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GEOTHERMAL FEASIBILITY STUDY
FOR
MALTING INVESTMENTS INC.

October 1981

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by

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1.0 INTRODUCTION

The purpose of this study is to determine the engineering feasibility of using geothermal heat in the kilning, germination, and steep water cooling processes for a malting facility. The study is based upon a malting facility with an annual capacity of malting three million bushels of clean graded barley per year or 8,220 bushels per day.

Capital cost figures used in the feasibility study are budget prices for the basic equipment only, they do not include any other costs such as installation, instrumentation or design and engineering costs.

Utility prices are based upon \$0.03 per kilowatt hour and \$0.4548 per therm for natural gas.

2.0 SCOPE OF STUDY

The study includes the following:

- . Estimated refrigeration requirements for steep water and germination spray water requirements.
- . Estimated refrigeration requirements for germination cooling.
- . Cooling tower make up water, maximum and yearly demand.
- . Estimated BTU requirements for kiln operation, showing the peak demand, and a typical daily demand for each month of the year, indicating peaking requirements (additional BTU's required).
- . Estimated geothermal water requirements per year.
- . Effluent disposal
- . Estimated yearly supplementary energy requirements for kilning, germination, steep water and spray water requirements.
- . Discussion regarding the use of whatever geothermal water is required for the process operations from the existing source, versus using supplementary energy to reduce the geothermal flow requirement to 800 gpm.

3.0 SUMMARY OF STUDY

The refrigeration study shows that there is no advantage in using geothermal heat to provide refrigeration, therefore, electrically driven centrifugal refrigeration compressors are recommended.

The kiln study shows there is a distinct operating cost advantage in using geothermal heat, provided the cost of geothermal heat is less than that of natural gas.

Based upon the temperature of the geothermal water being 190°F, the average annual requirements would be two hundred million gallons. When the kiln is in operation the annual average geothermal flow rate would be 760 gallons per minute. Under extreme conditions with an outside temperature of - 12°F the maximum geothermal flow rate would be fourteen hundred gallons per minute.

Effluent would be about 260,000 gallons per day and would be treated to a sufficient degree to permit its use for irrigation purposes.

4.0 REFRIGERATION REQUIREMENTS

The maximum hourly refrigeration load for the cooling of steep water, germination spray water, and germinating barley has been calculated to be 711 tons, and 750 tons of refrigeration has been allowed for. The average monthly refrigeration loads have also been calculated, and are listed below. The above calculations are included in Appendix A.

Average monthly refrigeration loads:

	<u>Ton Hours</u>
January	68,230
February	61,627
March	68,230
April	66,030
May	122,508
June	199,566
July	274,738
August	255,237
September	187,538
October	101,586
November	66,030
December	<u>68,230</u>
	1,539,550

These loads can be met by using either centrifugal compressors or absorption refrigeration.

Absorption Refrigeration:

Two absorption refrigeration units would be required, each with a capacity of 375 tons. Hot water would be required at 670 gpm entering the unit at 185°F. This water would be in a closed loop and would be of good quality to avoid scale up and corrosion of the absorption refrigeration units. The water would be heated via a plate and frame heat exchanger using 670 gpm of geothermal water, entering at 190°F and exiting at 165°F. The exit water would be returned to an injection well.

Capital Cost:

Absorption refrigeration 750 ton.	\$515,000
Plate and frame heat exchanger.	<u>\$ 30,500</u>
Total	\$545,500

Annual operating cost (allowance for the cost of geothermal water has not been made.)

Two 30 HP unit pumps

$$1,539,550 \times 60 \times 0.97 \times \$0.03/750 = 3,584$$

20 HP water pump

$$1,539,550 \times 60 \times 0.8 \times \$0.3/750 = \frac{2,955}{6,539}$$

Centrifugal Compressors:

Two centrifugal compressors would be required, each with a capacity of 375 tons and rated at 0.82 KW/ton.

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Capital Cost:

Two centrifugal compressors at 375 tons each rated at 0.82 KW/ton

Net total cost \$97,500

Annual Operating Cost

$1,539,550 \times 0.82 \times \$0.03 = \$37,873$

Cooling Tower Refrigeration:

Two cooling towers will be required, one for refrigeration to cool 1,875 gpm from 87°F to 75°F and the other to cool 300 gpm of steep water and germination spray water from 100°F to 70°F.

Capital Cost: \$36,000

Annual operating cost

Operating hours $1,539,550/750 = 2053$

Fans 45HP $\times .08 \times 2,053 \times 0.03 = \$ 2,217$

Pump 70HP $\times 0.8 \times 2,053 \times 0.03 = \$ 3,449$

Total annual operating costs \$ 5,666

Annual make up water $2,053 \times 60 \times 45 = 5.5 \times 10^6$ gallons

Annual blow down water $2,053 \times 60 \times 21 = 2.6 \times 10^6$ gallons

Cooling tower steep water and germination spray water.

Capital Cost \$12,000

Annual operating cost

Operating hours $365 \times 12 = 4,380$

Fan 10HP $\times 0.8 \times 4,380 \times 0.03$ \$1,051

Pump 10HP $\times 0.8 \times 4,380 \times 0.03$ \$1,051

Total annual operating costs \$2,102

Annual make up water $4,380 \times 60 \times 24 = 6.9 \times 10^6$ gallons

Annual blow down water $4,380 \times 60 \times 8 = 2.1 \times 10^6$ gallons

Reviewing the capital cost and operating costs of the absorption refrigeration system and the centrifugal compressors. The capital cost of the absorption refrigeration system is \$448,000 more than the cost of the centrifugal system, although the absorption system annual operating costs are \$31,334 less per year. This represents a 14 year pay back. Consideration has not been made for the cost of geothermal water. Thus a centrifugal compressor system would be recommended.

Since cool water is not available, 211,000 gallons per day have to be cooled to 55°F to provide steep water and germination spray water. In order to keep the tonnage of the refrigeration system as low as possible, this load of 2,200 tons per day will be spread over a period of hours and the chilled process water will be stored in a 211,000 gallon storage tank. This will ensure ready availability at steeping in. More importantly however, it will provide an excellent buffer to utilize the refrigeration system and the cooling tower at their maximum efficiency. This will be considered, in detail, in the preliminary and final engineering stages. Also considered, will be alternative methods of cooling the steep and germination water to reduce refrigeration requirements during the cool weather.

5.0 KILN REQUIREMENTS

The Btu requirements for kiln operation are based upon the following:

The kiln would have two floors and the kilning cycle would be twelve hours. During the first eight hours of the cycle the kiln air would flow only through the upper bed. During the last four hours the kiln air would flow through both the lower and upper bed.

Air flow to the kiln heating unit was based upon 243 pounds of dry air per bushel of malt per hour. At kiln exhaust conditions of 80°F dry bulb, 90% relative humidity and an atmospheric pressure of 25.818 inches of mercury the volume of the exhaust air would be equivalent to 65.9 cubic feet per minute. The above flow would be maintained for the first ten hours after which it would be reduced to 182.3 pounds of dry air per bushel. During this latter stage of high temperature kilning, cool air would be bypassed into the space below the upper bed to ensure the kiln air temperature was reduced before passing through the upper bed.

All climatic data is based upon USAF ETAC hourly observations for Klamath Falls during the following periods:

January '48 - December '54

September '59 - March '69

May '69 - May '70

The low temperature used for determining peak demand is - 12°F as the above climatic data indicates that extremes below - 12°F are not significant.

In Appendix - B (kiln), the following data has been included:

Average daily kiln heat requirements for each month of the year with and without exhaust kiln air heat recovery.

Maximum kiln heat requirements at - 12°F with and without exhaust kiln air heat recovery.

Summary of kiln heat requirements shown in the Appendix B.

	<u>Without Heat Recovery</u>		<u>With Heat Recovery</u>	
	<u>Daily</u>	<u>Monthly</u>	<u>Daily</u>	<u>Monthly</u>
	Btu x 10 ⁶	Btu x 10 ⁹	Btu x 10 ⁶	Btu x 10 ⁹
January	648.0	20.09	401.0	12.43
February	615.6	17.24	397.2	11.12
March	592.5	18.37	391.4	12.13
April	551.2	16.54	388.7	11.66
May	508.3	15.77	385.3	11.94
June	463.9	13.92	385.8	11.57
July	408.0	12.65	364.1	11.29
August	426.7	13.23	372.5	11.55
September	461.5	13.85	386.2	11.59
October	522.2	16.19	387.9	12.02
November	592.3	17.77	391.2	11.74
December	642.9	<u>19.93</u>	401.4	<u>12.44</u>
		195.55		141.48

Maximum Btu per hour demand at -12°F outside air temperature without heat recovery is 80.2×10^6 with heat recovery the maximum Btu per hour demand is reduced to 43.2×10^6 .

Capital and operating costs for a conventional kiln with and without heat recovery are compared to those for a geothermal heated kiln below.

Conventional kiln indirect heating without heat recovery.

Capital Cost

Indirect heating units with

controls 80.2×10^6 BTUH

maximum demand.

Total

\$785,000

Annual operating costs

Natural gas 45.48 cents per therm,

electric power 3.0 cents per KWHR

$$\frac{195.55 \times 10^9 \times 0.4548}{10^5} = 889,361$$

Connected horsepower 230

$$230 \times 0.8 \times 12 \times 365 \times 0.03 = 24,178$$

Total operating costs

\$913,539

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Conventional kiln indirect heating with heat recovery.

Capital cost

Indirect heating units with
controls 43.2×10^6 BTUH \$ 678,000
maximum demand.

Heat recovery system	<u>666,621</u>
Total	\$1,344,621

Annual operating costs

Natural gas 45.48 cents per therm,
electric power 3.0 cents per KWHR

$\frac{141.48 \times 10^9 \times 0.4548}{10^5}$	=	\$643,451
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Connected horsepower 160

$160 \times 0.8 \times 12 \times 365 \times 0.3$	<u>16,819</u>
Total operating costs	\$660,270

Geothermal Kiln Heating

The proposed method of heating the kiln with geothermal water is shown on the attached sketch Figure 1, which depicts the worst case with an outside air temperature of -12°F .

Geothermal water will be pumped to a plate heat exchanger, where it will heat a glycol solution that will be used as the heating medium for the kiln heating coils. The geothermal water from the heat exchanger will flow to a reinjection well. The purpose of

using a heat exchanger, is to protect the kiln heating coils from the corrosion and scale up that would result if geothermal water was circulated directly in the coils. The plate heat exchanger is simple to dismantle and can be descaled more easily than the heating coils. The heat exchanger will be capable of heating the glycol solution to within 5°F of the geothermal water.

The system will be capable of heating the kiln air up to 155°F without the use of supplementary heat. When kiln air is required at temperatures above 155°F the glycol solution will be heated by a hot water heater so as to provide the desired kiln air temperature. At high heat kiln conditions, when the kiln air is required at 185°F, the glycol solution will be heated to 210°F.

The kiln air drying cycle of times and temperatures will be controlled by a data trak unit KTC. The kiln air temperature will be controlled by a temperature indicator controller. The set point of this controller will be an input from the data trak unit KTC. During the period that the kiln air is between 120°F and 155°F the flow of geothermal water to the heat exchanger will be modulated by a bypass valve. When kiln air temperatures above 155°F are required, the high temperature switch TSH will operate two solenoid valves, the first will close the geothermal bypass valve, and open the natural gas supply valve. The second solenoid valve will open the glycol solution inlet valve to the water heater and will close the glycol solution valve between the heat exchanger and the kiln heating coils. The glycol solution will be heated in the water heater to provide the desired kiln air temperature as set by the data trak unit KTC. The temperature indicator controller will modulate the gas supply valve to the hot water heater.

Capital cost:

Heat exchanger	\$217,000
Hot water heater	46,000
Heating coils	<u>580,000</u>
Total	\$843,000

Annual operating cost (allowance for the cost of geothermal water has not been made.)

Glycol recirculation pump 60HP

$$60 \times 0.8 \times 12 \times 365 \times \$0.03/\text{KWH} \quad \$ 6,307$$

Supplementary heat at 10.9×10^6

for 2 hours per day. Natural

gas \$0.4548 per therm

$$\frac{10.9 \times 10^6}{10^5} \times 2 \times 365 \times 0.4548 = \frac{\$ 36,188}{\$ 42,495}$$

In heating the kiln with geothermal water source at 190°F , the need for supplementary heat occurs only during the time that the kiln air temperature is above 160°F . In the kilning cycles outlined in this report, temperatures in excess of 160°F are only required for 2 hours when the air flow rate has been reduced to 182.3 pounds of air per bushel. Thus supplementary heat required is $182.3 \times 8220 \times 0.02405 \times 30 = 10.9 \times 10^6 \text{ BTU/Hr.}$

WHEN THE EXHAUST AIR TEMPERATURE REACHES 155°F, NATURAL GAS WILL BE USED TO SUPPLEMENT THE GEOTHERMAL HEAT. THE GAS SUPPLY WILL BE MODULATED TO MAINTAIN AN EXHAUST AIR TEMP. AT 155°F.

Fig. 1

6.0 ESTIMATED GEOTHERMAL WATER REQUIREMENTS PER YEAR

<u>Month</u>	<u>Average Daily Water Requirement</u>	<u>Days/Month*</u>	<u>Total Monthly Water Requirement</u>
January	917.5 GPM	31	20.5x10 ⁶ Gallons
February	870.0	28	17.5
March	836.2	31	18.7
April	775.7	30	16.8
May	712.8	31	15.9
June	647.8	30	14.0
July	565.9	31	12.6
August	593.3	31	13.2
September	644.2	30	13.9
October	733.2	31	16.4
November	835.9	30	18.1
December	910.0	31	20.3

Total Gallons Required Per Year = 197.9x10⁶

* 1 Day = 12 operating hours.

In considering the possibility that the supply of geothermal water could be restricted to 800 gpm, the simplest solution to provide for average conditions, would be that of storage.

Average geothermal water requirements for January are 917.5 gpm, thus, during the kilning cycle of twelve hours, 660,600 gallons of geothermal water will be required. If the flow rate was restricted to 800 gpm, the quantity available would be 576,000 gallons. Thus, storage facilities would be required for 84,000 gallon and the pumping cycle from the geothermal well would be extended from 12 hours to 13.76 hours.

The feasibility of geothermal water storage to reduce supplementary energy costs, during extreme conditions would be considered in the preliminary engineering phase.

7.0 EFFLUENT DISPOSAL

Steeping and germinating operations are the primary and secondary, wastewater sources from malting operations. Malting wastewater contaminants consist principally of highly soluble organic compounds, most of which are readily biodegradable. The actual quantities of wastewater and contaminants can vary significantly from plant to plant, depending on the number of steep water changes and the contact time for each change.

The quantity of wastewater produced by the malting facilities including clean-up and cooling tower blow down is estimated to be approximately 260,000 gallons per day. This amount does not include the sanitary wastewaters.

It is proposed to treat the production wastewater on-site to a degree sufficient to allow its use, after treatment, for irrigation purposes. Sanitary wastewaters will be separately collected and disposed of.

For purposes of this study it is assumed that the method of treatment of process wastewaters will be the activated sludge process, (an aerobic biological treatment method). Treated and clarified process wastewaters will be accumulated in an aerated storage pond for use as irrigation water. Excess biological sludge generated in the biological treatment system can be periodically withdrawn and applied to pasture or crop land.

Sanitary wastewaters generated by the estimated 10 employees at the site will be discharged to a septic tank and then disposed of to a leaching system.

It is estimated that the order-of-magnitude capital cost associated with construction of appropriate wastewater treatment facilities would be approximately \$300,000 exclusive of irrigation disposal facilities or plant process sewers.

8.0 LIFE CYCLE COST ANALYSIS

Life cycle cost analysis for the conceptual geothermal Barley Malting Plant at Klamath Falls, Oregon, appears in the following table.

It was assumed that the system would come on line in 1982. The 20 year forecasts assume a seven percent economic inflation rate over the project life, and additional inflation rates for conventional fuels as forecast by the Oregon Department of Energy "Fifth Annual Report" as follows:

Natural Gas

9.0% through 1984
9.2% through 1989
10.0% through 1994
10.2% through 2001

Electrical Power

7.9% through 1987
9.1% through 2001

Column 1 provides the difference between the natural gas costs for a conventional plant versus a geothermal plant and projects these cost savings over the next 20 years at the assumed rate of inflation for natural gas.

Column 2 provides the difference between the electricity costs for a conventional plant versus a geothermal plant and shows these cost increases over the next 20 years at the assumed rate of inflation for

electricity. Since these costs are higher for the geothermal system they are assigned to that system and subtracted from column 1.

Column 3 provides the difference between maintenance costs for a conventional plant versus a geothermal plant and shows these cost increases over the next 20 years at the assumed annual economic inflation rate. Since these costs are higher for the geothermal system they are assigned to that system and subtracted from column 1.

Column 4 calculates the net operating income for each of the 20 years by subtracting columns 2, 3 and the annual depreciation cost for years 1 through 5, from column 1.

Column 5 calculates the annual percentage depletion allowance for the geothermal system based on the appropriate percentage allowed for the year or 50 percent of net operating income, whichever is lower.

Column 6 subtracts the calculated depletion allowance from column 5 to arrive at the net income before taxes.

Column 7 calculates the federal income taxes owed due to the net annual savings of the geothermal system assuming a 46% tax rate.

Column 8 is column 7 subtracted from column 6.

Column 9 adds the depletion allowance, the first year tax credits and the depreciation expense for the first five years. These amounts

are then added to column 8 to arrive at the 20 year after tax cash flow which is presented in column 10.

Column 11 discounts the cash flows from column 10 at the calculated rate of return to arrive at a net present value equal to the additional capital investment required for the geothermal plant.

It should be noted that only the difference in costs of the energy systems were considered in this analysis. The total capital cost of \$729,100 represents the additional amount of capital required for the geothermal system. The total cost of the geothermal system was estimated to be \$1,031,600. This cost includes two production wells drilled to 750 feet, supplying 1100 gallons per minute of 224°F fluid.

Business and energy tax credits were taken on the entire cost of \$1,031,600 assuming that drilling costs would be capitalized rather than expensed in the first year. The assumption was also made that there would be sufficient tax liability to take the entire tax credit in the first year.

TABLE 1

LIFE CYCLE COST ANALYSIS
FOR
A GEOTHERMAL BARLEY MALTING PLANT

INVESTMENT
TAX CREDIT 440175

STRAIGHT LINE
DEPRECIATION 352140

EQUITY FINANCING 729100
DEBT FINANCING 0
COST OF CAPITAL 15%
TOTAL CAPITAL COST 729100
NET PRESENT VALUE 729100
RATE OF RETURN 163.3785%

	1	2	3	4	5	6	7	8	9	10	11 ^a
	NATURAL GAS CONVENTIONAL SYSTEM	ELECTRICITY GEOTHERMAL SYSTEM	MAINTENANCE GEOTHERMAL SYSTEM	NET OPERATING INCOME	PERCENTAGE DEPLETION ALLOWANCE	NET INCOME BEFORE TAXES	FEDERAL INCOME TAX	NET INCOME AFTER TAXES	ADD DEPLETION DEPRECIATION & TAX CREDIT	AFTER TAX CASH FLOW	DISCOUNTED CASH FLOW 163.3785%
YEAR ZERO AMOUNT	1066466	17416	4228								
YEAR											
1982	1162448	18785	4524	786999	232490	554509	255074	299435	1024805	1324240	502790
1983	1267068	20261	4841	889826	228072	661754	304407	357347	580212	937559	135157
1984	1381104	21854	5179	1001931	220977	780954	359239	421715	573117	994832	54451
1985	1508166	23572	5542	1126912	226225	900687	414316	486371	578365	1064736	22127
1986	1646917	25424	5930	1263423	247038	1016385	467537	548848	599178	1148026	9058
1987	1798434	27423	6345	1764666	269765	1494901	687654	807246	269765	1077011	3227
1988	1963890	29918	6789	1927122	294583	1632505	750995	881603	294583	1176187	1338
1989	2144567	32641	7264	2104662	321685	1782977	820169	962808	321685	1284493	555
1990	2359024	35611	7773	2315640	353854	1961786	902422	1059365	353854	1413218	232
1991	2594927	38852	8317	2547758	389239	2158519	992919	1165600	389239	1554839	97
1992	2854419	42387	8899	2803133	428163	2374970	1092486	1282484	428163	1710647	40
1993	3139861	46244	9522	3084094	470979	2613115	1202033	1411082	470979	1882061	17
1994	3453847	50453	10189	3393206	518077	2875129	1322559	1552569	518077	2070647	7
1995	3806140	55044	10902	3740194	570921	3169273	1457865	1711407	570921	2282328	3
1996	4194366	60053	11665	4122648	629155	3493493	1607007	1886486	629155	2515641	1
1997	4622191	65518	12482	4544192	693329	3850863	1771397	2079466	693329	2772795	1
1998	5093655	71480	13355	5008819	764048	4244771	1952595	2292176	764048	3056225	0
1999	5613208	77984	14290	5520933	841981	4678952	2152318	2526634	841981	3368615	0
2000	6185755	85081	15291	6085383	927863	5157520	2372459	2785061	927863	3712924	0
2001	6816702	92823	16361	6707517	1022505	5685012	2615106	3069906	1022505	4092412	0
TOTAL	63606688	921408	185462	62499818	9650949	51088169	23500558	27587611	11851824	39439435	729100

SIMPLE PAYBACK 1 YEARS
DISCOUNTED PAYBACK 17 YEARS

APPENDIX A

REFRIGERATION

Steep water requirements:

Steeping is based upon 8 gallons/BU

First 24 Hours

1	Steep	65,760
2	In	
3		
4		
5		
6		
7		
8		
9		
10		
11		
12	Drain	
13		
14	Spray	2,000
15		2,000
16		2,000
17		2,000
18		2,000
19		2,000
20		2,000
21		2,000
22		2,000
23		2,000
24		2,000
		<u>92,760</u>

Second 24 Hours

1	2,000
2	2,000
3	2,000
4	2,000
5	12,000
6	2,000
7	2,000
8	2,000
9	2,000
10	2,000
11	2,000
12	2,000
13	12,000
14	2,000
15	2,000
16	2,000
17	2,000
18	2,000
19	2,000
20	2,000
21	12,000
22	2,000
23	2,000
24	2,000
	<u>78,000</u>

Since both stages of steeping are occurring simultaneously
steep water usage per 24 hours = 92,760 + 78,000 = 170,760 Gallons

Germination bed spray water requirements, turning machine 1.25 ft per minute

155/1.25 = 124 Minutes
Spray Rate = 50 GPM Max
124 x 50 = 6,200 Gal per compartment spray

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Each compartment is sprayed once per day.

Spray water requirements per 24 hours = $6,200 \times 5 = 31,000$ gallons

Steep water cooling requirements per 24 hours, assuming cooling tower water temperature is 70°F .

180,000 gallons to cool from 70°F to 55°F .

Germination spray water requirements per 24 hours

31,000 gallons to cool from 70°F to 55°F

$$\begin{array}{l} \text{Total } 211,000 \text{ gallons to cool from } 70^{\circ}\text{F to } 55^{\circ}\text{F} \\ \frac{211,000 \times 8.345 \times 15}{12,000 \times 24} = 92 \text{ Tons} \end{array}$$

Assuming cooling tower water at 80°F to cool from 80°F to 55°F

$$\frac{211,000 \times 8.345 \times 25}{12,000 \times 24} = 153 \text{ Tons}$$

GERM & STEEP HOUSE HEAT GAIN

<u>AREA</u>		<u>U</u>	<u>T</u>	<u>BTUH</u>
94 x 35	3,290	.10	50	16,450
55 x 35	1,925	.10	50	9,625
65 x 35	2,275	.10	50	11,375
169 x 35	5,915	.10	50	29,575
159 x 35	5,565	.10	50	27,825
224 x 35	7,840	.10	50	39,200
169 x 159	26,871	.06	73	117,695
94 x 55	5,170	.06	73	22,644
169 x 159	26,871	.50	18	241,839
94 x 55	5,170	.50	18	46,530
65 x 55	3,575	.50	18	32,175
65 x 55	3,575	.06	73	15,659
65 x 35	2,275	.10	50	11,375
55 x 35	1,925	.10	50	9,625

Lights 11,520 x 1.5 x 3.4
 Turning Machine & Unloader
 1 x 40 HP + 1 x 20 HP

58,752

88,200

778,544

NOTE:
 TOTAL HEIGHT 35 FT.
 LENGTH 224 FT. WIDTH 159 FT

SPACE REQUIREMENTS
 AIR HANDLING, STEEP
 & GERMINATION
 SCALE: NONE

GERM AIR TEMPERATURE GAIN

Air Flow 6.5 SCFM per bushel capacity 5 pieces at 8,220 RU each

$$\frac{8,220 \times 5 \times 6.5 \text{ SCFM} \times 60 \text{ Min/Hr} \times 29\# \text{ MOL}}{359 \text{ CF MOL}} = 1,294,822 \text{ Lb air/hr}$$

1,294,822 Lb air saturated at 50°F contains

$$1,294,822 \times 53.59/7000 = 9,885 \text{ Lbs H}_2\text{O}$$

$$\begin{array}{rcl} \text{Heat Equivalent} & 1,294,822 \times 0.2405 & = 311,405 \\ & 9,885 \times 1.0 & = \underline{9,885} \\ & & 321,290 \end{array}$$

$$\begin{array}{rcl} \text{Air Stream Temperature Rise} & & \\ \text{Room Gain} & \frac{778,544 \text{ BTUH}}{321,290} & = 2.42^\circ\text{F} \end{array}$$

$$\begin{array}{rcl} \text{Respiration} & \frac{3,904,500 \text{ BTUH}}{321,290} & = 12.15^\circ\text{F} \end{array}$$

Germ Air	50
Room Gain	2.42
Respiration Gain	12.15
Fan Inlet	<u>64.57</u>

GERM AIR MAKE UP

Germination Air

Capacity 5 pieces at 8,220 Bu Each
Air 6.5 SCFM/BU

$$\frac{8,220 \times 5 \times 6.5 \text{ SCFM} \times 60 \text{ MIN/HR} \times 2.0\% \text{ MOL}}{359 \text{ CF MOL}} = 1,294,822 \text{ Lb Air/Hr}$$

$$= 1,294,822 \text{ Lb Air/Hr}$$

$$90\% \text{ Recycle} = 1,165,340 \text{ Lb}$$

$$10\% \text{ Exhaust} = 129,482 \text{ Lb}$$

Fresh air make up assuming 105°F RH 20% to be cooled to 50°F

$$129,482 \times 55 \times 0.2405 = 1,712,723 \text{ BTUH}$$

$$\frac{1,712,723 \text{ BTUH}}{12,000 \text{ BTUH}} = 143 \text{ Tons}$$

GERM AIR MAKEUP WATER CONDENSING & COOLING

GRAINS H₂O
DRY AIR

At 105°F 25% RH
At 50° 100% RH

88.50
53.59
34.91

$$\frac{34.91 \times 129,482}{7,000} = 646 \text{ lbs H}_2\text{O/Hr}$$

646 Lbs H₂O per Hr condensed from 105°F to 50°F

$$\begin{array}{rcl} \text{H}_2\text{O vapor at 105°F BTU/LB} & = & 1106.9 \\ \text{H}_2\text{O liquid at 50°F BTU/LB} & = & 50.0 \\ \hline & & 1056.9 \end{array}$$

$$\frac{646 \times 1056.9}{12,000} = 58 \text{ Tons}$$

$$\text{H}_2\text{O to cool from 105°F To 50°F} = \frac{129,482 \times 53.59}{7,000} = 991 \text{ Lbs}$$

$$\begin{array}{l} \text{To cool 991 lbs H}_2\text{O from 105°F to 50°F} \\ \frac{991 \times 55}{12,000} = 5 \text{ Tons} \end{array}$$

GERM AIR RECYCLE COOLING

$$1,294,822 \times .9 = 1,165,340$$

To cool from 64.6°F to 50°F = t 14.6°F

1,165,340 Lb Dry Air saturated at 50°F

$$\text{Contains } \frac{1,165,340 \times 53.59}{7000} = 8,921 \text{ Lbs H}_2\text{O}$$

$$\begin{array}{rcl} \text{Heat equivalent } 1,165,340 \times 0.2405 & = & 280,264 \\ 8,921 \times 1.0 & = & 8,921 \\ & & \hline & & 289,185 \end{array}$$

$$\frac{289,185 \times 14.6}{12,000} = 352 \text{ Tons}$$

$$\begin{array}{rcl} \text{At 64.6°F and 90\% RH Grains H}_2\text{O/Lb dry air} & = & 91.49 \\ \text{At 50°F and 100\% RH Grains H}_2\text{O/Lb dry air} & = & 53.59 \\ & & \hline & & 37.90 \end{array}$$

$$\frac{1,165,340 \times 37.90}{7,000} = 6,309 \text{ Lb H}_2\text{O per hour}$$

Account has not been taken for condensing this water, as evaporation from the germinating piece will reduce the heat content of the recycle air by an equivalent amount.

REFRIGERATION SUMMARY

REFRIGERATION TONS

Steep & Germ Spray Water	153
Germ Air Make Up Cooling	143
Germ Air Make Up Water Condensing	58
Germ Air Make Up Water Cooling	5
Germ Air Recycle Cooling	352
	<u>711</u>

Allow for 750 Ton Unit.

APPENDIX BKILN HEAT REQUIREMENTS

Kiln air flow is based upon 243 lbs of dry air per bushel during the drying cycle.

At the initial operating kiln exhaust conditions of:

80°F dry bulb
90% relative humidity
25.818" Hg atmospheric pressure

The exhaust air flow per bushel will be 65.9 CFM calculated as follows:

80°F dry air at 29.921" Hg = 13.601 FT³/Lb.
80°F H₂O vapor at 29.921" Hg = 21.844 FT³/Lb.

Weight of dry air at 8,220 bu $8,220 \times 243 = 1,997,460$ Lbs.

Dry air volume at 80°F
 $1,997,460 \times 13.601 = 27,167,453$

H₂O volume at 80°F
 $1,997,460 \times 0.02231 \times 0.9 \times 21.844 = \frac{876,097}{28,043,550}$

Volume at 25.818" Hg $\frac{28,043,550 \times 29.921}{25.818} = 32.5 \times 10^6$

Exhaust air volume per bushel 80°F 90% RH 25.818" Hg
 $= \frac{32.5 \times 10^6}{8,220 \times 60} = 65.9$ CFM

Heat requirements for kilning have been calculated assuming that kilning would start at 12 noon. Dry bulb temperatures were obtained from:

USAF ETAC
Means and Standard deviations
Dry Bulb temperature deg F from hourly observations
Klamath Falls Oregon/Kingsley Field, 48-54, 59-70

Relative humidity data was obtained from the same source, 48-54, 60-70.

Air flow to the kiln heating unit is 243 Lb/Bu/Hr dry air from 12.00 hrs to 21.00 hrs, the quantity is then reduced to 182.3 Lb/Bu/Hr and is blended with cool air between the beds to reduce the air temperature before it passes through the upper bed.

Calculations

Btu required to heat air

$$243 \times 8220 \times 0.2405 \times \Delta t = 4.804 \times 10^5 \times \Delta t$$

$$182.3 \times 8220 \times 0.2405 \times \Delta t = 3.604 \times 10^5 \times \Delta t$$

Btu required to heat moisture

$$243 \times 8220 \times \text{Lb. H}_2\text{O/Lb Dry Air} \times t$$
$$= 1,997,460 \times \text{Lb. H}_2\text{O/Lb Dry Air} \times \Delta t$$

$$182.3 \times 8220 \times \text{Lb. H}_2\text{O/Lb Dry Air}$$
$$= 1,498,506 \times \text{Lb. H}_2\text{O/Lb Dry Air} \times \Delta t$$

KILN HEAT REQUIREMENTS MAXIMUM DEMAND

Temperature extremes for Klamath Falls have been recorded for 82 years. In only 10% of these years have temperatures below -12°F been recorded. In studying the climatic data compiled by USAF ETAC temperatures below -12°F are rare and occur during the night time. In extremely low temperature weather, kilning could be carried out during the day time.

Maximum BTUH demand without heat recovery

<u>HEAT EQ.</u>	<u>TEMP. REQD.</u>	<u>TEMP. IN</u>	<u>Δt</u>	<u>BTUH x 10⁶</u>
4.804 x 10 ⁵	155	-12°F	167°F	80.23
3.604 x 10 ⁵	185	-12°F	197°F	71.0

Maximum BTUH demand with heat recovery

<u>HEAT EQ.</u>	<u>TEMP. REQD.</u>	<u>TEMP. IN</u>	<u>Δt</u>	<u>BTUH x 10⁶</u>
4.804 x 10 ⁵	155	65°F	90	43.24
3.604 x 10 ⁵	185	80°F	105	37.84

COOLING TOWERS MAKE UP AND BLOW DOWN

Steep water and spray water 211,000 gallons per day to cool from 100°F to 70°F.

Assume cooling takes place over 12 hour period.

$$\text{GPM} \quad \frac{211,000}{12 \div 60} = 300 \text{ gpm}$$

Cooling water for refrigeration 1,875 gpm to cool from 87°F to 75°F

Assume acceptable cooling tower concentration of 2

Cooling tower refrigeration

$$\begin{array}{lll} \text{Make Up} & 2.4\% = 1,875 \times 0.024 & = 45 \text{ gpm} \\ \text{Blow down} & 1.1\% = 1,875 \times 1.1 & = 21 \text{ gpm} \end{array}$$

Cooling tower steep water and spray water

$$\begin{array}{lll} \text{Make up} & 7.9\% = 300 \times 0.079 & = 24 \text{ gpm} \\ \text{Blow down} & 2.8\% = 300 \times 0.028 & = 8 \text{ gpm} \end{array}$$

Cooling tower requirement to cool germ air spray water from 100°F to 70°F

Average annual psychometric data

Rel. Hum 63.4
Dry Bulb 46.2
Wet Bulb 39.3
Dew Point 32.3

Dry Bulb 50°F 100% RH
Dry Bulb 46.2°F 63.4% RH

#H₂
#Dry Air
0.007655
0.004202
0.003453

Germination air per hour 1.3×10^6 lb/hr
Assume average air make up at 50%
Annual spray water required

$$\frac{1.3 \times 10^6 \times 365 \times 24 \times 0.003453 \times 0.5}{8.345} \quad 2.4 \times 10^6 \text{ gal.}$$

Davy McKee

Assume water condition

Rel. Hum. 20%
Dry Bulb 70°F
Wet Bulb 50°F

100% Air make up

#H₂O

#Dry Air

0.007655

0.003612

0.004043

50°F Saturated
70°F 20% RH

GPM of germ spray water required

$$\frac{1.3 \times 10^6 \times 0.004043}{60 \times 8.345} = 10.5 \text{ GPM}$$

This load can be accomodated by the process water cooling tower.

REFRIGERATION YEARLY SUMMARY

Steep and germ spray water cooling have been assumed to be a constant cooling demand since no data is yet available regarding the source of this water.

	Ton Hours	% Time 50°F WB
January	68,230	
February	61,627	
March	68,230	
April	66,030	
May	122,508	24.3
June	200,029	54.3
July	274,738	81.7
August	255,237	74.1
September	187,538	49.8
October	101,586	14.9
November	66,200	
December	68,230	