MASTER

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MASTER

THE USE OF LOW-QUALITY GEOTHERMAL HEAT IN GRAIN DRYING AND RELATED AGRICULTURAL APPLICATIONS

QUARTERLY REPORT
FOR PERIOD JANUARY 4, 1977 TO APRIL 4, 1977

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1.0 Objective

The objective of this study is the analysis of the application of low-grade geothermal heat (65 to 150°C) to commercial drying of grasses and grains and to selected fruits, vegetables, and livestock products. A detailed costing and systems analysis will be performed for a geothermal alfalfa dehydration process, most probably in combination with other drying and related agricultural processes that could use waste and off-season heat. We will compare geothermal energy costs with those of present energy sources and with the risks of natural gas curtailments. A net energy analysis of geothermal use for the applications selected will be performed. The regional and national impacts of geothermal drying for agribusiness, other interest groups, and the public will be evaluated. We will recommend policies designed to optimize these impacts. Finally, we will disseminate our results to agribusiness, geothermal operators and leaseholders, regulatory agencies, and legislators.

2.0 Abstract

During the second quarter state profiles of geothermal area crop acreage, production, dollar value, and drying energy were begun. Technical feasibility analyses were done for four geothermally augmented, natural gas alfalfa dryers, a steam-tube predryer design, and an all-geothermal conveyor dryer; costing is underway. Details of a geothermal conveyor-type alfalfa dryer in New Zealand were obtained. A computer simulation of rotary drum dehydration was acquired and extensively modified for use in determining operating parameters and performance for low-temperature geothermal alfalfa dryers. We determined the most important nutrients in alfalfa from a market standpoint and assessed experimental results showing the changes nutrients undergo in conventional drying; indications are that low-temperature drying will yield an acceptable product. Innovative techniques for alfalfa processing were identified for potential geothermal application. Markets, institutional characteristics, and the outlook for growth in the dehydrated alfalfa industry were examined, and a list of existing plants near geothermal resources was compiled. Only three plants were close enough to permit geothermal retrofitting; two plants, at El Centro, California, and Twin Falls, Idaho, are the subject of site-specific studies in which detailed costs and siting options are to be analyzed.

3.0 Overview of Second-Quarter Progress

The most significant findings during the second quarter were in the area of defining the present status and future prospects of the alfalfa dehydration industry. This industry was chosen at the outset of the project to serve as a case study of the potential for geothermal energy use in agricultural drying for several reasons.

A great deal of alfalfa is grown throughout the western states in which geothermal resources are located. The alfalfa dehydration process is energy intensive—one of the most intensive agricultural drying processes in fact, and dehydrators are threatened today by increasing natural gas prices; gas deliveries have already been curtailed to alfalfa dehydrators. All of these factors seem to promise that the conversion from natural gas combustion to geothermal hot water as the heat source could be an important example of fossil fuel conservation and a significant new use for geothermal energy in itself. Our proposal accordingly emphasizes both the retrofitting of present alfalfa "dehy" plants and the construction of new ones located near geothermal sources.

Telephone interviews with dehy industry spokespeople and with the operators of the dehy plants nearest to identified low-temperature hydrothermal resources revealed an industry with a future made uncertain by more than rising energy prices. (Section 8.0 of this report outlines the industry in more detail.) During the early 1970s, an export market grew rapidly; it has since been lost to Canada, where energy costs are lower and government subsidies have been made. The few dehy plants in geothermal states have been particularly vulnerable to shrinking exports as many tended to produce mainly for export. Nationally, the currently somewhat less competitive position of dehy with respect to other feedstuffs has reduced the market from its 1970 peak of 1.7 million tons to about 1.3 million tons; the outlook for the near term is for a stable market at about this level of production. Adjustments to overcapacity have been made through declines in new plants and the closing of some existing plants.

The smaller market for dehy makes investment in new plants located at geothermal resources appear to be unattractive at present. We have thus concentrated on the potential for retrofitting present plants near geothermal systems. Because there are only a few such plants (see Figure 8 in Section 8.0), this study must stress local impacts rather than national ones.

Less emphasis will be placed on the potential for fossil fuel conservation in the dehy industry itself. Correspondingly more emphasis will be placed on how our findings for the alfalfa dehydration industry can be applied to other food and feed dehydration applications. We are confident that this study at the very least can illuminate some of the obstacles inherent to geothermal energy use in agricultural drying and to agricultural applications in general.

The route we propose to follow in completing this project has become clearer during the second quarter. Table I is a tentative list of the chapters to be included in the final report. These chapters will be the

Table I

TENTATIVE FINAL REPORT CHAPTERS

0. Introduction/overview

1. State profiles of crop production and drying energy use in geothermal areas.

2. Geothermal transmission and reinjection.

3. Dryer designs: a. air heat-exchanger (base case)
   b. heat-pump designs
   c. steam-tube predryer
   d. conveyor dryer

4. Parametric analysis of low-temperature drum drying (results of computer model).

5. High-temperature, large heat pumps.

6. Nutrient conservation with low-temperature alfalfa drying.

7. Processed alfalfa markets and institutional characteristics--location of industry, production history, and outlook for growth.

8. Two case studies of geothermal alfalfa dehydration (full description of resource, industry, market, and costs at Heber and Twin Falls sites).

9. Outlook for multicrop geothermal drying centers (results of an analysis of marginal costs and benefits of locating drying facilities for several promising crops at geothermal resources).

10. National importance of geothermal energy for crop drying; policy recommendations.

11. Planner's guide to the use of geothermal heat for agricultural applications (how this study can be used as a handbook).

end products of the seven study tasks outlined in the first quarterly report. The chapters do not correspond to the tasks in a one-to-one relationship. However, the list of chapters better describes the organization of the study at this point. Therefore it will be used here and in the third quarter report for measuring project progress.

4.0 State Analyses of Crop Acreages, Production, Value, and Energy Required for Drying (Chapter 1)

The basis of Chapter 1 will consist of bar charts depicting for geothermal areas (defined below) the acreage, production in thousands of tons, and dollar value of each of approximately 20 crops that presently are dried. Also shown for each crop will be the estimated energy now used for drying and the energy that would be required were heat from geothermal resources to be the sole source of process heat for dehydrating these crops. In other words, there will be two scenarios. The first assumes only that crops in geothermal areas contribute to the national production of finished dehydrated products in direct proportion to the ratio of geothermal area raw crop to national raw crop. Thus if 6 percent of all apples grown in the United States are dried, this scenario will assume for the purpose of calculating energy use that 6 percent of apples grown in geothermal areas are dried geothermally.

The second scenario will attempt to define an upper limit to geothermal heat use in drying the 20 crops by asking, "What if production of each dehydrated product were distributed so that, where possible, only geothermal heat was used?" For some raw commodities, say apples, enough production might exist near geothermal resources for the entire market for dried apples to be satisfied by dehydrating just those apples near the resources. We will assume that geothermal energy use for drying these crops is distributed in direct proportion to crop production in each geothermal area. For other commodities, say rice, even if one assumed that the entire raw production were dried with geothermal heat, the market could not nearly be satisfied because not enough rice is grown in geothermal areas. For these crops, energy use estimates will be based on dehydration of the entire production in each geothermal area.

The "geothermal area," which is the basic unit for which crop statistics have been compiled, has been defined two ways. The first definition is simply the whole county area for those counties partly or wholly within 50 miles of identified geothermal resources; there are 275 such counties in 11 western states. The second definition restricts the areas to only those portions of the 275 counties that are actually within the 50-mile radii.

Crop statistics have been compiled for all 275 counties. They will be used under the first definition to give "whole-county" totals by state for crop acreages etc. The statistics will also be weighted by the areal fraction from the second definition to give "50-mile" figures. Two parallel data bases are thus available, the 50-mile one appropriate to crops that must be processed near the field and the whole-county one for crops that can be transported further.

Crop acreages, production, values, and drying energy consumption for the whole of each of the 11 states also will be calculated. Against these figures may be evaluated the 50-mile and whole-county totals in order to estimate how significant agricultural drying with geothermal heat might be relative to particular states.

During the second quarter, basic data gathering for county areas, crop acreages, and production was completed by Midwest Research Institute. Several national data bases had to merge in order to accomplish this. Data relating to the portions of counties within 50 miles of geothermal resources were obtained in the first quarter and stored on a portable computer cassette tape at The Futures Group. A simple computer program to perform summations of these crop data by state was begun; these summations will be represented as bar graphs or tables in the final report.

These bar graphs will allow us to choose several agricultural commodities for further analysis. The objective here is to evaluate the concept of multi-crop drying centers in Chapter 9. The bar graphs will also permit us to estimate where and how much fossil fuel might be displaced by geothermal energy. They will point roughly to locations where new drying facilities could profit from geothermal use. A knowledge of what other crops are the best candidates for geothermal application will enable us to report our findings about the alfalfa industry in a wider and more meaningful context. Finally, we should be able to make valid generalizations in Chapter 10 about the national potential for geothermal drying of most of the important agricultural commodities.

5.0 Geothermal Alfalfa Dryer Designs (Chapter 3)

Three means for dehydrating alfalfa using geothermal heat were outlined in the first quarterly report. The first was geothermal "augmentation" in which the drying air is preheated geothermally and then raised to the conventional rotary drum temperature of 500 to 1000°C (1000 to 1800°F) by natural gas combustion. The second method was to use a different type of dryer with an air temperature of about 150°C (302°F) so that geothermal water could provide all the heat required. Finally, we proposed to investigate a large heat pump to raise the temperature from geothermal fluids enough to provide high temperature inlet air to a conventional drum dryer.

By the close of the second quarter, Midwest Research Institute had completed initial technical feasibility analyses for six alternative heat exchanger/dryer combinations. They were awaiting the responses from equipment manufacturers that would permit equipment specification and capital costing of each combination.

Four of the dryer schemes are of the geothermal augmentation type. A fifth utilizes a geothermal steam-tube predryer with a drum dryer to complete the dehydration process. The last drying system outlined corresponds to the second method above; this is a conveyor or belt-type dryer. In addition to MRI's preliminary work on the conveyor dryer, full details of the geothermal alfalfa plant at the Broadlands field in New Zealand were obtained from the engineering firm that designed it. This plant, described in Section 5.1 below, utilizes a drag-conveyor system similar to the one we are investigating.

The concept of a large heat pump, or several of them in series, to boost the temperature available from geothermal hot water resources several hundred degrees Fahrenheit was studied and rejected for serious consideration in our project. Several heat pump manufacturers were contacted, but none knew of an off-the-shelf or prototype unit capable of boosting heat flows on the order of 10^7 to 10^8 Btu/hour to the required temperature, 1000 to 1800°F. Many expressed the opinion that such a heat pump would be extremely inefficient, and therefore prohibitively expensive, even if geothermal inlet heat were free.

Figures 1 through 6 are the preliminary flow diagrams prepared by MRI for their six alternative heat exchanger/dryer systems. Figure 1, the "base case" geothermal augmentation design, uses a secondary loop coupled to a simple air heat exchanger to provide preheated air to the drum dryer. Both steam and isobutane working fluids are being considered. If the drum dryer system consisted of two Heil 105 drums with a combined capacity of 6 tons/hour of dried alfalfa, then 9 to 18% of the heat required for drying (to the standard dehy moisture content, 10% by weight) could be supplied by geothermal heat. By way of comparison, this is somewhat more natural gas saving than provided by exhaust gas heat recovery systems for these drum dryers.

The system shown in Figure 2 utilizes a turbine-driven compressor to drive a heat pump that in turn generates preheated air at a higher temperature than Case 1. The turbine is driven by the expansion of the isobutane secondary fluid; heat for expansion is geothermal. This unit is commercially available as the "Magma-Max." Five heat exchangers are required for the entire system, making it quite expensive.

Case 3 is similar except that steam is used to drive the turbo-compressor. A less expensive steam flash tank substitutes for one of the heat exchangers. An estimated 20 pounds of geothermal water at the nominal temperature of 270° F would be required to produce 1 pound of steam in the flash tank.

In Case 4 the heat pump working fluid is flashed steam as well, which eliminates another heat exchanger and introduces another flash tank. Perhaps 25 pounds of hot water per pound of steam generated would be needed here.

Case 5 consists of a steam-tube rotary predryer using geothermal steam, coupled to be a conventional natural gas-fired drum dryer. The link between the two might be a fixed mechanical conveyor, or the two could be located some distance apart. If a dehy plant was to be converted to geothermal this could permit the steam-tube dryer to be located at the geothermal source, while the drum dryer, pelleting mill, and rail loading facilities could remain at the rail siding. Of course, additional transportation between predryer and the main facility would be required. The impact of this factor on total plant operating cost and energy consumption will be evaluated for this dryer system alternative for at least one of the two case study sites.

Figure 6 shows a unit that is no longer manufactured, the Folmer alfalfa dryer. This unit is similar in principle to the conveyor dryer used by the Broadlands Lucerne Company, New Zealand. The Folmer design had an evaporative capacity of 1260 to 1460 pounds of water per hour when an air inlet temperature of 200 to 250°F was used. This evaporative capacity corresponds to only about 1 ton per hour of greenchop alfalfa throughput (560 pounds of dehy).

The Proctor-Schwartz cattle feed dryer, a variation of a standard food processing conveyor type, is comparable in throughput to standard drum dryers. A 12 foot wide by 98 foot long model can handle 11 tons/hour of 75 percent moisture alfalfa (3 tons/hour dried to 10 percent); cost is quite reasonable at $135-185,000. We are optimistic about the feasibility and cost of the conveyor-type dryer: its air temperature requirement is inherently suited to low-temperature geothermal resources, and such a dryer is operational in New Zealand. Moreover, what is learned about use of geothermal heat for conveyor dryers is likely to be applicable to several crops besides alfalfa.

All six heat exchanger/dryer alternatives will be costed and compared using an assumed geothermal water temperature of 120°C (248°F) and a spectrum of water quality characteristics typical of 16 hot springs selected at random from a list of those with estimated subsurface temperatures of 150°C or below. Silica content ranges from 51 to 115 ppm (parts per million) for these hot springs; total dissolved solids, from 176 to 3360 ppm. The assumed geothermal water temperature of 120°C (248°F) corresponds to the USGS subsurface estimate for the Cedar Hill, Twin Falls County, Idaho resource. (This resource is the one nearest to the dehy plant in the town of Twin Falls, about 12 miles distant.) Only the most promising of the heat pump, geothermal-augmentation cases (Case 3) will undergo this analysis.

Case 3 also will be analyzed for the brine characteristics of the Heber KGRA. Pending availability of adequate dryer and heat exchanger design data from manufacturers, the conveyor design will be analyzed for the Heber resource. Brine temperatures at Heber range from about 149 to 177°C (300 to 350°F), and total dissolved solids are about 14,000 ppm, making fairly extensive modifications to the Twin Falls designs probable.

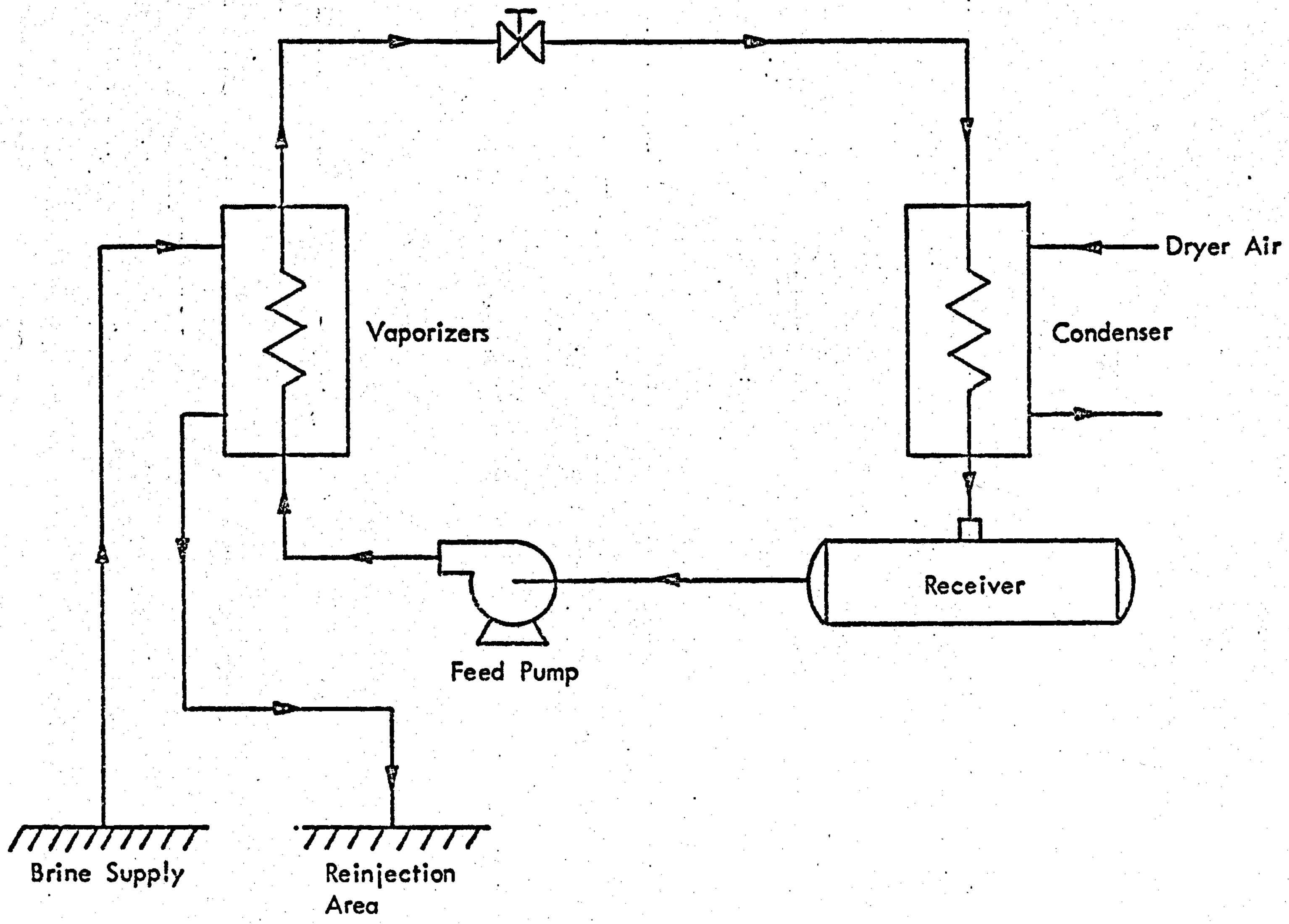


Figure 1. Case 1: Base case geothermal augmentation design

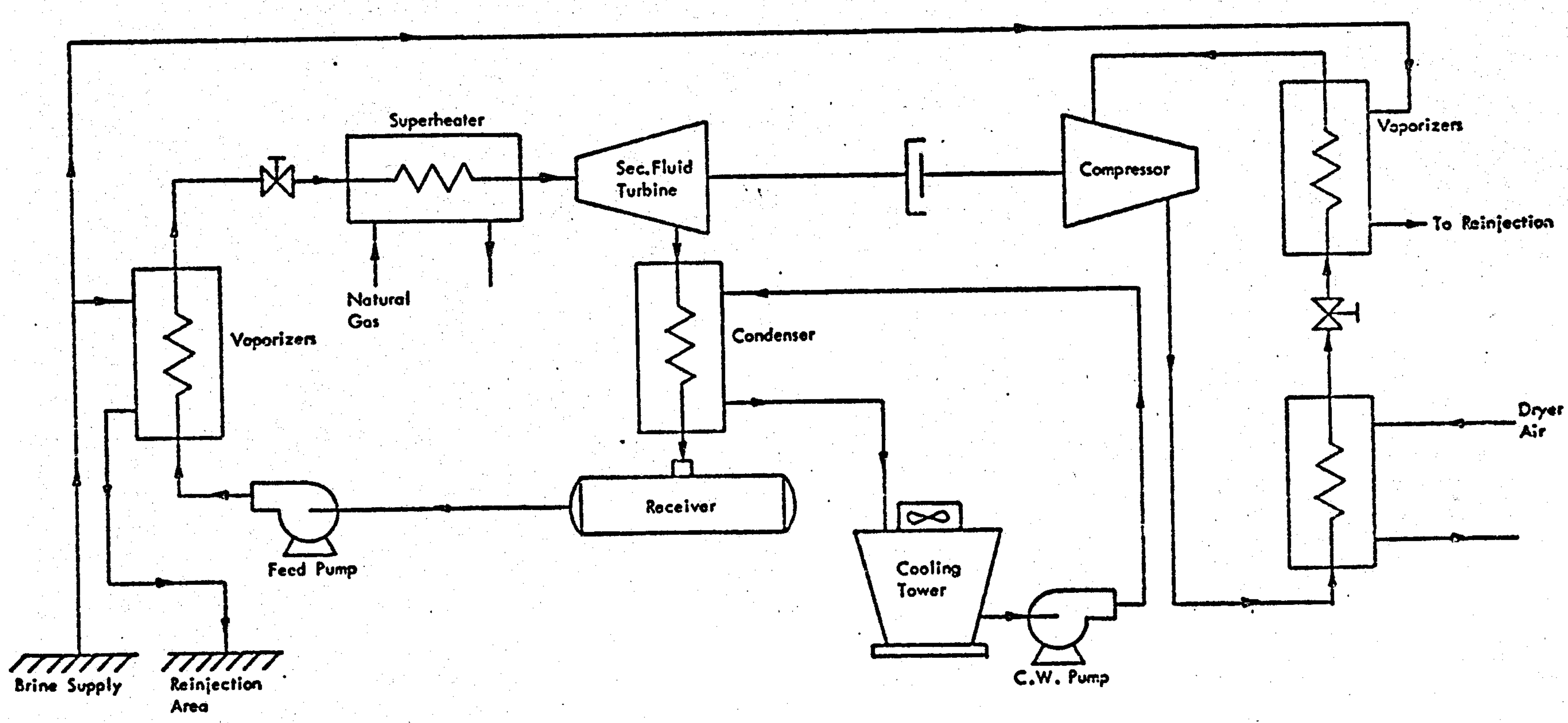


Figure 2. Case 2: Geothermal augmentation with heat pump, isobutane turbine and heat pump circuits.

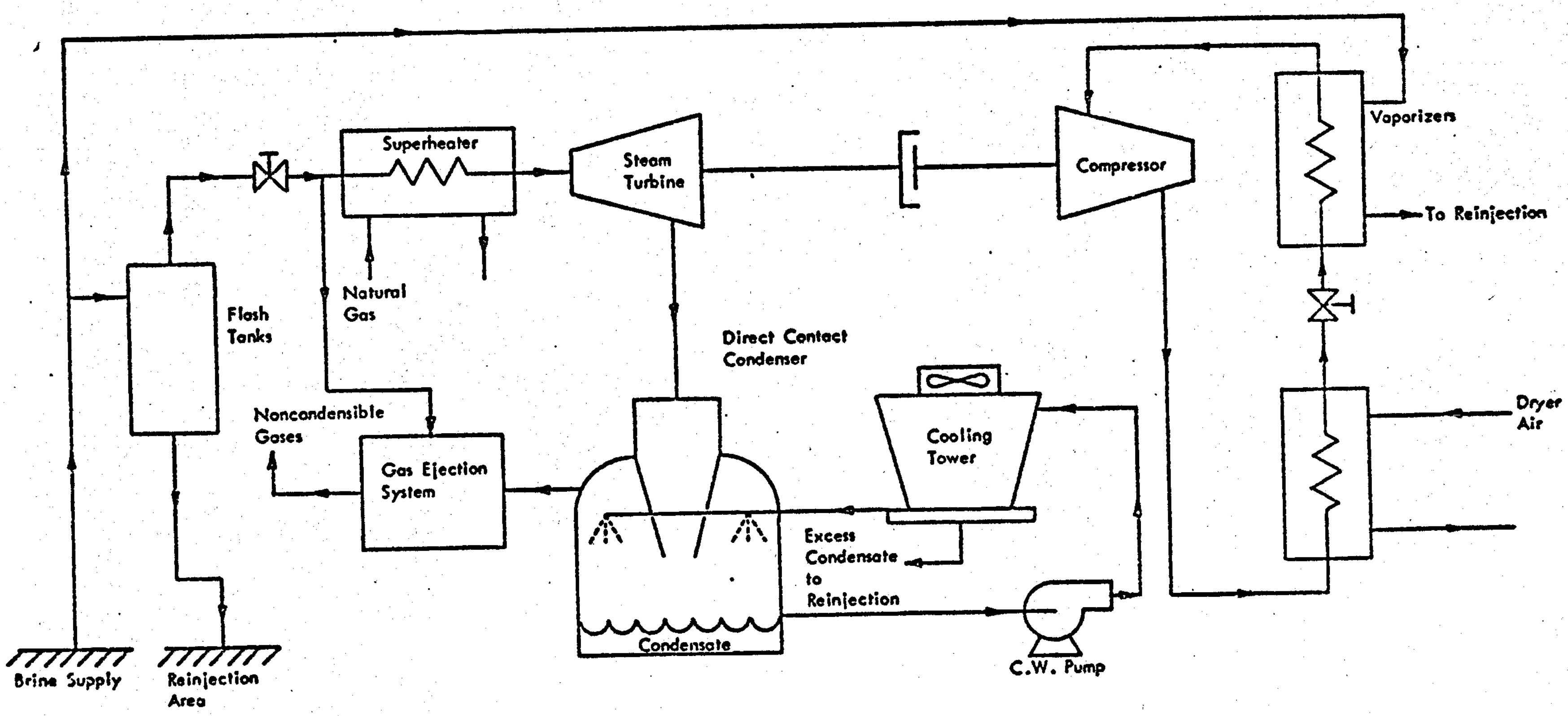


Figure 3. Case 3: Geothermal augmentation with heat pump, steam-driven turbine

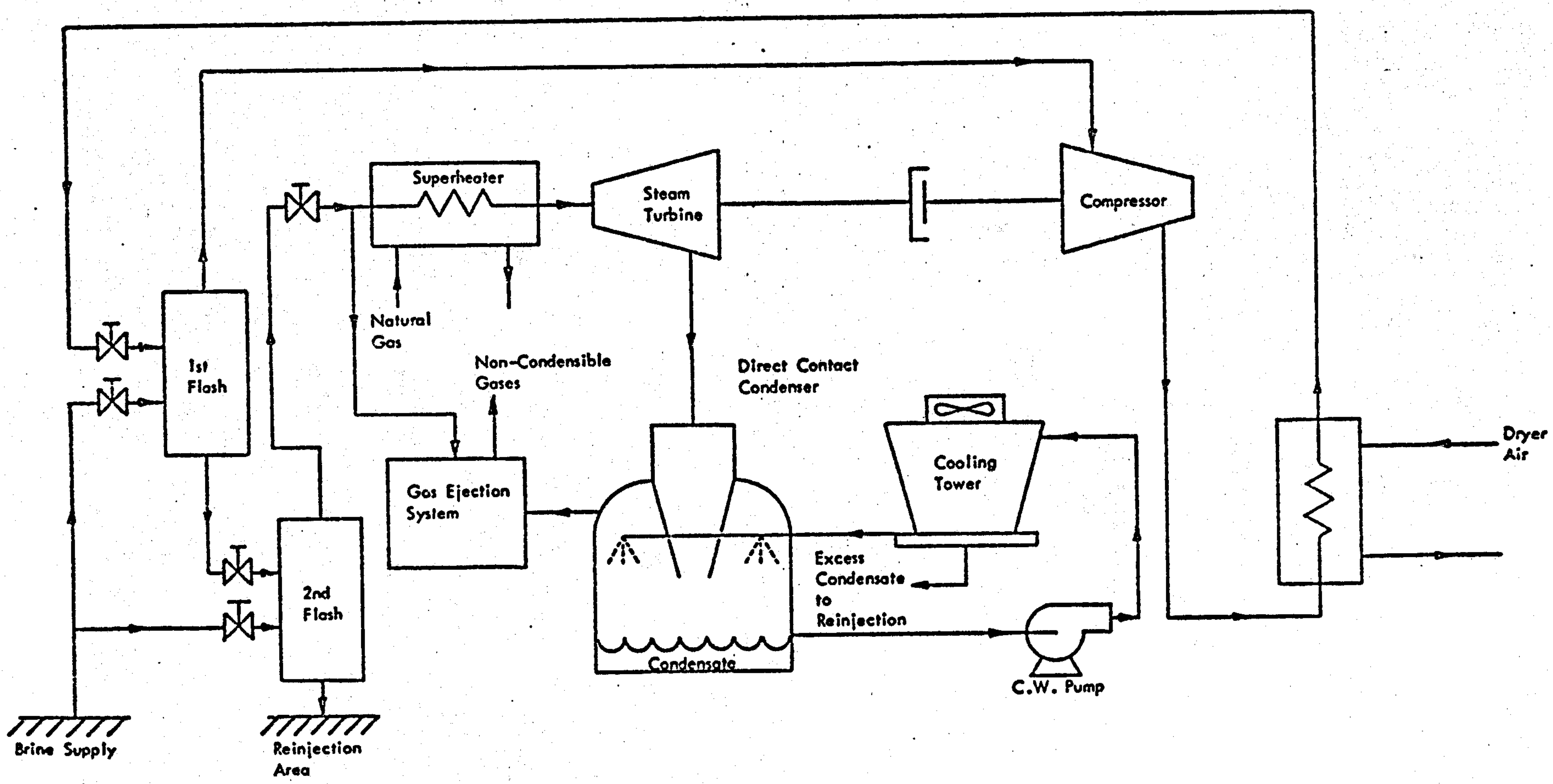


Figure 4. Case 4: Geothermal augmentation with heat pump, steam-driven turbine and steam heat pump

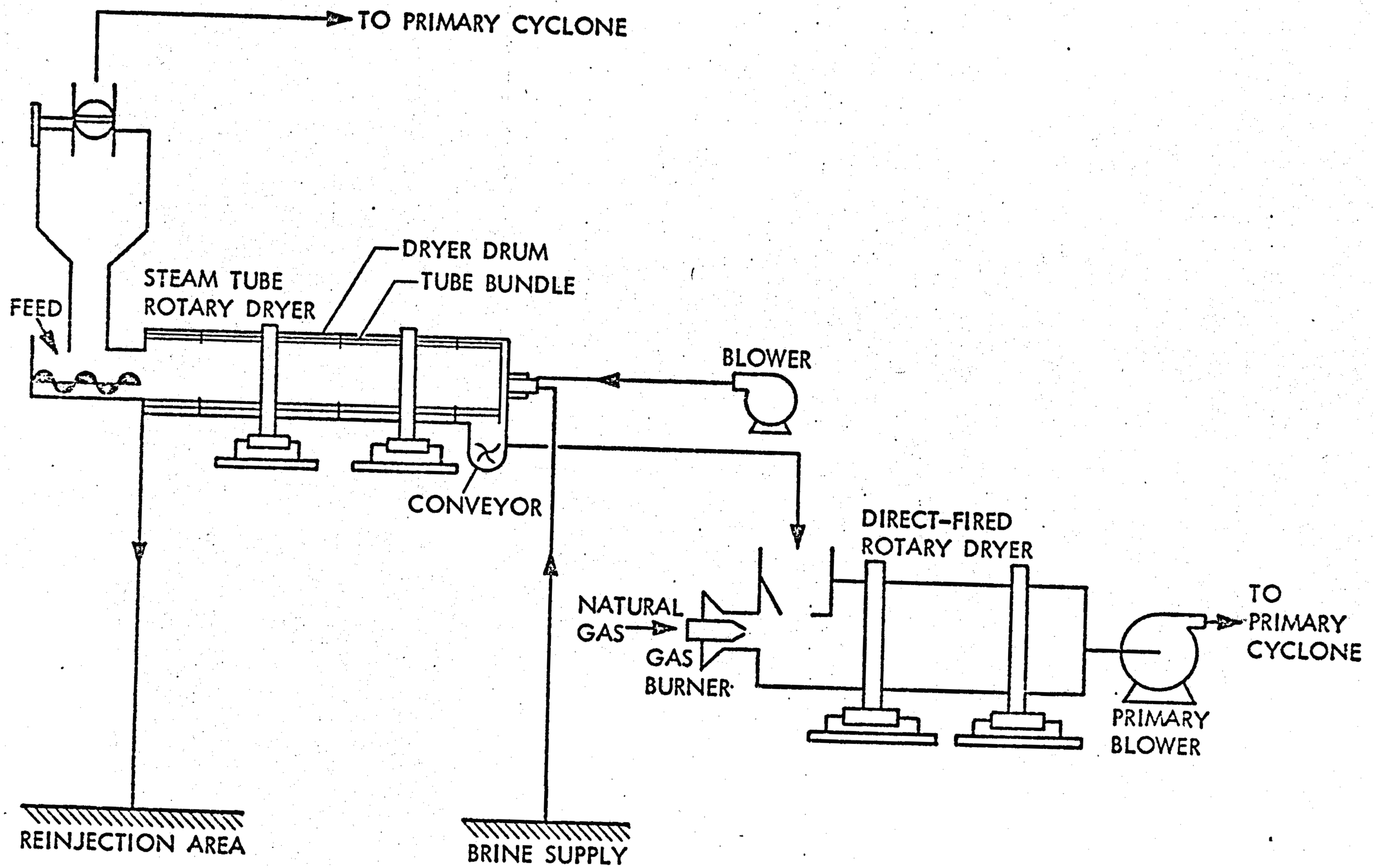


Figure 5. Case 5: Steam-tube predryer coupled to gas-fired drum dryer

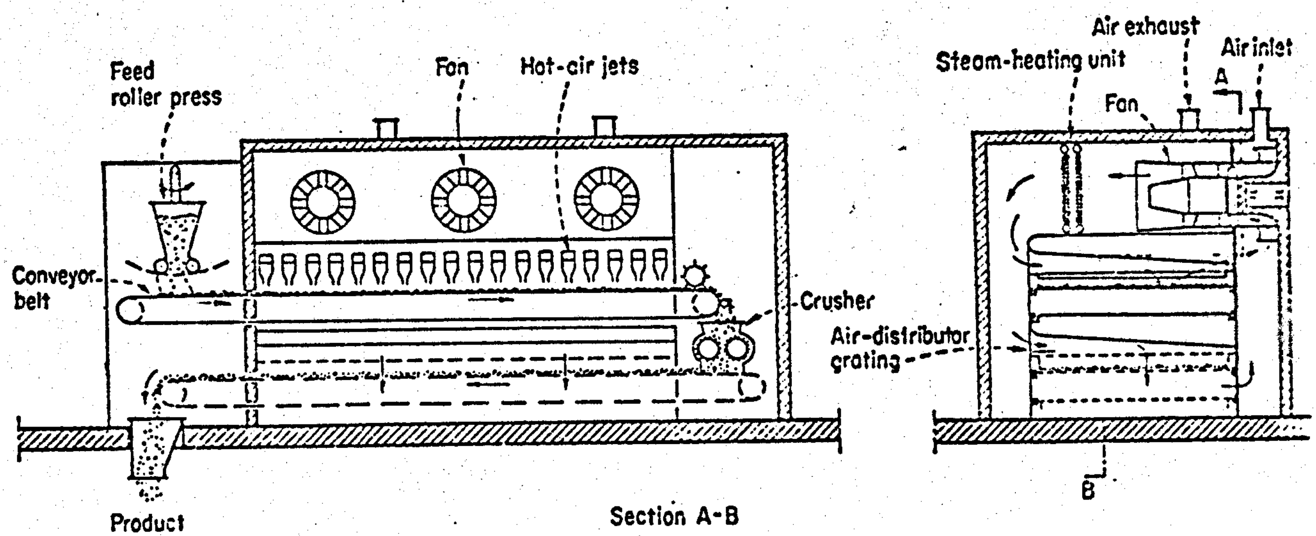


Figure 6. Case 6: The Folmer alfalfa dryer

5.1 Description of the Geothermal Broadlands Lucerne Company Plant, New Zealand

The following information is a summary of a very useful telephone conversation with Ken Pirie, Industrial Division Manager, Fisher and Paykel Engineering, Ltd., Auckland, New Zealand. Pirie was in charge of the design of the lucerne plant at the Broadlands geothermal field, about 35 miles south of the town of Rotorua. The plant is owned by a cooperative of a dozen farmers who grow lucerne on the eastern side of the Waikato River; geothermal wells of the Broadlands field are dotted within this farmland.

The dryer is a fixed bed, double-pass, drag conveyor type. The bed is louvered to permit the air stream to pass up through the alfalfa from below. The conveyor system is 100 feet long, composed of two 50 foot sections 8 feet wide. The wet alfalfa is first carried up an input conveyor and into the first section. It is dropped onto the second section, further dried, and then moved with an auger material-handler to the hammer-mill and pelletizer. The airstream from below nearly "floats" the alfalfa above the bed in a pile 15 inches deep. There were initial problems in handling the material where the first section dropped the alfalfa onto the second and at the auger. Holes in the enclosures caused leaks of alfalfa out of the dryer at first.

The heat exchanger is a steel fin-tube type, a coil eight rows deep, galvanized on the outside, 5 fins/inch. A total of 15,000 square feet of surface area is used. This was thought to be a conservative, but the geothermal steam is 20% by volume incondensable CO_2 so that the coil should be 20% larger. Some slight problems with silica scaling have been encountered, but the material-handling problems have been worse.

Harvesting of raw alfalfa is mostly done less than 7 miles away, and the furthest field is 20 miles away. The alfalfa grown in the Broadlands contains about 28 % protein when raw. A rotary mower cuts the alfalfa, which is windrowed in the field and then picked up and trucked to the plant a short time later. This method appears to be used because the Broadlands dryer requires longer stems (in order to create large air spaces in the alfalfa piled on the conveyor) than ordinary U.S. cutting practice provides.

Dry geothermal steam is fed into the coil exchanger at 350°F. The pressure is constant at 150 psi (pounds per square inch). Ambient air (60 to 80°F) is passed over the coil and heated to 200 to 290°F. Air flow rate is variable from 42,000 to 50,000 cfm (cubic feet per minute) to permit different initial moisture contents in the alfalfa input. The inlet moisture of the alfalfa varies from 65 to 85% at the end of summer and in early spring, respectively. The alfalfa is slightly wilted during harvesting and transport. The outlet moisture content of the alfalfa ranges from 8 to 12% and usually is about 10%. Outlet air temperature is 120°F dry bulb, 90°F wet bulb. Alfalfa throughput is about 1 ton/hour on a dry weight basis (5 tons/hour wet basis). Annual production is 1800 tons dry pellets, but much more is possible.

A rotary dryer design was investigated and rejected before the conveyor design was chosen. Retention time was found to be excessive, demanding an extremely long drum or numerous passes of the material through the drum.

All geothermal development is administered by the New Zealand Ministry of Works. In order to promote development, the Broadlands Lucerne Company was given use of the steam from a borehole 50 feet from the plant at no charge for the first two or three seasons of operation. (This borehole was part of the extensive development of the Broadlands by the government.) In addition, the government provided, or backed, loans to build the plant.

Steam now comes from a dedicated borehole about 1 mile away, put into service when the first failed. The government financed the extra piping required to connect the new well with the plant because it felt responsible for assuring a continued steam supply. Having operated for two or three seasons, the plant operators must now pay for the steam. The "posted" price for steam is $29/ton dried alfalfa, but the plant operators feel they will be able to drop it to $20/ton through negotiations with the government. Alfalfa plant management is confident that its operation will remain viable.

The cost of fossil energy (oil), if it were used, would be about $40/ton of 10% moisture product. All other alfalfa dehydrators in New Zealand burn oil, and conservation measures mean that they must produce a 14% moisture product. Protein loss during storage is now a problem for them due to this higher moisture content.

A new dryer with 1-½ tons/hour dry product capacity is under construction by the Broadlands Lucerne Company. At the suggestion of the Ministry of Works, this plant will utilize a "total flow" of hot water and steam rather than the flashed dry steam used in the present dryer. The government offered the lucerne plant free use of the 100°C tailwaters from the new Broadlands power station. Fisher and Paykel's feasibility analysis showed that it was still cheaper to pay for dry steam at an assumed price after negotiation rather than to use the free tailwaters. Piping cost made the latter too expensive.

In order to reduce retention time and thus the length of a rotary drum dryer Pirie suggested that we might want to consider juice expression or more prewilting before drying. Another suggestion was that a fluidized bed dryer in which the wet alfalfa would be fed into the bottom of a large cylinder or inverted cone and then floated/dried upward for discharge at the top.

6.0 Parametric Analysis of Alfalfa Dryers (Chapter 4)

During this reporting period The Futures Group has activated a computer simulation of rotary drum dehydrators for use in examining the range of design and operating parameters that would be required to implement the use of geothermal sources in the dehydration process.

The computer code is based on an analysis performed by Air Resources, Inc., for the American Dehydrators Association in 1975. A copy of this analysis was provided to The Futures Group by the American Dehydrators Association. The computer code was obtained from Leo Pederson of the University of California at Davis.

In the course of adapting the program to The Futures Group IBM 5100 it has been extensively rewritten in a number of areas. The present program can consider either single or triple pass dehydrators and can be used for the analysis of both gas fired or heat exchanger supplied systems.

During the next few weeks this program will be used to examine the performance of both state-of-the-art dehydrators and rational design variations of these to determine the sets of conditions and design parameters which will allow effective dehydration of alfalfa using geothermal energy sources. This will include both total geothermal supply and the use of the geothermal source for preheating operations in conventional installations.

7.0 Nutrient Quality and Market Value of Low Temperature Dried Alfalfa (Chapter 6)

The overall objective of Chapter 6 is to determine whether alfalfa can be dried with air heated by 150°C or less geothermal water to yield a nutritious and marketable product. Research for the first two elements of the chapter was largely completed during the second quarter. The first element is a determination of the most important nutrients contributed by dehy to mixed poultry feeds, the main dehy market in the western states. The second element is to be a discussion of others' experimental results showing what happens to these nutrients when alfalfa is dried under various conventional conditions of time, temperature, and so on. The implications of these experiments for low-temperature geothermal drying will then be discussed.

We originally hoped that a specially designed experiment could be performed for this study to evaluate directly various low-temperature drying regimes. This would be desirable because other researchers seem to have confined drying tests to the 600 to 1800°F air temperature range. However, the cost of a worthwhile experiment was estimated at $5000 to $50,000, much too high to justify inclusion in this study.

A third element of Chapter 6 will be nutrient quality estimates for alfalfa dried in rotary drum dryers operated at low temperature. The parametric analysis of Chapter 5 will set forth a set of drying conditions that are optimized for feasibility and maximum throughput. Whether product quality is still likely to be acceptable under these conditions will be considered in this element.

Another check also will be made on our conclusions. Since we know nutrient characteristics for both the raw alfalfa and the dehydrated product at the New Zealand plant, changes in the nutrients due to drying can be derived. Then, by comparing the drying process at the Broadlands plant with our proposed low-temperature process, we can infer the product to be expected from our design.

7.1 Summary of First Results

Alfalfa is a desired ingredient in animal feed rations because of its color (it masks other ingredients), its pigmentation (making egg yolks and broiler skins yellow), its high protein content, and its vitamins and minerals. Certain unidentified growth factors also have been associated with alfalfa. Dehydrated alfalfa is produced in various grades, usually defined by percent of protein. Higher grades (17-22 percent protein) are required for those animals that do not ruminate (form a cud) because nonruminating animals, such as poultry and swine, cannot digest the large portions of cellulose found in lower grades of dehy.

The market for dehy in the western geothermal states is for the higher grades, since most dehy goes into poultry feeds. This is true for both local and export markets. Those dehy components most desired for poultry are xanthophyll (for yellow pigmentation), protein (essential amino acids such as tryptophan and lysine), and vitamin A (from carotene). Xanthophyll is the most valuable ingredient that dehy contributes to poultry feed from a market standpoint. If xanthophyll were not required in the ration, dehy would have little competitive advantage over other feed ingredients and would enter the ration at a much lower price.

Xanthophyll content in dehy can serve as a good overall quality index because conditions that allow high-xanthophyll meal will produce a meal high in carotene (provitamin A), tocopherol (vitamin E), and other nutrients as well. Since protein degradation is associated with high front-end or inlet temperatures, protein losses may not be of much concern with a low-temperature dryer. Xanthophyll losses, on the other hand, appear to be a function of low moisture content of the product. It has been shown that overdrying under conventional drying conditions can reduce xanthophyll retention independent of temperature.

In order to obtain nutrient loss values under a wider variety of conditions, we looked at losses obtained when alfalfa was prewilted in the field prior to conventional dehydration in order to save energy. Under the more extreme prewilting conditions, greater losses of xanthophyll and carotene were obtained than under normal drying conditions. Even larger losses of carotene and xanthophyll occur when alfalfa is allowed to dry completely in the field (sun-cured alfalfa). These prewilting and sun-cured data were not encouraging, since they suggest a xanthophyll loss when drying is done with low temperatures for longer periods. From discussions with a number of scientists in this area, however, we gain the impression that it would be very difficult to predict what the consequences would be when drying with a low temperature system for longer periods. Biological systems interact with themselves and with physical parameters in complex ways.

Fortunately, the Broadlands Lucerne Company plant is operating under drying conditions similar to those that our low temperature dryer would require. The designer of the Broadlands dryer--Fisher and Paykel Engineering, Ltd.--has supplied us with an analysis of the dehy product from this plant. This analysis shows a xanthophyll quality comparable with that currently on the market in the western United States. We therefore are reasonably sure that the alfalfa produced by our low-temperature geothermal dryer would be marketable and of good commercial grade.

7.2 Other Alfalfa Products with Potential for Geothermal Application

In addition to our study of the established alfalfa dehydration process, we have been investigating "state-of-the-art" alternatives for which geothermal energy might be used. The processes described below offer the possibility of producing human food in addition to animal feed. While it is not possible to perform a rigorous feasibility study of these processed for geothermal application, we will suggest in the final report what directions such a study might take.

Alfalfa supplies feed constituents to two categories of livestock. The first includes ruminant animals such as cattle, sheep, and horses that need long fiber "roughage" for best performance. The second is nonruminants, such as chickens or swine, that have a limit to their alfalfa consumption because they cannot digest the significant quantities of fiber found in alfalfa. While alfalfa contains relatively low amounts of energy and is limited in palatability, it provides a large amount of protein--even more than soybeans, as shown by the data in Table II. Since most of the protein and vitamins are located in the leaves, while most of the fiber is in the stem, separation or fractionation of these two plant parts can improve and better adapt alfalfa to current and future markets. The "separation milling" process can generate these fractions by sieve or air separation; such separated products have been produced commercially.

Table II

PROTEIN PRODUCTION BY PLANTS AND ANIMALS (KG/ACRE)

Lucerne* (alfalfa)	675
Soybeans	260
Barley	195
Milk (from forage)	144
Broiler hens (from grains)	66
Beef (from forage)	49
Pigs (from grains)	46

*Value is true protein

SOURCE: Walter J. Bray, "Green-Crop Fractionation," New Scientist, Vol. 70, No. 995 (April 8, 1976), p. 66.

Another separation process involves crushing, which separates the fiber-rich residue from the protein-rich juice. In addition to providing separation, crushing or pressing dewaters the alfalfa significantly. Less natural gas is required, chemicals associated with low palatability are removed, and greater flexibility in product and harvesting schedule results. Table III shows the percentage reduction in gas needs with various degrees of pressing.

It also has been demonstrated that subsequent drying of the residue (presscake) as performed in conventional dryers allows a greater dehydration rate than with conventional greenchop dehydration because the crushed cells yield water much more readily than intact ones. This would further reduce the energy needed.

Because of the potential improvement in quality, new markets, and energy savings, wet processing (or mechanical dewatering) of alfalfa has been and is currently a "hot" research area. Much of the research in the United States centers around the production of the high-protein, high-xanthophyll juice coagulant, which is termed "Pro-Xan." A high quality protein for human consumption also can be produced and has been shown to be effective in the treatment of protein deficiency disease. Figure 7 illustrates the many variations of the wet fractionation procedure.

Commercialization apparently has been held back by the lack of a developed market and uncertainty surrounding technical optimization. A new economic assessment, including some technical improvements, is forthcoming from the Western Regional Research Laboratory in Albany, California. George Kohler, chief of operations at the laboratory, reports that more interest in commercialization is emerging in the United States. Much more enthusiasm is found in Europe and especially in France, where a plant has been in operation for a number of years.

Partial dewatering of the presscake permits a reduction in the energy requirement for complete dehydration. Also, the juice fraction is processed at a relatively low temperature. Both of these factors lead us to believe that low-temperature geothermal heat could be included in the wet fractionation procedure to produce an important vegetable protein.

Table III

FUEL SAVINGS WITH WET PROCESSING*

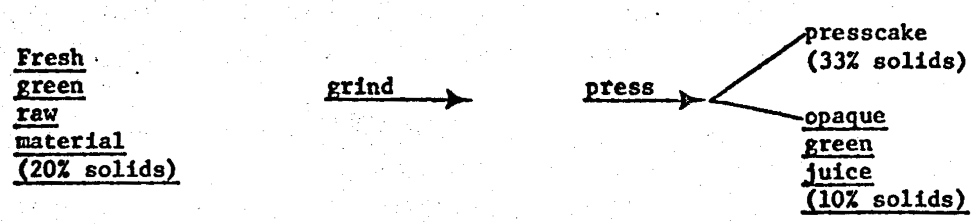
	Wet product to dehydrator (pounds)	Moisture in cake (%)	Water to evaporate in dehydrator (pounds)	Water to evaporate from protein+ (pounds)	Water to evaporate from brown juice (serum)++ (pounds)	Total gas required for evaporation (cubic feet)	Reduction in gas needs (%)
Unpressed lucerne	100	80	79	-	-	118	-
Presscake, 35% press	65	75	47	4.5	29	89	25
Presscake, 50% press	50	70	34	6.5	41	81	31
Presscake, 62.5% press	37.5	63	23	8.2	52	71	41

* Calculations based on processing 100 pounds fresh lucerne containing 20 pounds dry matter.

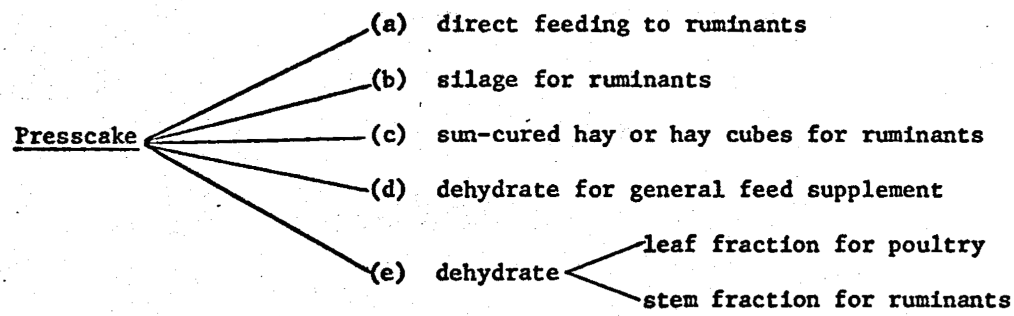
+ Atmospheric pressure dryer taking product to 93% dry matter using 1.5 cubic feet gas/pound water evaporated.

++ Triple-effect evaporator taking product to 50% dry matter syrup using 0.42 pound steam/pound water evaporated.

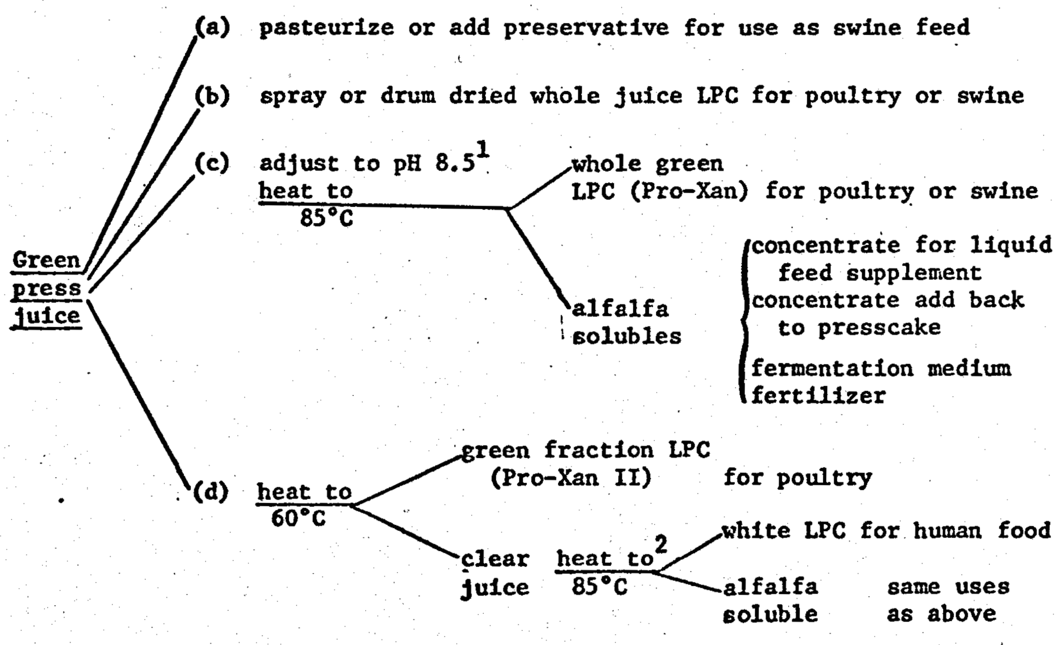
SOURCE: G. O. Kohler, E. M. Bickoff and D. De Fremery, "Mechanical Dewatering of Forage and Protein Byproduct Recovery," First International Green Crop Drying Congress, Oxford, England, April 8-13, 1973.



Basic wet process steps



Alternative treatments and uses for the presscake



Alternative treatments and uses for the press juice

[1]Other methods of coagulating the whole leaf protein concentrate (LPC) include acidification, precipitation with solvents, etc.

[2]Other methods of recovering whole LPC here include acidification, ultrafiltration, gel filtration, etc.

SOURCE: George O. Kohler, "Wet Processing of Alfalfa: Introduction to Symposium," Twelfth Technical Alfalfa Conference Proceedings (Mission, Kansas: American Dehydrators Association), February, 1975, pp. 65-66.

Figure 7. Wet Fractionation Processes for Alfalfa

8.0 The dehydrated alfalfa industry (Chapter 7)

The rapid expansion of the dehydrated alfalfa industry during the 1940's and early 1950's was stimulated by the promotional efforts of natural gas companies seeking an outlet for gas sales during their summer off-peak season. Natural gas continues to be the principal source of energy for dehydration of alfalfa, though promotional activities have ceased due to recent shortages of supply of natural gas. By and large, the industry has tended to locate where natural gas supplies were available and where gas consumption patterns fit in well with the growth period for alfalfa.

There are estimated to be about 250 dehy plants in the country, concentrated largely in the Midwest (see Figure 8). In the far west, California with about eight plants known to be active, leads the other states. Oregon, Idaho, Arizona, and New Mexico have one or two plants each. (Colorado also has about a dozen plants, all located in the eastern part of the state, remote from geothermal resources.)

Current annual U.S. production of dehy is about 1.3 million tons, down from a peak of 1.7 million tons in 1970. The dehy produced in the Midwest is purchased by local feed formula manufacturers and livestock feedlots (within a radius of 100 to 200 miles of each plant) or shipped to the large feed companies in the East. California's market had been dominated by exports to Japan. The recent decline of Japanese purchases in the United States because of the competition of Canadian dehy, however, has had a serious impact on the California dehy industry. Shipments to Japan, which ran as high as 255,000 tons in 1971, were down to 51,000 tons in 1976.

The industry may have excess capacity at present. The loss to Canada (where dehy production has been promoted and partially subsidized by the government) of much of the foreign market is probably permanent. The domestic market dehy competes on a cost per nutrient basis with other feed formula ingredients. Though it is valued in poultry as a pigmenting agent, its low-energy, high-fiber content limits the amount that can be mixed into feed rations. A relatively stable market is felt to exist at about the current production level, provided production costs (energy, labor, and price of green chop) do not escalate faster than the prices for other feedstuffs.

Energy cost for drying is an important component of dehy price, representing at least 10% of the present price of the product. The possibility of sharp future rises in the price of natural gas and the prospect of gas curtailments (which have already occurred for periods of several days to a couple of weeks for some dehydrators, particularly in the Southwest during the winter) have given dehydrators concern about being able to maintain adequate profit margins. Diesel oil is often used as a back-up to natural gas, but at current prices of twice that of gas per Btu, it is problematic as to whether oil can be an economic alternative.

While it is apparent from the distribution of dehy plants in the country that few are located in geothermal areas, certain individual plants in the Far West may be close enough to geothermal sources to take advantage of geothermal heat for drying, provided the delivered energy prices will be at

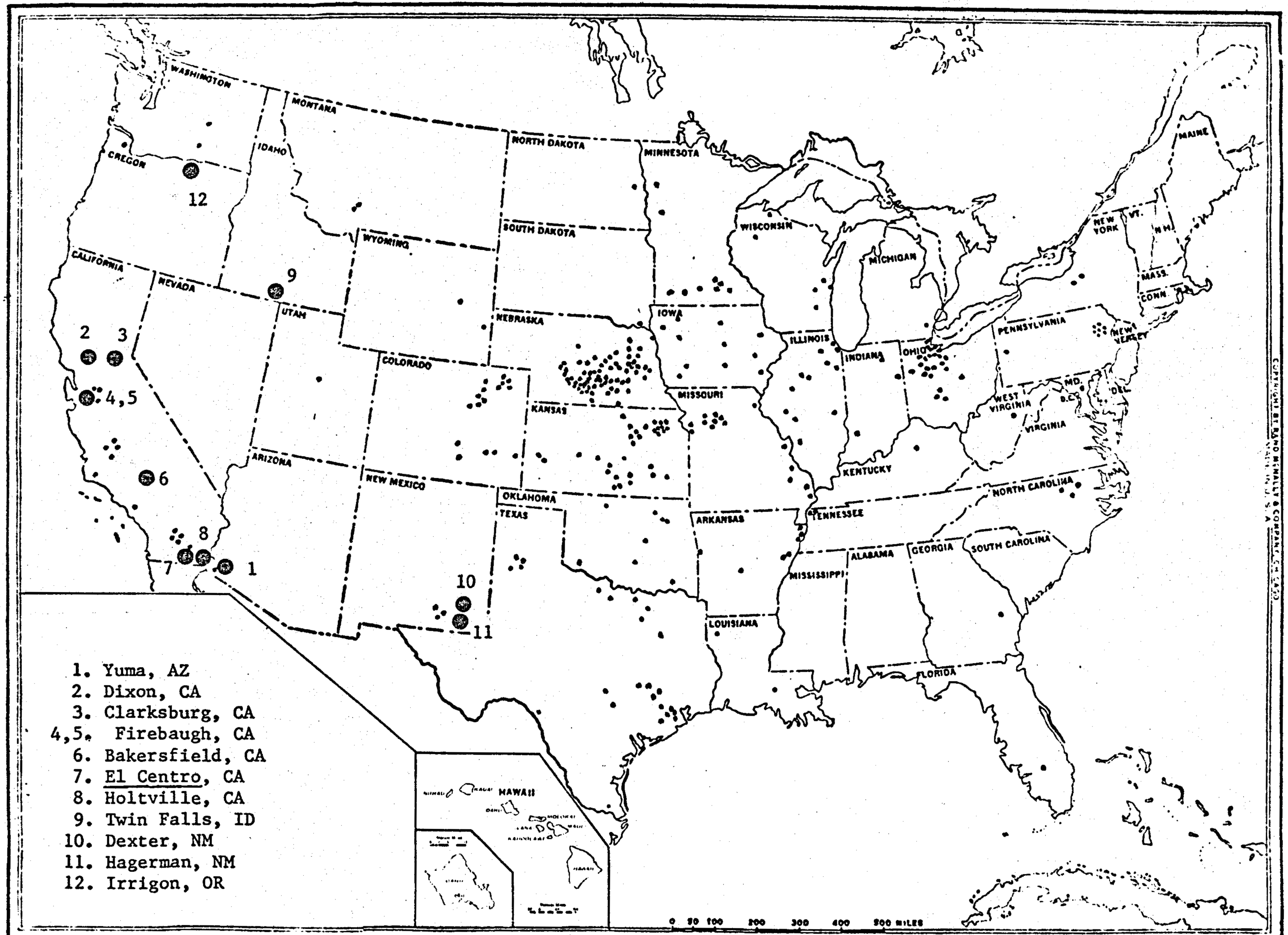


Figure 8. Distribution of Dehy Plants in the United States

least cheaper than oil (see Table IV). However, because of the high expense in piping geothermal liquids and because of the need for a dehydrating plant to be within 10 to 20 miles of its source of fresh alfalfa, the utility of geothermal heat must be examined on a case-by-case basis.

Table IV

OPERATING DEHY PLANTS IN THE WESTERN UNITED STATES AND IDENTIFIED GEOTHERMAL RESOURCES

Map No.	Dehy Plant Location	Nearest Geothermal Resource(s)	Distance (mi)
1	Yuma, AZ	Dunes KGRA, CA	25
2	Dixon, CA	(Jackson's) Napa Soda Spring Napa Soda S. Rock (Priest)	25 25
3	Clarksburg, CA	(Jackson's) Napa Soda Spring Napa Soda S. Rock (Priest)	35-40 35-40
4, 5	Firebaugh, CA	Mercey Hot Spring	25
6	Bakersfield, CA	Sespe Hot Springs	55
7	El Centro, CA	Heber KGRA	2.5
8	Holtville, CA	East Mesa KGRA	6
9	Twin Falls, ID	Hot well near Cedar Hill	12
10	Dexter, NM	Radium Hot Spring	160
11	Hagerman, NM	Radium Hot Spring	160
12	Irrigon, OR	Ritter Hot Spring	70

9.0 Site-specific analysis of geothermal alfalfa dehydration (Chapter 8)

The objective of Chapter 8 is to integrate all of the preceding elements of the study in order to examine them as parts of a system. This integration will allow consideration of cost tradeoffs among the elements, for example, the cost of hauling alfalfa versus geothermal water piping cost. We hope to perform this analysis for two active dehy operations, one near El Centro, California, and the other near Twin Falls, Idaho. These two were chosen partly because they span a wide range of plant operating conditions, dehy markets, and geothermal resource types. Moreover, these dehy plants are two of only three in the United States that are within 15 miles of identified hydrothermal systems. (The third plant is located in Holtville, California, near East Mesa KGRA, a high-temperature resource.) Therefore, if geothermal retrofitting is not feasible for either of these two locations, one may infer that it will not be feasible for any U.S. location.

During this reporting period we contacted the operators of both United Alfalfa Mills at El Centro and Protein Processors, Inc., in Twin Falls. Both operators were very forthcoming about technical details, alfalfa supply, markets, and costs. Wally Heard of United Alfalfa Mills indicated in a followup conversation that he would be willing to cooperate further in a case study if preliminary costs for geothermal energy and new drying equipment were attractive. Ellwin McVicker, the operator of the Twin Falls plant, also has expressed his willingness to cooperate with us. Should the initial costs for energy and dryer modification/replacement be unattractive to the operators, the case studies will conclude with assessments of which costs were excessive. Should the initial capital and energy costs be within plant investment and operating expense capabilities, more detailed analysis of geothermal retrofitting will be performed.

9.1 The El Centro/Heber KGRA Site

United Alfalfa Mills is located on a rail siding of the Southern Pacific Railroad, a quarter-mile south of Interstate 8 and about 2.5 miles southeast of the center of El Centro (see Figure 9). Across the road to the north of the dehy plant is the Valley Nitrogen Plant, subject of one of the site-specific PRDA nonelectric studies. Three miles to the south is the center of the Heber anomaly with its concentration of geothermal wells. (We have made initial contacts with the ERDA contractor for the Valley Nitrogen Plant geothermal study and with Chevron Resources Company, the chief lease holder and operator at the Heber anomaly.)

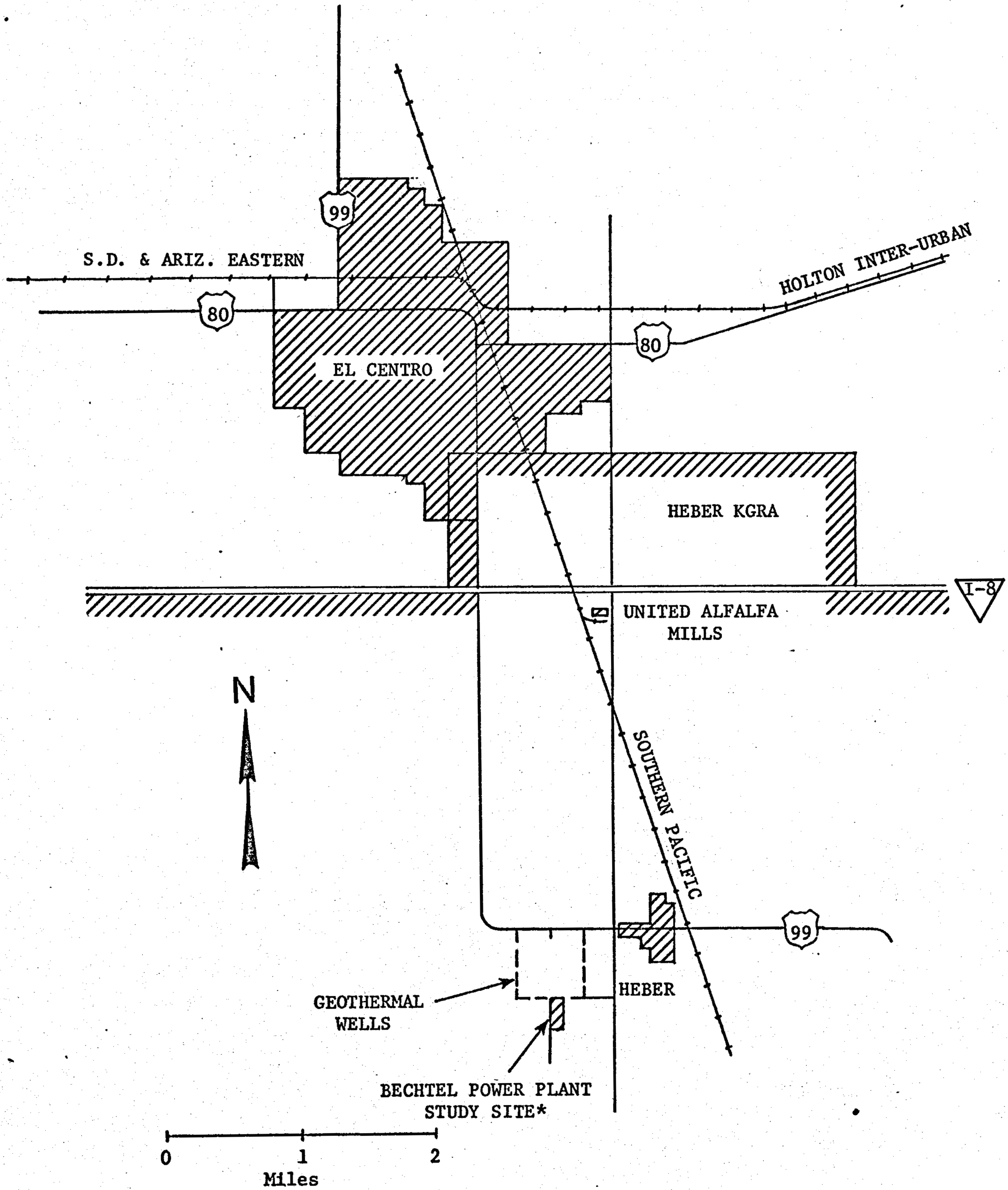
The dryers consist of two 18,000 pounds/hour (evaporative capacity) drums and two 22,000 pounds/hour drums. The four drums together can produce about 10 dry tons/hour of 12% moisture, 17% protein dehy-- this is quite a large plant. All dehy is exported to Japan, which is part owner of the plant, for use in poultry feeds. Dehy production accounts for 50% of United's business; the remainder is cheaper sun-cured alfalfa for local markets. The export market is supplied via rail and the port of San Diego; the local market, all within a 250-mile radius, is supplied by truck.

Greenchop alfalfa is delivered in plant-owned trucks from independent growers mostly within 10 miles of the plant. Perhaps 20% of the alfalfa comes from farms 10 to 20 miles away. The climate and irrigation permit 11 cuttings of alfalfa annually for a year-round plant operating season.

Heard is worried about the rising cost and declining availability of natural gas. His cost for gas is $11 to $12/ton of dehy at present, and gas was curtailed recently for four days. The use of standby fuel oil would increase the energy cost per dehy ton by a factor of six. With his present energy sources, a long gas curtailment or a significantly higher price for gas would make dehy production untenable. Increased production of sun-cured alfalfa to substitute for dehy would be the most likely alternative.

Heard was optimistic about his market for dehy, however, saying that California could move more tonnage to Japan than it now does. Japanese poultry feeds once contained 2.5% dehy and now contain only 1%. He seemed to feel this trend could reverse with a consequent growth of 50 percent in the Japanese dehy demand. Cost is his main concern, not markets. He is therefore willing to consider a sizable investment in geothermal energy if the unit energy cost is not much higher than the present natural gas cost.

If the initial geothermal energy and capital costs are reasonable, we will go on to explore several plant siting options. The entire plant might be shifted south toward Heber along the railroad tracks to the point nearest to the center of well-drilling activity. A pipeline from wellhead to plant would be little more than a mile long in this case. Or only the dryer might be moved, with output shuttled to the present plant site for pelleting and shipping. A third option might be cooperation with Valley Nitrogen Plant on a geothermal pipeline, allowing the alfalfa mill to remain where it is. These schemes and hybrids will be investigated during the third quarter assuming that initial capital costs are low enough to warrant it.



*location approximated from J. W. Hankin et al, "Conceptual Design and Cost Estimate for a 10-MWe (Net) Generating Unit and Experimental Facility Using Geothermal Brine Resources," Proceedings: Second U.N. Symposium on the Development and Use of Geothermal Resources, San Francisco, Calif., May 20-29, 1975 (Washington, D.C.: U.S. Government Printing Office, 1976), pp. 1985-1996.

Figure 9. El Centro dehy plant and Heber KGRA

9.2 The Twin Falls Area Site

The Protein Processors dehy plant is located about three-quarters of a mile south of U.S. Route 30 and 2 1/2 miles southeast of central Twin Falls on a siding of the Union Pacific Railroad (see Figure 10). (Less than a half-mile south on the same siding is the Amalgamated Sugar factory identified in Table 3-1 of TRW's "Use of Geothermal Heat for Sugar Refining," Quarterly Report for the Period October 4, 1976 to January 10, 1977 [SAN/1317-1, February 1977]). The nearest identified geothermal resource is the Cedar Hill area about 12 miles to the southeast. A 236 meter water well discharges about 2050 liters/minute at 38°C (775 feet, 540 gallons/minute, 100°F). The USGS* estimates subsurface reservoir temperature at 120°C (248°F).

The dehydrating plant consists of two drums, one a 10 foot diameter by 30 foot long model, the other an 8 by 24 unit. Total capacity is about 4 tons/hour of 9 to 10% moisture dehy; greenchop is field-wilted to 65% moisture before drying to conserve energy. Total production last year was 10,000 tons. A like amount of alfalfa was sun-cured. About 50% of the dehy was exported to Japan via rail and the Portland docks. The remainder was trucked to eastern Washington, California, and Utah for poultry feed formulation.

The main greenchop supply area is located around the towns of Kimberly and Hansen. Most alfalfa comes from farms 8 to 10 miles away; the furthest, from 14 miles. The growing season is only 90 days long, from May 20 to November 1, allowing four cuttings.

Natural gas presently costs about $14.50 to $18.50/ton of dehy. The plant has been on interruptible service for some time. One and a half to two weeks of supply was curtailed in October 1975. On November 2, 1976, notice of curtailment for the winter was given; in previous years the plant had operated until about November 20. A further 20% increase in the cost of gas would make dehy production uneconomic, according to the operator, Ellwin McVicker. Rather than use oil as a back-up fuel, all artificial dehydration would be discontinued.

McVicker specified three requirements for any relocation of his plant that might be necessary to utilize geothermal energy. Greenchop alfalfa must be available at little more than the present supply radius. A rail siding location is needed for export shipments. And EPA air pollution regulations must be satisfied at the dryer site.

Siting options appear to be fewer and less promising for the Twin Falls case than for the El Centro case. The straight-line distance of 12 miles between the present plant location and Cedar Hill appears to eliminate pipeline delivery of geothermal hot water as an alternative (unless cooperation with the Amalgamated Sugar factory increased the heat load enough to make piping practicable). The dryer portions of the plant might be moved to Cedar Hill; the alfalfa suppliers in the Kimberley-Hansen area could be retained at about

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*White and Williams (eds.), Assessment of Geothermal Resources of the United States--1975, Geological Survey Circular 726 (1975), Table 5, p. 40.

the present hauling distance. Shipping facilities would remain where they are in this case. Or the rail loading terminal might be moved to Hansen in order to reduce the distance between it and the dryer(s) at Cedar Hill from 14 to 8 miles (all roads follow the section line grid). These are very tentative suggestions that may not survive the initial capital and energy cost screenings.

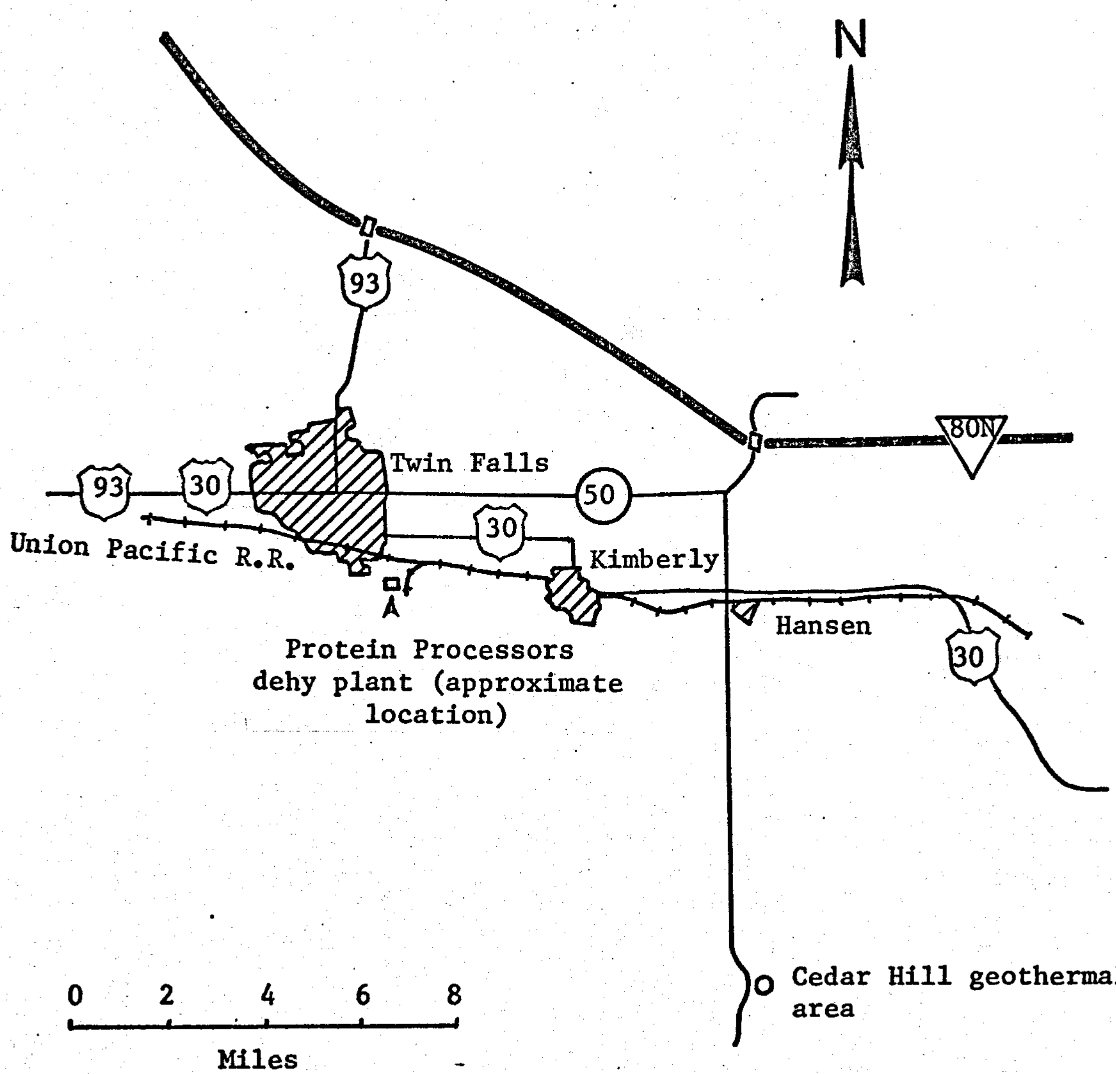

Figure 10. Twin Falls dehy plant and Cedar Hill geothermal area