could use geothermal energy at a much lower cost of electricity (Cuniff, et al, 1979).

## Potential Uses of Geothermal Energy

The principal uses for geothermal energy in the Durango area are for space and water heating. Numerous opportunities are available for using geothermal energy. New residents and an active tourist business mean a large demand for hot water and space heat. In a resort area, space and water heating needs are large relative to the population. Those large facilities located nearest the resource areas would allow for use of the energy with a minimum of transmission costs. Among these are the Tamarron Resort, which has 320 condominium units plus restaurants, a lodge, sauna, indoor swimming pool, and conference facilities (Stan Wadsworth, pers. comm., 1979). The nearby Rockwood subdivision could also use the energy, the elimination of the need for retrofitting in new structures enhancing the economic viability of such a project. Since in both cases, geothermal energy is competing with expensive electrical heat, it could be considerably less expensive for building owners. Just how much money could be saved can be determined only through a detailed analysis.

There are other large facilities more distant from the resource areas that could use the energy. These include State-owned buildings such as the National Guard building, Highway Department buildings and Ft. Lewis College buildings, which could use the energy for space and water heat. The commercial, smaller public and residential buildings in Durango could eventually also convert to geothermal energy.

Industrial users could provide a market for the geothermal energy, as well, and in turn, low-cost energy could help attract new industry. The existing industries with temperature requirements commensurate with the estimated geothermal resources temperatures are listed on Table A-9. As industrial demands grow, more industrial uses of geothermal energy could be found. The total energy demand in Durango is forecast to be about $2.5 \times 10^{12}$ Btu by the year 2000.

Developing the energy is dependent upon the various considerations that have been indicated. Steps required and a possible schedule for developing the geothermal energy are shown on Figure A- 3.

TABLE A-9

EXISTING POTENTIAL INDUSTRIAL PROCESS USERS OF GEOTHERMAL ENERGY

Durango, Colorado
1976

| Industry | Standard Industrial Classification | Number of Plants | Low-grade Heat Required ($10^{10}$ Btu's)* |
|---|---|---|---|
| Bottled and Canned Soft Drinks | 2086 | 2 | .44 |
| Prepared Foods | 2048 | 1 | 2.06 |
| Confectionary Products | 2065 | 1 | .16 |
| Food Preparations (honey) | 2099 | 1 | .28 |
| Meat Packing | 2011 | 1 | .14 |
| Sawmills and Planing Mills | 2421 | 1 | .14 |
| | | | 3.22 |

SOURCE: Coe and Solar Energy Research Institute

FIGURE A-3

DURANGO SITE
SCENARIO FOR DEVELOPMENT

| Activity | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|
| Preliminary geophysics | --- | | | | | | | |
| Gradient holes, eval. | | ------ | | | | | | |
| Feas. studies for space heating | --- | | | | | | | |
| Leases | | -- | | | | | | |
| Permits for test well | | | ---- | | | | | |
| Drill test well, eval. | | | -- | | | | | |
| Permit to dev. system | | | --- | | | | | |
| Water rights | | | -- | | | | | |
| Rights of way | | | -- | | | | | |
| Loan or bond | | | -- | | | | | |
| Design system | | | | --- | | | | |
| Construct system | | | | ----- | | | | |
| Install in new structure, then retrofit existing | | | | ----- | --- | | | |
| Permit to dev. well | | | -- | | | | | |
| Dev. test well | | | | -- | | | | |
| Heat on line (.07 x $10^{12}$ Btu's/yr.) | | | | | --- | | | |

*U.S. mean average plant size

Development Opportunities and Constraints- There are opportunities for development of geothermal energy in the Durango area. For the most part, they center around the tourist industry. The estimated one million visitors in the area each year use substantial amounts of heat and hot water. In addition some light industrial uses may be possible, including timber drying. Those structures nearest the known geothermal areas seem to afford the most economical means for development and, given the alternatives, seem to stand a good chance of incurring significant savings on fuel bills. There are, however, several conditions that have limited geothermal development.

The first constraint to such development is the lack of information about the resource and about the economic feasibility. Secondly, unless a private user or developer should become interested in developing the resource in the area, another major constraint will be the lack of front-end funds. Since Durango is not a target city for either economic development or for energy impact funds, potential federal grant programs or a federally-guaranteed loan seem the most plausible, were the community or a cooperative to initiate a project. The last constraint and the most difficult to overcome is the virtual lack of an intrepreneur, either private or government, who is aware of the energy and its value and willing to devote time and effort to see it developed. Until such a person takes on the task, either for personel benefit or the good of the community, or both, the energy will likely remain underground.

## INTRODUCTION

The potential for use of geothermal energy in Colorado seems to be substantial. As described by Barrett and Pearl (1978), at least 56 separate areas have surface manifestations of hydrothermal (hot water) resources. In all, some 120 thermal springs and wells with temperatures over 20°C have been located. These have surface temperatures ranging from 20°C in several areas to a high of 83°C at Hortense Hot Spring southwest of Buena Vista. Using the technique of geochemical modeling, subsurface temperatures estimated for all the 56 areas are between 20°C and slightly over 200°C. The discharge rate is from 1 gallon per minute (gpm) at a number of springs to 2,263 gpm at Glenwood Springs. Contrary to popular opinion, some waters are quite pure, with the total dissolved solids ranging from 84 mg/l at Eldorado Springs southwest of Boulder to a high of 21,500 mg/l at Glenwood Springs (Barrett and Pearl, 1976). Figure 1 shows the resource areas.

The term "geothermal energy" is a term that means different things to different people. To some, it means an exotic resource that might at some point in the distant future, after an enormous technological breakthrough, contribute to the energy supply. To others it is a fluid in which to swim or bathe, either simply for pleasure or for improvement of one's health and well-being. To an increasing number it means a practical, environmentally compatible energy resource that can, right now, help to relieve an overdependency upon fossil fuels.

Expressed most concisely, geothermal energy is "the natural heat, steam, and hot waters of the earth's interior." (Pearl, 1972). It is, in fact, a practical energy resource which is readily usable with existing technology. Although techniques for using heat that is not contained in fluid, known as hot dry rock, are in the developmental stage, geothermal steam and hot water have been used for many years. Lardarello, Italy, has generated electricity with geothermal resources since 1904. Wairakei, New Zealand, and the Geysers in California have more recently begun generating electricity. In 1975 worldwide geothermal generating capacity was estimated to be 1100 MWe (The Futures Group, 1975). Reykjavik, in southern Iceland, uses natural hot water to heat 11,000 houses, plus some greenhouses and swim pools (Zoega, 1974). In Hungary geothermal energy is used to heat homes, greenhouses, cattle stalls, pigsties, chicken houses, hospitals, garages, machine shops, municipal buildings, factories, as well as for hot water supplies and for cooling and drying of agricultural products (Boldizsar, 1974). Other areas using geothermal energy are Japan and Russia, and, in the United States, Boise, Idaho, Klamath Falls, Oregon, and Pagosa Springs, Colorado. Facilities in these areas demonstrate that the technology and know-how are readily available for using geothermal resources.

In the United States, geothermal energy is considered to have significant potential, both for the generation of electricity and for use as direct heat, although estimates of the specific amounts vary widely. As a result, recent Federal policies have been initiated to encourage geothermal development. In 1970 the U.S. Congress passed the Geothermal Leasing Act to allow for issuance of geothermal leases on Federal lands (PL 91-581). In 1974 the Federal Energy Research Development and Demonstration Act was adopted, providing the mandate for geothermal programs that include resource assessment, planning and system development (PL 93-410). Among the planning programs is the Southwest Regional Geothermal Development Operations Research Project, of which this study is a part.

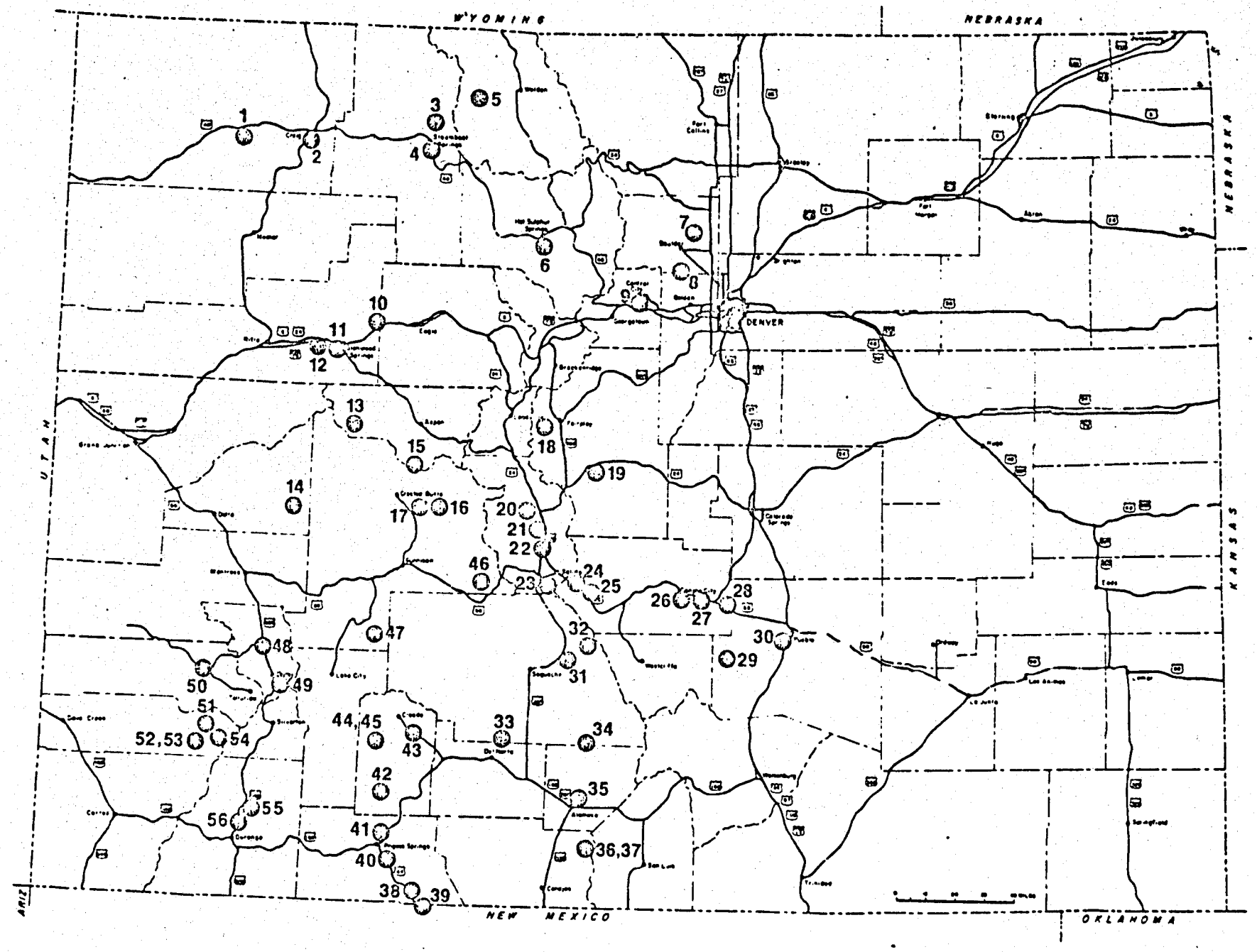



FIGURE 1. GEOTHERMAL RESOURCE LOCATIONS (THERMAL SPRINGS AND WELLS) IN COLORADO.

TABLE 1 (Cont.)

| Thermal Areas | Areal Extent ($mi^2$) | Thickness (st.) | Temp. (°C) (midpoint) | Total Btu ($10^{15}$) | Useable Btu ($10^{15}$) |
|---|---|---|---|---|---|
| Florence 28 | 1.0 | 200(S) | 42 | .0083 | .0005 |
| Don K. Ranch 29 | 1.5 | 500(N) | 45 | .0353 | .0021 |
| Clark Well 30 | 1.1 | 200(S) | 40 | .0083 | .0005 |
| Mineral 31 | 10.1 | 1000(S) | 70 | .9406 | .0564 |
| Valley View 32 | 1.05 | 1000(F) | 50 | .0593 | .0036 |
| Shaw's 33 | 0.63 | 500(N) | 45 | .0148 | .0009 |
| Sand Dunes 34 | 1.5 | 500(N) | 75 | .0776 | .0047 |
| Splashland 35 | 1.5 | 500(N) | 75 | .0776 | .0047 |
| Dexter/McIntyre 36/37 | 1.2 | 1000(F) | 35 | .0339 | .0020 |
| Dutch Crowley/Stinking 38/39 | 1.52 | 200(S) | 65 | .0257 | .0015 |
| Eoff Well 40 | 1.5 | 200(S) | 50 | .0169 | .0010 |
| Pagosa 41 | 2.15 | 200(S) | 80 | .0485 | .0029 |
| Rainbow 42 | 0.99 | 1000(F) | 45 | .0466 | .0028 |
| Wagonwheel Gap 43 | 4.24 | 500(N) | 115 | .3789 | .0227 |
| Antelope/Birdsie 44/45 | 2.38 | 500(N) | 44 | .0537 | .0032 |
| Waunita 46 | 1.4 | 200(S) | 135 | .0606 | .0036 |
| Cebolla 47 | 1.86 | 500(N) | 60 | .0700 | .0040 |
| Orvis 48 | 0.55 | 500(S) | 75 | .0285 | .0017 |
| Ouray 49 | 2.07 | 1000(F) | 80 | .2336 | .0140 |
| Lemon 50 | 0.81 | 425(S&F) | 43 | .0149 | .0009 |
| Dunton/Geyser/Paradise 51/52/53 | 1.16 | 400(S) | 50 | .0262 | .0016 |
| Rico 54 | 1.74 | 1000(F) | 63 | .1407 | .0084 |
| Pinkerton/Mound 55 | 0.98 | 180(S) | 50 | .0100 | .0006 |
| Tripp/Trimble 56 | 1.0 | 500(N) | 58 | .0357 | .0021 |
| | | | | 5.9142 | .3549 |

(S) Stratigraphic reservoir
(F) Fracture reservoir
(N) unknown

TABLE 1

Resource Assessment

of

Hydrothermal Resources in Colorado

by Jay D. Dick and Richard H. Pearl

February, 1978 (unpublished)

| Thermal Spring Areas | Areal Extent ($mi^2$) | Thickness (ft.) | Temp. (°C) (midpoint of estimate) | Estimated Total Btu ($10^{15}$) | Estimated Useable Btu ($10^{15}$) |
|---|---|---|---|---|---|
| Juniper 1 | 1.01 | 200(S) | 63 | .0163 | .0009 |
| Craig 2 | 1.3 | 500(N) | 55 | .0428 | .0026 |
| Routt 3 | 0.5 | 1000(F) | 138 | .1110 | .0067 |
| Steamboat 4 | .52 | 250(S) | 70 | .0122 | .0007 |
| Brand's Ranch 5 | 0.36 | 200(S) | 49 | .0039 | .0002 |
| Hot Sulphur 6 | 1.35 | 599(N) | 75 | .0698 | .0042 |
| Haystack Butte 7 | 1.54 | 300(S) | 40 | .0174 | .0010 |
| Eldorado 8 | 0.35 | 1000(S) | 35 | .0099 | .0006 |
| Idaho 9 | 1.12 | 1000(F) | 80 | .1260 | .0076 |
| Dotsero 10 | 0.84 | 250(S) | 39 | .0075 | .0005 |
| Glenwood 11 | 1.32 | 250(S) | 65 | .0279 | .0017 |
| South Canyon 12 | 0.1 | 1000(S) | 75 | .0103 | .0006 |
| Penny (Avalanche) 13 | 1.61 | 1000(F) | 75 | .1670 | .0100 |
| Colonel Chinn 14 | 1.55 | 200(S) | 51 | .0181 | .0011 |
| Conundrum 15 | 0.45 | 500(N) | 45 | .0106 | .0006 |
| Cement Creek 16 | 1.1 | 150(S) | 45 | .0078 | .0005 |
| Ranger 17 | 1.11 | 150(S) | 45 | .0078 | .0005 |
| Rhodes 18 | 1.53 | 1000(F) | 35 | .0432 | .0026 |
| Hartsel 19 | 0.87 | 500(N) | 70 | .0409 | .0025 |
| Cottonwood Creek 20 | 1.38 | 1000(F) | 170 | .3894 | .0234 |
| Mt. Princeton 21 | 3.14 | 1000(F) | 200 | 1.0632 | .0638 |
| Browns Canyon 22 | 3.23 | 1500(S&F) | 100 | .7291 | .0438 |
| Poncha 23 | 2.19 | 1000(F) | 145 | .5150 | .0309 |
| Wellsville/Swissvale 24/25 | 0.94 | 240(S) | 40 | .0085 | .0005 |
| Canon City 26 | 0.52 | 100(S) | 50 | .0029 | .0002 |
| Freemont Natatorium 27 | 1.0 | 220(S) | 43 | .0095 | .0006 |

## STATUS OF GEOTHERMAL DEVELOPMENT IN COLORADO

Geothermal resources already contribute to Colorado's energy supply. In fact, since the early 1900's, practical uses of geothermal resources have been common in Pagosa Springs, in Southwest Colorado. Residents there have used hot-water wells to heat numerous buildings, including the County Court House, schools, churches, the newspaper office, a liquor store, 2 hotels, 2 service stations, a drugstore, and a bank, as well as for the swimming pool and spa. Although the corrosion of heating system equipment, along with the low price and availability of natural gas induced the conversion of some geothermal systems to natural gas, 12 wells are still in use. (Dick and Galloway, unpublished report, 1978). A list of the known wells is found in the Appendix.

Where resources are in use in other parts of the State, most are used for swimming pools or baths. A few wells or springs serve other purposes, however, among them space heating and agriculture, including greenhouses, a fish farm and algae-growing. Table 3 shows the known users and uses in geothermal resource areas throughout the state.

Interest in developing the geothermal resources in Colorado has grown since the beginning of the 1970's. Because of the problem of transporting the energy to the user, most of the recent interest has been in geothermal power generation. Toward this end, some leasing and exploration activity have occurred. It is commonly believed, however, that Colorado's resources offer high enough temperatures for power generation in only a few areas, given today's economic criteria. Efforts toward the development of low-temperature uses such as space or water heating of industrial or agricultural process use so far seem minimal. However, several planning and preliminary engineering studies emphasizing these uses are either completed or underway. Judging from conversations with potential developers throughout the state, interest is growing. If a planned development of a district heating system in the town of Pagosa Springs is funded by the Department of Energy, this may well be the first step toward significant development of the low-temperature geothermal resources throughout Colorado.

TABLE 9
CATEGORY II B
AREAS OF KNOWN ACTIVITY

| Area Name | Number | Use | Distance | 1975 Estimated Dwelling Units | 1975 Estimated Natural Gas Demand ($10^{12}$Btu's) | 2020 Estimated Dwelling Units | 2020 Estimated Natural Gas Demand ($10^{12}$Btu's) | Estimated Usable Energy Available ($10^{12}$Btu's) | Estimated Usable Energy Available Per Year for 30 Years ($10^{12}$Btu's) |
|---|---|---|---|---|---|---|---|---|---|
| Glenwood | 11 | space heat Glenwood Springs | 0 | 1,784 | .32 | 3,796 | .68 | 1.7 | .06 |
| Hartsel | 19 | space heat Fairplay | 16 | 215 | .04 | 271 | .04 | 2.5 | .08 |
| Splashland | 35 | Alamosa | 2 | 2,807 | .50 | 8,083 | 1.44 | 4.7 | .16 |
| Sand Dunes | 34 | Baca Grande | 14 | 225 | .02 | 10,000 | 1.78 | 4.7 | .16 |
| Shaws | 33 | greenhouse | 0 | NA* | .02 | NA | NA | .9 | .03 |
| Mineral/Valley View | 31/32 | space heat Saguache | 12 | 226 | .04 | 380 | .06 | 60.0 | 2.00 |
| | | timber kiln | | | .04 | | | | |
| | | barley melting | | | .22 | | | | |
| | | potato flakes | | | .86 | | | | |
| Pagosa Springs | 41 | space heat Pagosa Springs | 0 | 524 | .09 | 1,481 | .26 | 2.9 | .10 |
| Waunita | 46 | space heat Gunnison timber drying | 22 | 1,880 | .33 | 4,326 | .77 | 3.6 | .12 |

*Not applicable

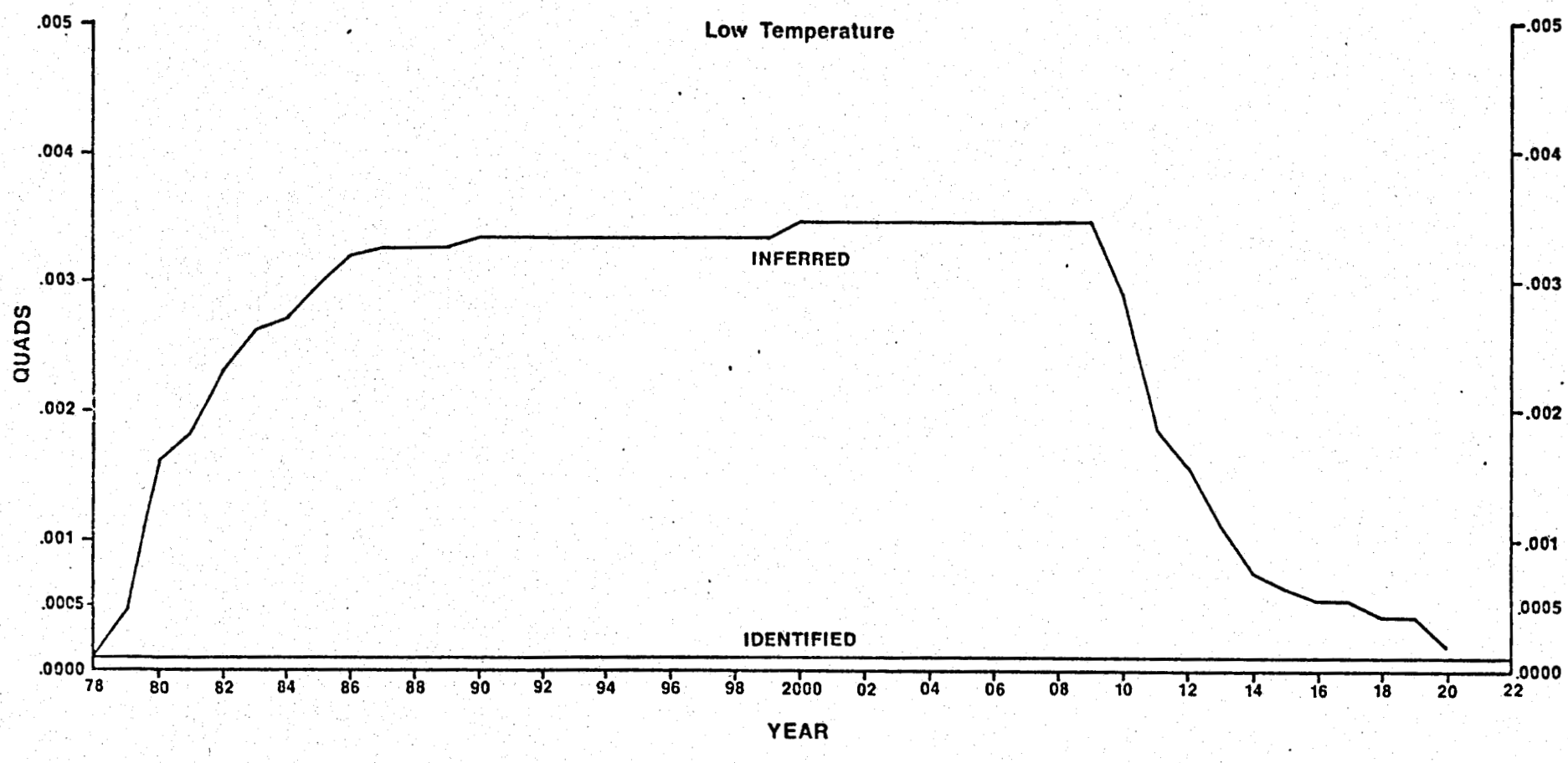
TABLE 10
CATEGORY III B
AREAS OF MODERATE POTENTIAL

| Area Name | Number | Use | Distance | 1975 Estimated Dwelling Units | 1975 Estimated Natural Gas Demand ($10^{12}$Btu's) | 2020 Estimated Dwelling Units | 2020 Estimated Natural Gas Demand ($10^{12}$Btu's) | Estimated Usable Energy Available ($10^{12}$Btu's) | Estimated Usable Energy Available Per Year For 30 Years ($10^{12}$Btu's) |
|---|---|---|---|---|---|---|---|---|---|
| Juniper/Craig | 1/2 | space heat Craig | 24/.7 | 1,809 | .32 | 2,241 | .40 | 3.5 | .12 |
| Brand's Ranch | 5 | space heat Walden | 16 | 325 | .03 | NA | NA | .2 | .007 |
| South Canyon | 12 | space heat New Castle | 8 | 247 | .05 | NA | NA | .6 | .02 |
| Penny | 13 | space heat Carbondale Basalt | 12 13 | 549 | .10 | 1,050 | .19 | 10.0 | .33 |
| Col. Chinn | 14 | space heat Paonia | 3 | 444 | .08 | NA | NA | 1.1 | .04 |
| Cement Creek/ Ranger | 16/17 | space heat Crested Butte | 7 | 289 | .05 | NA | NA | 1.0 | .03 |
| Hellsville/ Swissvale | 24/25 | space heat Salida | 4 | 1,729 | .31 | NA | NA | .5 | .02 |
| Canon City/ Fremont | 26/27 | space heat Canon City | 0 | 4,264 | .76 | NA | NA | .8 | .03 |
| Don K Ranch/ Florence | 28/29 | space heat Florence | 18/4 | 1,051 | .19 | NA | NA | 2.1 | .09 |
| Clark | 30 | space heat new subdivision at Pueblo | 0 | 225 | .02 | NA | NA | .5 | .02 |

TABLE 9
CATEGORY III A
NO KNOWN ACTIVITY BUT HIGH POTENTIAL

| Area Name | Number | Use | Distance | 1975 Estimated Dwelling Units | 1975 Estimated Natural Gas Demand ($10^{12}$ Btu's) | 2020 Estimated Dwelling Units | 2020 Estimated Natural Gas Demand ($10^{12}$ Btu's) | Estimated Usable Energy Available ($10^{12}$ Btu's) | Estimated Usable Energy Available Per Year For 30 Years ($10^{12}$ Btu's) |
|---|---|---|---|---|---|---|---|---|---|
| Routt/Steamboat | 3/4 | space heat<br>Steamboat | 0 | 1,004 | .18 | 1,832 | .33 | 7.4 | .25 |
| Hot Sulphur Springs | 6 | space heat<br>Granby<br>Kremmling<br>Hot Sulphur Spgs. | <br>14<br>14<br>0 | 820 | .14 | NA | NA | 4.2 | .14 |
| Haystack Butte | 7 | space heat<br>new subdivision | 0 | 337 | .03 | NA | NA | 1.0 | .03 |
| Eldorado Springs | 8 | space heat<br>resort | 0 | 112 | .02 | NA | NA | .6 | .02 |
| Idaho Springs | 9 | space heat<br>Idaho Spgs. | 0 | 707 | .13 | 2,985 | .53 | 7.6 | .25 |
| Ouray | 49 | space heat<br>Ouray | 0 | 281 | .05 | 832 | .15 | 14.0 | .47 |
| Dunton/Geyser/ Paradise | 51,52,53 | Dunton | 0 | 10 | .002 | NA | NA | 1.6 | .05 |

Figure 7.
POSSIBLE GEOTHERMAL ENERGY DEVELOPMENT SCHEDULE
FOR COLORADO



# VIII

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