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HAYSTACK RESOURCES COMPANY
Greenhouses - Near Boulder, Colorado

May 1985

Prepared by:

Gene Culver, Associate Director and
Kevin Rafferty, Research Associate
Geo-Heat Center
Oregon Institute of Technology
Klamath Falls, OR 97601

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HAYSTACK RESOURCES COMPANY
GREENHOUSES--NEAR BOULDER, COLORADO
MAY 1985

BACKGROUND

Haystack Resources Company owns 33 acres and has water rights for up to 12,000 acre feet per year, a few miles north of Boulder, Colorado. There are two warm water wells on the property, an abandoned oil well, and a new well drilled by Haystack. The company is developing an agricultural center where greenhouses supplied with geothermal water and heating systems will be leased to growers.

The new well was completed and tested in early 1983 at the site designated as Haystack Test Well No. 3 by H.R.S. Water Consultants Inc. The following data is taken from their report to Haystack Resources Co.

Total depth: 3,250 ft

Casing program

8-5/8 in. O.D.	to 2,807 ft
5-1/2 in. O.D. plain steel	2,807 ft to 2,888 ft
Alternating 5-1/2 in. slotted and sst screen	2,888 ft to 3,230 ft
5-1/2 in. plain steel	3,230 ft to 3,250 ft

Completed in and fully penetrates the Dakota Sandstone aquifer.

Shut-in pressure: approximately 13.5 psi

Pump test results:

specific capacity @	76 gpm - .61 gpm/ft
specific capacity @	150 gpm - .43 gpm/ft
specific capacity @	250 gpm - probably less than .43 gpm/ft

Water level after 72 hrs @ 150 gpm: 407 ft

Temperature after 72 hrs @ 150 gpm: 134°F

Values calculated from pump test:

Transmissivity:	594 gpd/ft to 654 gpd/ft
Storage coefficient:	3.0×10^{-5} to 1.96×10^{-3}

More information including water analysis, pump down curves, temperatures during pumping, and computer modeling results all taken for H.R.S. Water Consultants report are included in the appendix.

Haystack has contacted several greenhouse and equipment suppliers requesting price quotes. Equipment specified was for conventional fuels even though the suppliers knew about the well. Haystack contacted the Geo-Heat Center in February requesting information on geothermal heating of greenhouses and requested a feasibility study in March.

SUMMARY AND CONCLUSIONS

1. System type is apparently already determined, at least for Phase 1, by grower preference--the preference being radiant tubes under benches.
2. A radiant system can provide the heat required to meet transmission losses. It is doubtful that a radiant system can meet the load if infiltration becomes a significant factor such as in high winds as the house loses tightness through aging. Good maintenance should be practiced.
3. An all-air system will require approximately 25% less geothermal water than a radiant system.
4. An all-air, or combination, system can provide better snow removal than a radiant system.
5. A natural gas-fired, forced-air auxillary system could provide effective peaking and snow removal.
6. Energy saver curtains must be opened when snow is expected.
7. Specific capacity of the well under peak flow conditions is expected to be between .32 and .36 gpm/foot. Average specific capacity will be higher--about .43 gpm/foot due to the fluctuating nature of greenhouse heat loads.
8. Pump setting will be determined by decisions on system type for future construction phases. Minimum head for gas separation (if downhole) should be adhered to.

PROPOSED FACILITIES

The first phase of development proposed is three gutter connected arch roof greenhouses, each 41.5 feet wide by 348 feet long. Covering is 100%

Polygal, a double structural polycarbonate sheet with a U value of 0.65. The houses will have an energy shade mounted near the roof providing an overall U value of 0.4. Desired inside temperature is 68°F and outside design temperature is -10°F. A cooling pad house 21 feet x 348 feet will be attached to one side wall, also with Polygal covering but no energy shade.

A 42 foot x 96 foot service and office building connected to the greenhouse by a 12 foot x 14.5 foot enclosed walkway will be located opposite the pad house. The service building is to be metal clad, gable roofed, with R19 insulation throughout. Inside temperature will be 68°F. Future expansion calls for an additional three greenhouses connected to the pad house.

Calculated heat losses are:

Greenhouse

transmission loss	=	2,156,548 Btu/hr
infiltration @ .75 AC/hr	=	<u>698,912 Btu/hr</u>
TOTAL		2,855,460 Btu/hr

Pad House

transmission loss	=	694,650 Btu/hr
infiltration @ 1.5 AC/hr	=	<u>216,469 Btu/hr</u>
TOTAL		911,110 Btu/hr

Service Building

transmission loss	=	15,477 Btu/hr
infiltration @ 1 AC/hr	=	<u>67,589 Btu/hr</u>
TOTAL		83,066 Btu/hr

Haystack had requested we review proposals submitted by equipment suppliers. Apparently there were some differences in the preliminary design specs submitted to us and the suppliers. We noted the following discrepancies:

1. Although the covering material was the same (Polygal), the supplier's information made no note of the energy shade. This would result in a difference in transmission loss through the roof of .4:.65.
2. Air and soil temperatures in the supplier's information were 65°F. We were requested to assume 68°F.

3. The supplier's information assumed 0 air changes per hour. Ordinarily this would be assumed for double poly houses or, perhaps, very tight structural sheet houses with no roof vents. The sketches we received showed 54 inch roof vents on the houses, double 54 inch vents on the pad house, and twenty-four 8 inch cooling vents with fans opposite the pad house. We believe that although initially infiltration may be near 0, after several years of use a more realistic value would be .75 air changes per hour.

HEATING SYSTEMS

The grower who will use the initial facilities desires radiant under bench tube heating. Several equipment suppliers can provide these systems.

Usually the systems consist of small tubes mounted under the bench screen on 4 to 6 inch centers. Inlet water temperature is 120°F to 125°F, with a 20°F water temperature drop. Thermal conductivity of the tubing is 2.6 Btu/°F/inch. System output is, therefore, 50 Btu/foot of bench area using 4 inch centers.

The bench system proposed will have 42,979 sq ft of growing area for 89.9% utilization of floor space. Heat output will be:

$$50 \cdot 42,979 = 2,148,950 \text{ Btu/hr.}$$

This is very close to the heat loss due to transmission. Overhead fan coil units with poly tube distribution can be used to make up the difference of

$$2,855,460 - 2,148,950 = 706,510 \text{ Btu/hr.}$$

In order to obtain even heat distribution 12 fan coils should be used, one at each gable end and two over the walkway in each house. These units will be required to operate only during the colder periods, the radiant system providing heat most of the time.

Geothermal water can be used directly in the radiant heat system if, and only if, care is taken in materials selection. The high hydrogen sulfide content of the water in combination with oxygen in concentrations as low as the parts per billion range can cause severe corrosion of copper and copper bearing alloys and most solders. Radiant tube systems sometimes have brass components, especially where the tubes are attached to the headers, and brass valves and soldered components. Plastic or stainless steel should be used in these components. Suppliers of all equipment and components that may come in contact with the geothermal water should be warned of the corrosive nature of the water and supplied with a water analysis.

Fan coils will have copper tubes and soldered connections and therefore cannot use geothermal water directly. Fan coils will be on a closed-loop system with stainless steel plate-type heat exchangers.

Both the fan coils and the radiant system could be on a closed-loop system eliminating the possibility of corrosion. There are, however, advantages in using the water directly. The first advantage is the reduction in size of the heat exchanger and associated control valves. At a cost of approximately \$2,500/million Btu/hr, this results in a savings of about \$5,000.

More importantly, direct use results in more efficient use of water, reduction of pumping costs, and provides the ability to increase the amount of greenhouse space on a given amount of water. Assuming 133°F water available at the exchanger and a 5°F approach, operating conditions would be:

Geothermal in 133°F
Geothermal out 110°F
Loop water out 128°F
Loop water in 105°F
Geothermal and loop ΔT 23°F

$$\text{Flow rate required} = 2,148,950 \div (500 \cdot 23) = 186 \text{ gpm}$$

Utilizing geothermal directly:

Geothermal in = 133°F
Geothermal out = 105°F
 $\Delta T = 28^\circ\text{F}$

$$\text{Flow rate required} = 2,148,950 \div (500 \cdot 28) = 153 \text{ gpm}$$

Using the heat exchanger on the radiant system requires 34 more gpm's or 22% more water to provide the same heating. Total calculated peak flows for a combination system utilizing geothermal directly in the radiant system and a closed-loop for the fan coils is:

Greenhouse	
radiant system	153 gpm
fan coils	35.3 gpm
Service building	8.4 gpm
Pad House	<u>49.8 gpm</u>
	246.1 gpm

An alternative system would be to utilize forced-air heating to provide all the heat to the greenhouse. Twelve fan coil units would be required and could be either floor mounted with under bench poly tube distribution or overhead with poly tubes. Since the fan coils can extract more heat from the water, this further reduces the peak flow for the greenhouse from 188.3 gpm to 156 gpm.

Greenhouse

All force air 12@ 11.44 gpm	= 137.3 gpm
Service building	= 8.4 gpm
Pad house	= <u>49.8</u> gpm
	195.5 gpm

So far as we can see there is no real reason to maintain the pad house at 68°F during the coldest nights. It would seem that maintaining 40°F would be more than ample to prevent freezing. On warmer sunny days, even during the main heating season when cooling may be required, the pad house would be as warm as the greenhouse due to solar heating. There should be no cold shock to the plants near the pad house when the cooling vents are open. Maintaining the pad house at 40°F would require only 32 gpm. Total peak flow would then be 177.7 gpm.

Utilizing the methods above, peak flow requirements, including future expansion, would be well within the capabilities of a single well.

Greenhouses 149,640 ft ² (incl. 5 ft in pad house)	274.6 gpm
Service building	8.4 gpm
Pad house (maintain 40°F min.)	<u>32</u> gpm
TOTAL	315.0 gpm

Fan coil selections and cost estimates for the all air system are included in the calculations in Appendix A.

Since the prospective lessee for Phase 1 development requires that 100% back-up natural gas heating be installed, this provides another method of reducing peak water flows, thereby allowing geothermal to handle the base load for a larger development. For example, a system could be designed where natural gas would handle that portion of the greenhouse load below 10°F, or 25% of the peak load. From the solar gain and load information on pp. 6-9 in Appendix A, we find the gas would be utilized approximately 260 hours per year or only 3% of the time. Time restraints on technical assistance under this USDOE grant did not allow further investigation of this option.

A word of caution on using the solar gain and heat load data on pp. 6-9 in the Appendix.

1. This data was generated using ASHRAE and Department of Defense data on the Denver area and may not be truly representative of Boulder. Actual data on Boulder is not available in the detail required for these calculations.
2. Zeros in some of the load and net load columns do not represent absolutely zero load--only that the load during that time is insignificant in relation to the total yearly load. Zeros result from averaging and rounding and engineering prudence should be used.

SNOW MELTING

Because of the high insulating factor of Polygal, snow melting must be considered. Ordinarily this is accomplished by hot water or steam fin tube radiation under the gutter area, providing more heat there. Because of the low temperature water available this will not be practical in this case.

Instead the fan coil units mounted at each end of each house to supply heat not supplied by the radiant system will be fitted with poly tube air distribution, with holes positioned to force air out toward the roof. These will be standard 180° punched hole tubes. The inboard holes then will be in nearly the standard heating position directing air downward.

Air leaving the tubes will be 110°F and about 100°F when it reaches the roof. This will produce 65 Btu/ft² heat loss through the roof at 20°F, enough to melt snowfall with .08 in. of water equivalent per hour. This is about the ASHRAE recommended design conditions for Colorado Springs for residential sidewalk snow melting. During heavy snowfalls the snow will build up on the roof but will continue to melt from underneath. The energy saver curtain must be opened when a snowfall is expected.

A purely radiant heat system would provide approximately two-thirds of the above heat loss through the roof. Snow cover is likely to remain on the roof for at least several days unless an auxiliary snow melting system is provided. This has been experienced in greenhouses in Idaho and Utah with normal forced-air systems and with no snow melting systems on well insulated houses.

WELL PERFORMANCE

Pump test data from H.R.S. Water Consultants indicates that well drawdowns, hence heating capacity, will be a major factor in future expansion of growing facilities.

H.R.S. ran two pump tests. The first was a step test at 76, 150, and 250 gpm. Specific capacities were respectively 61 gpm/foot and 150 gpm/foot. Unfortunately, the pumping level reached the pump setting before the level stabilized and H.R.S. estimated the 250 gpm capacity at less than .45 gpm/foot. In order to accurately predict specific capacities at rates greater than tested rates, data from at least three steps and preferably more are required.

H.R.S. also ran a constant rate (150 gpm) 72-hour test. Specific capacity of the well over the 72 hours was .34 gpm/foot.

Approximate trial and error graphical solutions for specific capacity using only two steps can sometimes be of value. Using these methods, we estimated, for 400 gpm flows, a specific capacity between .30 and .35 gpm/foot which agrees with the long-term test. Considering that the well is to be used for space heating and peak loads will rarely last 72 hours, the value of .34 was used to compute drawdowns for various heating options.

	Phase 1	Phase 2
Greenhouse		
radiant	153 gpm	306 gpm
fan coils	35.3 gpm	70.6 gpm
Service Bldg.	8.4 gpm	8.4 gpm
Pad House	<u>49.8 gpm</u>	<u>49.8 gpm</u>
	246.1 gpm	434.8 gpm
Drawdown @.34 gpm/ft =	723 ft	1,279 ft
Greenhouse		
all-air	137.3	274.6
Service Bldg.	8.4	8.4
Pad House	<u>49.8</u>	<u>49.8</u>
	195.5	332.8
Drawdown @.34 gpm/ft =	576 ft	979 ft

Assuming 100% natural gas back-up is required providing the opportunity for peaking, all-air systems with the pad house and service building to remain on geothermal and the pad house maintained at 40°F the amount of space available to Haystack for leasing could be doubled.

Greenhouses	412	gpm
Service Bldgs.	16.8	gpm
Pad Houses	<u>64</u>	gpm
	493	gpm

Drawdown @.34 gpm/ft 1,450 ft

Haystack should be aware of some possible problems in extrapolating reservoir conditions and specific capacities based on current information. H.R.S. noted in their report north-south structural trends and an ellipsoidal cone of depression. The 72-hour pump test draw down curve shows a nearly constant level between about 200 minutes and 2,000 minutes. This could be the result of in-leakage from fractures. At about 2,000 minutes, there is a sudden drop in water level which could be the result of an impermeable or semi-permeable boundry along a structural discontinuity. Observation Well 2 seems to indicate the same things.

In-leakage, if present, could result in either cooling or heating of the well, more likely cooling if leaking from above and heating if from below. In either case, it would be a long time considering the distance and relatively low average pumping rates. Reservoir pressure changes are seen many times faster than temperature changes.

The possibility of an impermeable boundary is probably of more concern. Even though average pump rates are low, peak rates, including future development, will be high perhaps for periods of a day or more. The boundry, if real, appeared at about 33 hours. At pumping rates of nearly 500 gpm, it would appear much sooner and could lower specific capacity much more than currently predicted.

A longer term step test with the pump setting deep enough to sustain at least 300 gpm for 72 hours while monitoring both observation wells should provide data required to more thoroughly analyze the reservoir. This may not be practical. At the very least, all three wells should be monitored during the actual operation of Phase 1 construction before proceeding with Phases 2 and 3.

Monitoring of the production well would provide valuable information to Haystack which will be very helpful in making decisions on future development. If possible, daily readings of water level should be taken early in the morning when it will be at or near the lowest level for the day, daily water temperature and a recording flow meter installed. These items, together with power consumption, will allow Haystack to predict how much additional space can be heated from this and future wells and their operating costs.

METHANE PRODUCTION

The Haystack well produces a considerable amount of high Btu methane gas dissolved in the water. It may be economical to collect and utilize this gas.

One of the pump price quotes in the Appendix includes a gas separator. This separator extracts the gas from the water expelling it into the annulus between the pump and well bore. The gas can then be collected at the surface. Another option is to separate the gas at the surface but has the disadvantage of reducing water temperature.

Methane gas, in economic quantities at least, is not a common occurrence in low temperature geothermal wells. We do not have expertise in the collection, handling and storage of gas and suggest Haystack obtain help from other sources.

Geothermal System Costs--All Air

Greenhouse		\$ 49,000
Pad House		16,000
Service Building		1,400
Mech. Equip. (HX)		13,000
Well Pump (incl. installation)		<u>36,100</u>
	subtotal	\$115,500
Labor		<u>8,000</u>
	subtotal	\$123,500
15% Overhead & Profit		18,500
20% Contingency		<u>24,700</u>
	GRAND TOTAL	\$166,700

Operating Costs--All Air @ \$.08/KWh Average Cost

Fans	.274	$\$/10^6$ Btu
Air Handlers	.312	
Well Pump	.886	
Circulating Pumps	<u>.104</u>	
	1.58	$\$/10^6$ Btu

Yearly load $5,678 \times 10^6$ Btu

First year elec. costs: \$8,971

APPENDIX

BOULDER GREENHOUSE

1

GREENHOUSE HEAT LOSS

BASIS: 68° INSIDE - 10° OUTSIDE 100% POLYCARBONATE
(INSULATION) (U=.65) 75 CH/HK 146x348
ROOF HAS ENERGY SHADE (U=.40)

SURFACE AREA:

$$\text{WALLS} = (10 \cdot 384 \cdot 2) + (10 \cdot 146 \cdot 2) + (10 \cdot 41.5 \cdot 5 \cdot 6)$$

$$= 11845 \text{ FT}^2$$

$$\text{ROOF} = (23 \cdot 384 \cdot 6)$$

$$= 52992 \text{ FT}^2$$

$$\text{SURFACE TO FLOOR RATIO:}$$

$$= (52992 + 11845) = (384146)$$

$$= 1.16:$$

TRANSMISSION LOSS:

$$\text{ROOF} = 52992 \cdot .40 \cdot 78 = 1653350 \text{ BTU/HK} \quad \Delta T \text{ FOR UNHEATED PAD HOUSE}$$

$$\text{WALLS} = 11845 \cdot .65 \cdot 78 = 600542 \quad (97344)$$

$$2156548 \text{ BTU/HK}$$

INFILTRATION @ 75 ACH

$$\text{VOLUME} = 10 \cdot 384 \cdot 146 = 560640 \text{ FT}^3$$

$$50 \cdot 41.5 \cdot 10 \cdot 384 \cdot 5 = 239040 \text{ FT}^3$$

$$(799680 - 60) \cdot .75 \cdot 1.08 \cdot 78 \cdot .83$$

$$= 698912 \text{ BTU/HK}$$

TOTAL HEAT LOSS: (GREENHOUSE)

$$= 2156548 + 698912$$

$$= 2855460 \text{ BTU/HK}$$

SERVICE BUILDING HEAT LOSS:

BASIS: 68/-10 100% METAL CLAD R-19 1 CH/HK
50x80x14.5
(50(2) + 80(2)) \cdot 14.5 \cdot 19 \cdot 78 = 15477 \text{ BTU/HK}

$$(50 \cdot 80 \cdot 14.5) \cdot (1.08 \cdot .33) \cdot (78) = 67589$$

TOTAL HEAT LOSS:

$$= 15477 + 67589$$

$$= 83066 \text{ BTU/HK}$$

PAD HOUSE HEAT LOSS:

BASIS: SAME AS GREENHOUSE EX. 1.5 CH/HK & NO ENERGY SHADE (ROOF @ .65)

$$\text{WALLS} = (384 \cdot 10) + (21.5 \cdot 10 \cdot 2) + (21.5 \cdot 10 \cdot 5 \cdot 2)$$

$$= 4485 \text{ FT}^2$$

$$\text{ROOF} = (24 \cdot 384)$$

$$= 9216 \text{ FT}^2$$

HEAT LOSS:

$$\text{WALLS} = 4485 \cdot .65 \cdot 78 = 227390 \text{ BTU/HK}$$

$$\text{ROOF} = 9216 \cdot .65 \cdot 78 = 46725$$

$$\text{INFIL} = 123290 \cdot 1.08 \cdot 78 \cdot .83 = 216469$$

$$\text{TOTAL HEAT LOSS} = 911111 \text{ BTU/HK}$$

HEAT LOSS SUMMARY:

GREENHOUSE - 2855460 BTU/HR
SERVICE BLDG - 83066
PAD HOUSE - 91111
ADJ FOR HEATED PAD HSE - (97344)

GRAUD TOTAL - 3152293 BTU/HR

USING TURE SYSTEM IN GREENHOUSE
E 132°F IN 105° OUT
∴ 27° ΔT

PEAK FLOW REQUIRED IN GREENHOUSE
 $2855460 \text{ BTU/HR} \div (500 \cdot 27) = \underline{211 \text{ gpm}}$

PEAK FLOW REQUIRED IN SERVICE BLDG
2 UNITS E 42000 BTU/HR EA.
E 200 ΔT
 $84000 \div (500 \cdot 20) = \underline{8.4 \text{ gpm}}$

PEAK FLOW REQUIRED IN PAD HOUSE
4 UNITS E 228000 BTU/HR
ASSUME HEAT EXCHANGER APPROACH OF 5°F
∴ 127° WATER TO COILS
ASSUME 13°F APPROACH TO SPACE TEMPERATURE
∴ 160 + 3 = 81°F LEAVING WATER
114°F LEAVING AIR

COIL SELECTION

EA	-	68°		
LA	-	114°	105	
EW	-	127		
LN	-	81	90	90
CEN	-	3580	-	5706
FA	-	6.00		9.5
FDS	-	4		
CODE	-	11		
EL	-	5000		
ROW	-	5	5	
FPI	-	35.3	18	87(9)
AIR	-			.58
EPN	-			
BTU	-			

4

11.7(2)

.58

12.44

130122

6

$12.44 \cdot 4 \text{ UNITS} = \underline{49.8 \text{ gpm}}$

TOTAL FLOW RATE:
 $49.8 + 8.4 + 211 = \underline{269 \text{ gpm}}$

MAIN GREENHOUSE

USING FORCED AIR HEATING IN MAIN GREENHOUSE

@ 4 UNITS / MODULE

12 UNITS IN ALL

REQUIRED CAPACITY:

$$2855460 \text{ BTU/Hr} \div 12 \text{ UNITS} = 237955 \text{ BTU/Hr EA}$$

COIL SELECTION

EA -	68			
LA -	105	11.4	1	110
EW -	127			
LW -	90	8.1	85	155
CFM -	5956	479		5246
FA -	10.0	8.0		8.75
FDS -	4			
CODE -	1			
EL -	5000			
ROW -	4	6		
FPI -	(1.5)12			11.4(12)
AREA -	.58			.87
GPM -	1298			11.44
BTU -	240205			240162

FLOW REQUIREMENT

$$12 \text{ UNITS @ } 13 \text{ gpm} = 156 \text{ gpm} \quad 37$$

$$211 - 156 = 55 \text{ gpm}$$

$$55 \div 211 = 26\% \text{ REDUCTION FROM TUBES.}$$

COMPARE FORCED AIR UNITS TO BIOTHEK TUBES.

FROM BIOTHEK QUOTE:

MATL	\$ 58426	(MATEKA MINUS GAS HEATERS)
LABOR	14002	76,926
	\$ 73488	
	91,888	

FORCED AIR SYSTEM COSTS

4 ROW 12 FIN 10 FT ² COIL -	2000
FAN 2000 CFM .65 in wg 1.5 HP	930
BOX	500
	<u>3430</u>

ACCESSORIES

AIR VENT	-	4
2" GATES @ 16	-	32
FLOW CONTROL VALVE	-	24
3WAY CONTROL VALVE	-	120
STRAINER	-	27
		<u>209</u>

$$12 \text{ UNITS @ } (3430 + 209) = \$43668$$

PIPING REQUIREMENTS @ 13 gpm/unit
IN MAIN GREENHOUSE

(4)

ASSUME 12 UNITS @ PER SIDE ALONG OUTSIDE WALLS.
FLOW ED LOOP = $6 \times 13 = 78$ gpm

3" - 320 (2) = 640	@ 3.44 = \$2202
2 1/2" - 240 (2) = 480	@ 2.71 = 1301
2" - 120 (2) = 240	@ 1.87 = 449
1 1/2" - 120 (2) = 240	@ 1.37 = 329
	<u>4281</u>
ADD FITTINGS 25%	1070
	<u>\$ 5351</u>

PIPING FOR PAD HOUSE:

4 UNITS @ 12.5 gpm ED.	
2 1/2" 100 (2) = 200	@ 2.71 = \$542
2" 100 (2) = 200	@ 1.87 = 374
1 1/2" 100 (2) = 200	@ 1.37 = 274
	<u>1190</u>
ADD 25% FITTINGS	298
	<u>\$ 1488</u>

4 UNITS FOR PAD HOUSE @ 3609 ea
\$ 14436

PIPING FOR SERVICE ROAD

ALONGSIDE

150' (2) @ 1" @ 1.14	= 228
25% FITTINGS	57
	<u>285</u>

2 HOT WATER UNIT HEATERS

@ 350 \$/ea	- \$350
AIR VENT	- 6
GATES (2)	- 32
3 WAY VALVE	- 120
STRAINER	- 27
FCV	- 24
	<u>\$ 559</u>

MECHANICAL PANT EQUIPMENT

HEAT EXCHANGER 4 MOP BR/Hr	- \$1000
4- 4" GATE VALVES @ 150	= 600
1- 4" STRAINER	= 935
2- PRESS GAGE @ 10	= 20
2- THERM @ 24	= 48
2- CIRC PUMPS 220 gpm @ 50'	= 2340
1- 4" GEO WATER VALVE	= 530
1- 100 GAL EXP TANK	= 200
1- MAKE UP & FILL	= 150
10% MKL MECH & ELE	1183
	<u>1183</u>
TOTAL	<u>\$ 13016</u>

EQUIPMENT ALL SUMMARY
 GREENHOUSE - 49019
 PAD HOUSE - 15924
 SERVICE BLDG - 1403
 PLANT - 13016
\$ 79362

LABOR - ALLOW 4 MAN CREW 2 WKS, @ 25\$/hr man
= 8000

ADD GAS FIRED HEATERS
14106

\$ TOTAL	101468
15% OVER O&P	11904
20% L&T	22674
GRAND TOTAL	<u>136046</u>

BOULDER SOLAR GAIN FROM 42x120 DATA
 HAYSTACK HOUSE EAST WALL - 3840 FT²
 WEST WALL - 3840
 ROOF - 52992

42x120 DATA
 1200 8.2
 1200 3.2
 5520 9.6

- SOLAR GAIN -

	1-5	6-8	9-16	17-19	20-24
J	11.97	59.6	841.6	54.4	19.6
F	14.8	95.4	1028	65.9	26.3
M	16.4	84.2	1161	75.2	29.9
A	16.6	86.1	1189	76.8	30.4
M	16.0	85.5	1141	74.2	29.4
J	20.2	99.8	1299	72.7	29.1
J	17.6	91.5	1261	81.9	32.2
A	17.3	89.6	1234	80.0	31.7
S	17.0	87.4	1207	78.1	31.0
O	14.9	69.8	1054	68.2	26.9
U	11.9	77.1	842	52.8	21.1
D	10.2	50.6	716	45.5	18.2

- HEATING LOAD -

J	331	199	439	178	297
F	229	138	311	132	221
M	286	172	358	133	222
A	215	129	173	84	141
M	108	65	85	353	53
J	43.5	33	150	12	19
J	0	0	0	0	0
A	0	0	0	0	0
S	102.4	61.5	236	27	45
O	176	105	124	77	127
U	296	178	330	152	253
D	307	185	408	281	169

- NET LOAD -

J	319	139	0	124	277 = 859
F	214	43	0	66	195 = 513
M	270	88	0	57.3	192 = 608
A	198	43	0	7	111 = 359
M	92	0	0	0	24 = 116
J	23	0	0	0	0 = 23
J	0	0	0	0	0 = 0
A	0	0	0	0	0 = 0
S	85.4	0	0	0	14 = 99
O	161	35	0	9	100 = 305
U	284	101	0	99	232 = 716
D	297	134	0	235	151 = 817
			0		4420

CLOUDY WEATHER ADJUSTMENT

	MPPS	W-MPPS	619 LOAD	CLOUD LOAD	80
J	.67	.33	816	269	215
F	.67	.33	581	192	154
M	.65	.35	663	232	186
A	.63	.37	586	143	114
M	.61	.39	185	72	58
J	.69	.31	61	19	15
J	.68	.32	0	0	0
A	.68	.32	0	0	0
S	.71	.29	113	33	26
O	.71	.29	306	89	71
N	.67	.33	660	248	174
D	.65	.35	814	306	245
			<u>4645</u>	<u>1573</u>	<u>1258</u>

TOTAL MONTHLY LOAD					
	NET LOAD	CLOUD LOAD	$\times 10^4$ TOTAL	$\times 10^4$ GAL/MO C 40	AVE GPM
J	859	215	1074	3.22	72
F	518	154	672	2.02	
M	608	186	794	2.38	
A	359	114	473	1.42	
M	116	58	174	.522	
J	23	15	38	.114	
J	0	0	0	0	
A	0	0	0	0	
S	99	26	125	.375	
O	305	71	376	1.13	
N	716	174	890	2.67	
D	817	245	<u>1062</u>	<u>3.19</u>	
			5678	17.04	→ 32 gpm

156 gpm @ 42° Δt
 50 gpm @ 37° Δt
 8 gpm @ 20° Δt

$$\frac{(156 \cdot 42) + (50 \cdot 37) + (8 \cdot 20)}{(156 + 50 + 8)} = 40.0^\circ \text{F } \Delta t$$

OPERATING COST OF AIR HANDLERS

$$5678 \times 10^6 \text{ BTU/YR} = 3752 \times 10^6 \text{ BTU/HK} \\ = 1513 \text{ HK/yr} \quad 504 \quad 1700 \quad (\text{FOR START/STOP})$$

$$1700 \text{ HK/yr} \cdot [(4 \text{ W. FS} \cdot .81 \text{ KW}) + (12 \text{ W. FS} \cdot .82)] \\ = 22168 \text{ kWh/yr} @ .08 = \underline{1773 \text{ \$/yr}}$$

ELECTRICAL ENERGY COST PER 10^6 BTU - FANS
UNIT 240000 BTU/HK @ .82 KW
 $(10^6 - 240000) \cdot .82 = 3.42 \text{ kWh} / 10^6 \text{ BTU}$
@ .08 \\$/kWh = .274 \\$/ 10^6 BTU

ELECTRICAL ENERGY COST PER 10^6 BTU - WELL PUMP
@ 40 PSI WELL HEAD
.43 gpm/ft

@ PEAK (214 gpm)
 $214 \div .43 = 497'$
 $40 / .433 = \frac{92}{589'}$

ASSUME OVERALL PUMP/DRIVE EFF OF .50 $(.667 \cdot .94 \cdot .80)$
 $1000000 \div (8.33 \cdot 40) = 3000 \text{ gal}$
 $3000 \div 214 = 14 \text{ min}$
 $(214 \cdot 8.33 \cdot 5.09) \div (.50 \cdot 33000) = 636 \text{ HP} \cdot .746 = 47.5 \text{ KW}$
 $47.5 \cdot (14/60) = 11.1 \text{ kWh} / 10^6 \text{ BTU}$
@ .08 \\$/kWh = .886 \\$/ 10^6 BTU

ELECTRICAL ENERGY COST PER 10^6 BTU - WELL PUMP
@ 75 PSI @ .43 GPM/FT

@ PEAK (277 gpm)
 $277 \div .43 = 644'$
 $75 / .433 = \frac{173}{817'}$

@ OVERALL EFF. OF .50

$1000000 \div (8.33 \cdot 27) = 4446 \text{ GAL}$
 $4446 \div 277 = 16.1 \text{ MIN}$
 $[(277 \cdot 817 \cdot 8.33) \div (.50 \cdot 33000)] \cdot .746 = 85.2 \text{ KW}$
 $85.2 (16.1/60) = 22.9 \text{ kWh} / 10^6 \text{ BTU}$
 $22.9 \cdot .08 = 1.83 \text{ \$/} 10^6$

BIN	TOTAL HOURS	%	ENERGY	9-16 hrs	Total minus 9-16	%
62	794	.118	670	245	549	063
57	776	.115	657	237	539	062
52	739	.110	625	244	495	057
47	729	.108	613	228	501	057
42	752	.112	636	198	554	063
37	724	.108	613	166	558	064
32	704	.105	590	158	546	062
27	555	.082	466	120	435	050
22	394	.059	335	73	321	037
17	243	.036	204	40	203	023
12	137	.020	114	24	113	013
7	84	.012	68	17	67	008
2	54	.008	45	10	44	005
-3	22	.003	17	5	17	002
-8	13	.002	11	1	12	001
-13	5	.0007	4	0	5	0005
-18	3	.0004	2	1	2	0002
-23	1	.0001	1	0	0	0
	<u>6729</u>	<u>.77</u>		<u>1767</u>	<u>4962</u>	<u>.57</u>

PRODUCTION WELL PUMP DESIGNED FOR MAXIMUM WELL PROD.

BELOW GROUND SURFACE)

Figure 8

CENTRILIFT—HUGHES

5421 ARGOSY AVENUE • HUNTINGTON BEACH, CA 92649
(714) 893-8511
(213) 598-9711

March 26, 1985

Geo Heat Center
Oregon Institute of Technology
Klamath Falls, Oregon 97601

Attention: Gene Culver

Reference: Centrilift-Hughes Proposal #2205-04-22-0424

Gentlemen:

Centrilift-Hughes is pleased to present for your consideration our equipment selections based on available data.

On our quotation #2205-04-22-0424, we have listed our 60 HZ design sized for 500 GPM and a total head of 1674'. All equipment specifications, i.e., length, weight, diameters, etc., can be found on the attached quotation sheet.

The constant speed (60 HZ) design noted above requires our 675 Series pump which will not accomodate a gas separator. Since you indicated that you have about 14% gas, I have also included a pump design - our 513 Series - which can be used with a gas separator.

In order to obtain the maximum flow possible from the gas separator design, we use a Variable Frequency Controller to run the pump from approximately 280 to 433 GPM (64 to 84 HZ). This is the maximum capacity at which we can run this pump.

We should also point out that the amount of gas may result in gas interference if the pump intake pressure is below 50 PSIG. By utilizing our Variable Frequency Controller, it would be a very simple procedure to "Dial" in a pump intake pressure and maximize production rates. I have included a brochure and curves detailing various benefits by using our V.F.C.

Our quotation includes everything necessary for a complete installation with the exception of tubing.

*Denver Rep
George Repchak
1873 S. Belaire St. suite 825
Denver CO 80222
(303) 691-5041*

A DIVISION OF HUGHES TOOL COMPANY

CENTRILIFT—HUGHES, Inc.

Geo Heat Center
March 26, 1985
Page 2

Centrilift-Hughes' terms are Net Thirty Days and our prices are F.O.B. Claremore, Oklahoma. The quoted prices do not include any applicable taxes, express charges, service upon installation or small stores items.

We appreciate this opportunity to quote on your requirements. Please call me at (714) 893-8511 if you would like further information.

Regards,

CENTRILIFT-HUGHES

Doug Hill
District Sales Manager

Enclosures

DH:sd

cc: Dave Tetreault

D-225B

CENTRILIFT-HUGHES EQUIPMENT QUOTATION

A DIVISION OF HUGHES TOOL COMPANY
200 W. Stuart Roosa Dr. • Claremore, Oklahoma 74017 • (918) 341-9600

DATE 3-26-85

Geo Heat Center

QUOTATION NO. 2205-04-22-0424A

Oregon Institute of Technology

SALESMAN Doug Hill

Klamath Falls, Oregon 97601

PUMP RATING	CAPACITY	TOTAL HEAD	FREQUENCY
	280 GPM	1675	64
	433 GPM	1675	84 Hertz

ATTN: Gene Culver

WELL NAME

FIELD NAME

LOCATION Boulder, Colorado

WELL DATA	SP.GR. 1.0	PERFS	SETTING DEPTH 1500	H ₂ O % 100		
	B.H.T. 134°F	PRIMARY VOLTAGE -480-	REQ. SURFACE VOLTAGE 3121	REQUIRED KVA 432		
	G.O.R. 14%	CASING O.D. 8 5/8	WEIGHT 28.5	TUBING SIZE 5½		
	NET LIFT 1400	SURFACE PSI 75 PSIG	FRICTION LOSS 112	T.D.H. 1685		
DOWNHOLE EQUIPMENT	☐ VARIABLE MOTOR	FREQUENCY H.P. 300	☐ 60 HERTZ VOLTAGE 2200	☐ 50 HERTZ AMPERAGE 80	WEIGHT 3545	PRICE 42,535.00
	PUMP 67	SERIES 725	MODEL HMB	LENGTH 25.8	990	10,922.00
		TYPE D225B	SERIES 513	MODEL GP-MT		
		HSG. NO. 14	HEAD SIZE 2 7/8	LENGTH 22.3		
	PUMP INTAKE	SERIES	MODEL	LENGTH		
	PUMP DSCHRG.	SERIES 513	MODEL GP	LENGTH .7	16	210.00
	GAS SEPARATOR	SERIES 513	MODEL GRS	LENGTH 3.25	130	3,650.00
	SEAL SECTION	SERIES 675	MODEL HSBP	LENGTH 7.7	480	4,775.00
	POWER CABLE	LENGTH 1600'	TYPE Centriline 200 #2			6,720.00
	FLAT CABLE	LENGTH 35'	TYPE CL 81	SERIES 725		995.00
	FLAT GUARDS					
	CABLE SADDLES					
	CABLE BANDS	125 22" Stainless Steel				122.50
	CABLE BANDS	25 30" Stainless Steel				28.75
	SWAGED NIPPLE					
	CHECK VALVE					
	DRAIN VALVE					
	SURFACE EQUIPMENT	EQUIPMENT COATING	TYPE	LENGTH		
MOTOR CONTROLLER		MODEL	SIZE	VOLTAGE		
ACCESSORIES INCLUDE: OVERLOAD ☐ UNDERCURRENT S.D. ☐ RECORDING AMMETER ☐ AUTO RESTART ☐ LIGHTING ARRESTER ☐ OTHER						
VARIABLE FREQUENCY CONTROLLER:			500 KVA			79,950.00
TRANSFORMERS		SIZE	TYPE			
		PRIMARY TAPS 480	SECONDARY TAPS 1905 - 3811			
OPTIONS	VARIABLE FREQUENCY TRANSFORMER		500 KVA			16,310.00
	JUNCTION BOX (VENTED-SAFETY)	JKV				395.00
	TUBING HEAD	8 5/8 x 5½ x #2 Round HHS				1,055.00
SERVICING EQUIP.					SUB-TOTAL	167,668.25
	CABLE GUIDE			Discount		(41,917.00)
	CABLE REEL					
	REEL SUPPORT	AS				
	SHIPPING CASE	REQUIRED				
	SHIPPING CASE					
	SHIPPING CASE					
NOTE: SERVICING EQUIPMENT MAY BE RETURNED FOR 100% CREDIT WITHIN 6 MO.					TOTAL	125,751.25

3001-MKT 7/83

CENTRILIFT-HUGHES RESERVES THE RIGHT TO USE FACTORY RECONDITIONED PARTS IN THE ASSEMBLY OF ITS PRODUCTS • TERMS-NET 30 DAYS • F.O.B. CLAREMORE OK