TECHNICAL REPORT

FOR THE PERIOD

JANUARY 1 THROUGH MARCH 31, 1977

MULTIFLASH FEED-AND-BLEED COUPLING FOR THE EVAPORATION AND CRYSTALLIZATION INDUSTRY

DENNIS J. BASUINO
PATRICK T. DOYLE

S. C. MAY
PROGRAM MANAGER

MASTER

PREPARED FOR
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT NO. E(04-3)-1328

BECHTEL CORPORATION

JOB NO. 11940

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

CONTENTS

TABLES

ILLUSTRATIONS

Section 1

Introduction

In October of 1976, Bechtel Corporation was awarded a contract by ERDA (Division of Geothermal Energy) to determine the technical and economic feasibility of using low temperature geothermal brine in place of steam from conventional sources for industrial multi-effect evaporation and crystallization. A key aspect of the study is that Bechtel's multiflash feed-and-bleed concept will be incorporated in the evaporation and crystallization processes to use the geothermal energy most effectively.

This document is the second quarterly report outlining work performed on this contract during the period of January through March 1977. This report discusses:

- Each of the three candidate industries, and how they were chosen.
- Other industries that might use geothermal brine in their evaporation/crystallization operations.
- Contacts made with people in these industries, and with manufacturers of evaporators and crystallizers.
- Modifications made in the evaporator heat and material balance computer program.
- Work being done on well/pipeline economics and the information available for this analysis.

Preliminary conclusions are discussed, and an outline of work to be performed during the next quarter is given.

1.1 Summary of Second Quarter Work

The actual work performed during January through March is summarized in Subsections 1.1.1 through 1.1.5, and discussed in detail in Section 2.

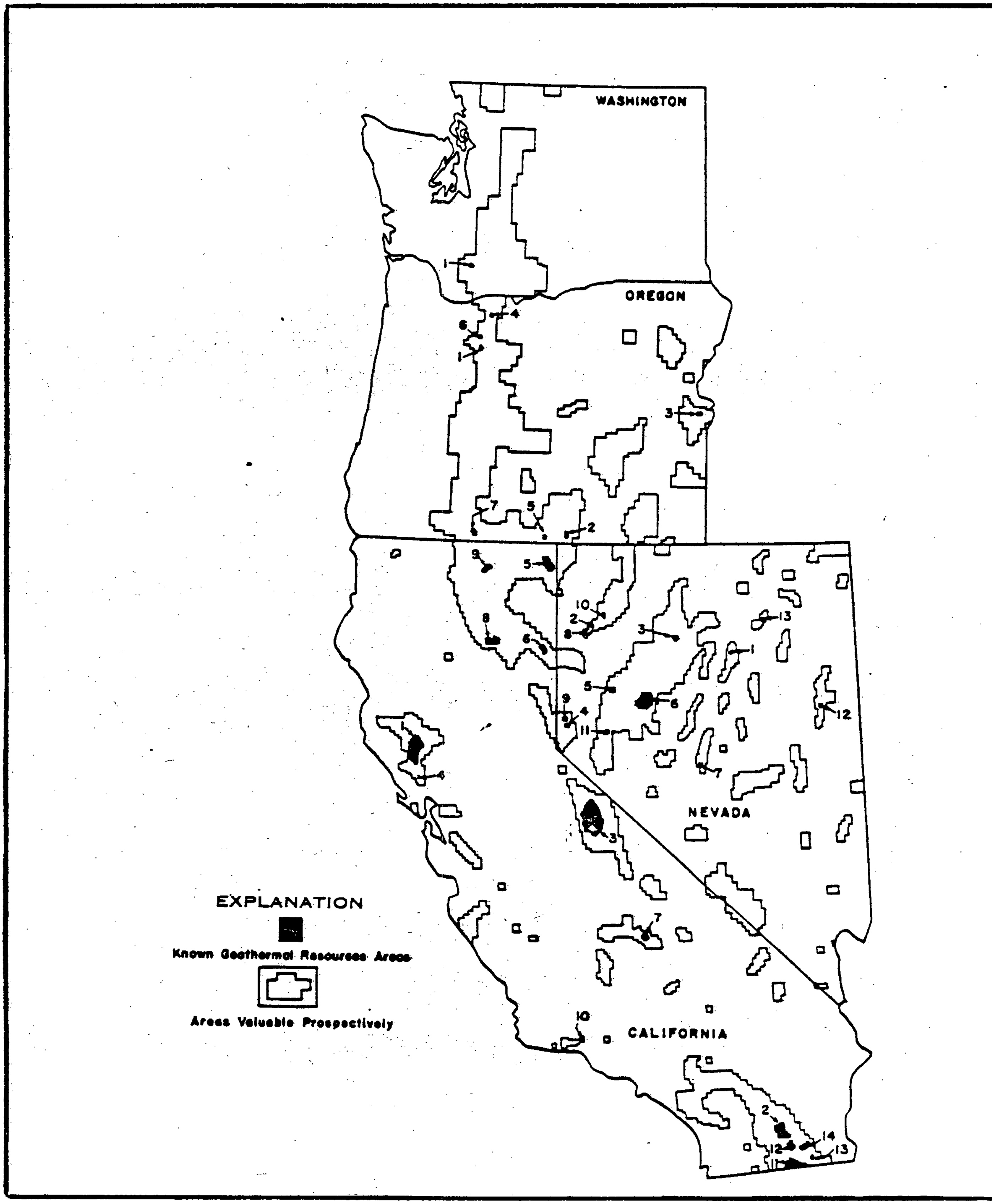
1.1.1 Selection of Candidate Industries

A number of industries use multiple effect evaporation or crystallization in some phase of their operations. Some of these are located in or near areas of known or potential geothermal sources (See Figures 1-1 and 1-2 for maps showing "prospective" geothermal resource areas). From among these industries, three have been selected as the "candidate industries" for this report:

- Preserved Fruits and Vegetables, (SIC industry group 203). Evaporator users in this industry include fruit and vegetable juice concentrators. Example case for this study: tomato paste production.

- Sugar and Confectionary Products, (SIC industry group 206). In this industry, both beet sugar and cane sugar producers use multiple effect evaporation. Example case: beet-sugar production.

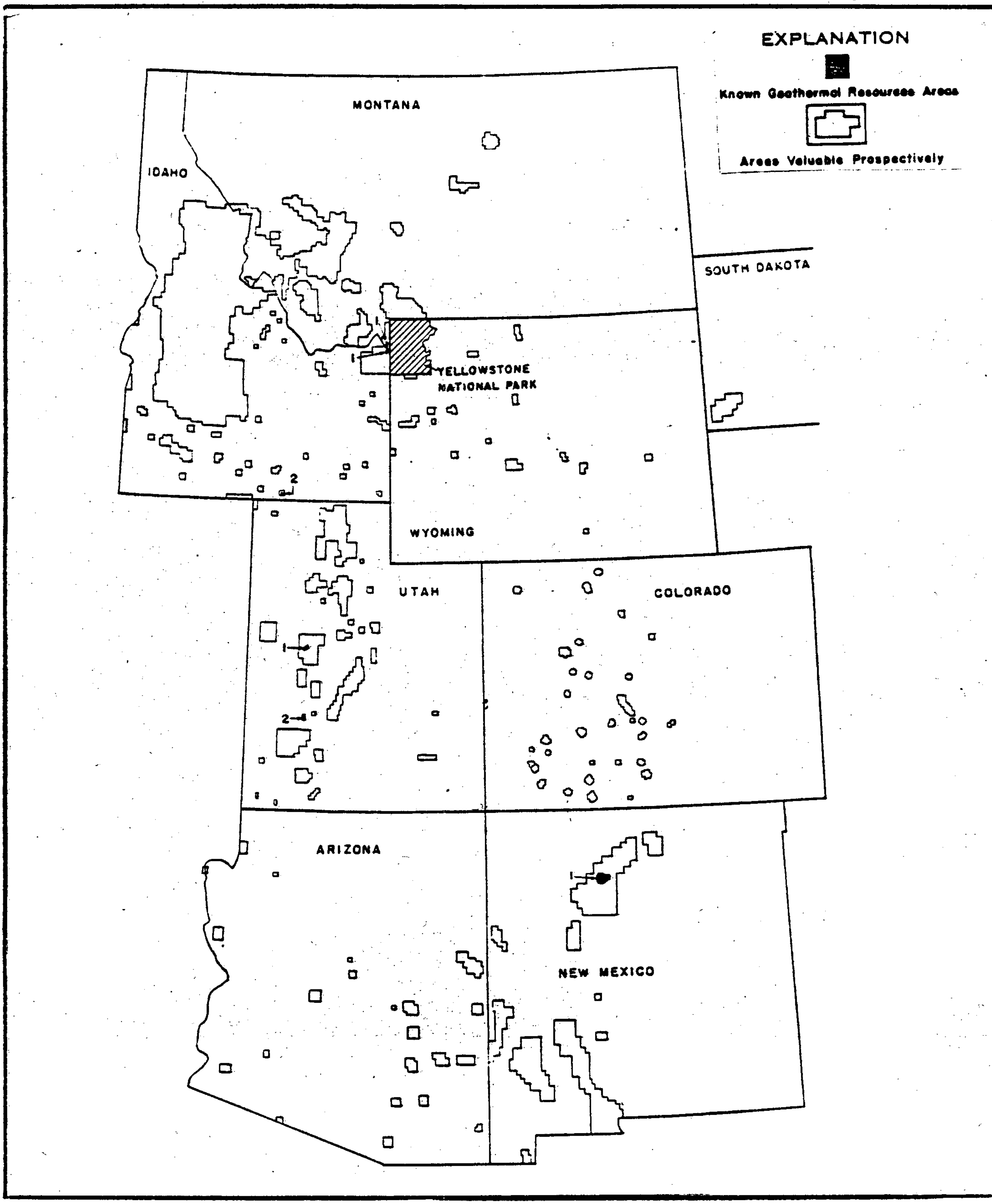
FIG. 1-1



LANDS CLASSIFIED FOR GEOTHERMAL RESOURCES

(KNOWN AND PROSPECTIVE)

Fig. 1-2



LANDS CLASSIFIED FOR GEOTHERMAL RESOURCES

(KNOWN AND PROSPECTIVE)

- Chemicals, (SIC industry group 28). This broad category includes such users of multiple effect evaporation/crystallization as inorganic salts producers and chlorine-caustic manufacturers. Example case: sodium chloride production.

Detailed studies of each of the candidate industries are in progress to determine the feasibility of using low temperature geothermal brine in their multi-effect evaporation/crystallization operations. In addition, work is being done to identify other industries that are potential users of low temperature geothermal brine for evaporation/crystallization.

1.1.2 Process Flow Diagrams

Work is in progress on the process flow diagrams for the candidate industries. Flow diagrams are being prepared for conventional plants, existing plants retrofitted for geothermal brine use, and new plants designed to use geothermal brine. Corresponding heat and material balances for these cases are being prepared using a modified version of the evaporator computer program developed for this study.

1.1.3 Industry Contact

In order to obtain the information necessary to evaluate the candidate industries, as well as to get the reaction of people working in these areas, several plant trips and meetings were arranged. A Tri/Valley Growers tomato paste concentration plant and a Spreckels beet-sugar factory were toured. Discussions were held with the Director of Engineering of each of these two companies, the plant manager of the Spreckels plant, and manufacturers of evaporator and crystallizer equipment.

1.1.4 Data Collection

In addition to that obtained from industry contact, important data was gathered from a variety of sources. Good information was collected on food industry energy requirements for concentration[55], salt manufacturing,[46, 53], well pipeline costs [48, 49, 50, 51], and potential geothermal source locations[52]. Collection of data necessary to evaluate the feasibility of geothermal use by the candidate industries is now nearly complete.

1.1.5 Well/Pipeline Economics

Preliminary economic analyses have been started. A standard format for these analyses is being developed so that the effect of the significant parameters (stream factor, brine flow, pipeline length, etc.) on geothermal steam cost can be easily shown.

1.2 Preliminary Conclusions

Preliminary conclusions drawn from the work performed during January through March 1977 are discussed in Subsections 1.2.1 through 1.2.4.

1.2.1 Industry Acceptance

Based on discussions with industry representatives, reaction to the replacement of fossil fuel generated process steam by steam from geothermal brine has been generally enthusiastic. These industries, of course, know of the energy problems in this country, and are making efforts to ensure that their own energy needs are satisfied. Already, in anticipation of interruptions in natural gas supplies, plant boilers are being converted to oil use. Admittedly, this is a stop-gap measure of which these industries are aware. However, individually, these organizations lack the technical and economic resources to develop new energy sources. Hence, the interest in a cooperative development of geothermal brine systems. A number of people in the industries that were contacted expressed a willingness to participate, to some degree, in programs that would further develop industrial geothermal use. There is some concern, though, about the economics and reliability of geothermal systems. If it is proven that the cost and dependability of geothermal systems are favorable, it is likely that industry acceptance will follow.

1.2.2 Plant Operating Factor

The plant operating factor - the fraction of the year that a plant is "on-stream" and producing a product, has a significant effect on the economics of geothermal brine use for that plant. Several of the industries investigated have lower than normal (85%+) operating factors. Tomato paste concentration plants, for example, normally operate less than four months per year. Thus, for the same geothermal brine flows, the cost of geothermal steam for a plant with an operating factor of 33% would be almost 2½ times as great as for an identical plant having a stream factor of 85%. To more efficiently use the geothermal resource in plants with low operating factors, an "industrial park" concept might have to be considered. With a number of users, the cost of the brine could be shared so that the plant that operates seasonally would not be as heavily penalized. There are, however, some disadvantages to this concept. A major drawback is that a number of possibly diverse industries would have to agree to build their plants together at a location potentially removed from the traditional sites for these industries.

1.2.3 Pipeline Length

Pipeline length is another factor that significantly affects the economics of using geothermal brine. Preliminary figures show that the cost of steam from geothermal brine based on a 10 mile pipeline system is from 50-300% higher than for a comparable system of one mile length. It may not be economical to transport the brine over any other than limited distances. In which case, a better definition of the location of geothermal resources is needed to accurately assess the potential use of geothermal energy by existing and future plants.

1.2.4 Additional Applications

In addition to the candidate industries chosen to be evaluated for this study, there are other promising areas of geothermal application.

A potential area of application - the Pulp and Paper industry, is a large user of energy for evaporation of black liquor and has many facilities in the Western United States.

The second promising area is a broad one - waste concentration. This includes the concentration of aqueous wastes for recovery, reuse, or disposal. For example: concentration of metals refining wastes to recover valuable by-product metals, concentration of alumina spent liquor for reuse, and concentration of power plant cooling tower blowdown for disposal.

A third potential area of application of geothermal brine for evaporation is the dairy industry. Here, evaporation is used for the production of dry milk and cheese whey products.

Section 2

Discussion of Second Quarter Work

This section gives a detailed account of the second quarter work summarized in Section 1.

2.1 Selection of the Candidate Industries

The Preserved Fruit and Vegetable, Sugar and Confectionary, and the Chemicals Industries were selected as the "candidate industries" based on the following criteria:

1. Is a significant user of energy in general, and in particular for its evaporation/crystallization operations.
2. Uses steam at 300^{o}F or less in its evaporators/crystallizers.
3. Is presently near or can be located near geothermal resources.
4. Taken together, the three selected candidates demonstrate the broad range of evaporation/crystallization conditions prevalent in industry.
5. There is a significant incentive to change to geothermal use.
6. Their process is such that geothermal brine systems can easily be integrated into it.

From within each candidate industry, an example process was chosen as typical of conditions to be found in other users of evaporation/crystallization in the industry group.

The requirements for selection as a candidate industry, along with the example cases for each, are discussed in the following sections 2.2 through 2.4.

2.2 Preserved Fruit and Vegetable Industry

Tomato paste concentration was chosen as an example case for this industry which includes vegetable and fruit juice concentration as users of multiple effect evaporation.

2.2.1 Tomato Paste Industry

Over 90% of the tomatoes produced in the Western United States are grown and processed in California. About 5 billion pounds of tomatoes per year are used for paste production in the U. S. The bulk of this is processed in the Sacramento and San Joaquin Valleys of California. For the evaporation step alone, 1.89×10^{12} BTU/yr (400,000 BBL oil/yr equiv.) of energy are required to produce the tomato paste[34, 55]. Natural gas and/or oil is used almost exclusively to produce the low pressure steam required for paste production. A listing of the companies in the Western U. S. that produce tomato paste is given in Table 2-1.

2.2.2 Plant Visit

In February, a visit was made to Tri/Valley Growers' tomato paste plant at Volta near Los Banos, California. The visit was made to get a first hand look at tomato paste evaporation operations so that the feasibility

Table 2-1

Western U.S. Tomato Paste Producers (19)

Firm	Factory Location
California Canners & Growers	Gilroy, California San Jose, California Stockton, California Sunnyvale, California Thornton, California
Contadina Foods	San Jose, California Woodland, California Riverbank, California Hollister, California Hanford, California
Del Monte Corporation	Modesto, California Stockton, California
Gangi Brothers Packing Company	Santa Clara, California
Heinz U.S.A.	Tracy, California
Hickmott Foods Inc.	Antioch, California
Hunt-Wesson Foods, Inc.	Davis, California Oakdale, California Hayward, California
Joan of Arc Company	Turlock, California
Kern Foods, Inc.	City of Industry, California
Libby, McNeill & Libby	Sacramento, California
NCC Food Corporation	San Jose, California Hollister, California
Pacific Coast Producers	Lodi, California Oroville, California
Ragu Foods Inc.	Merced, California
Sacramento Foods Division	Sacramento, California
Stanislaus Foods Products Company	Modesto, California

Table 2-1 (continued)

Firm	Factory Location
Sun Garden Packing Company	San Jose, California
Tille Lewis Foods, Inc.	Stockton, California (2) Modesto, California Antioch, California
Tri/Valley Growers	Modesto, California (2) Stockton, California Los Banos, California
Valley Tomato Products, Inc.	Stockton, California

of using low temperature geothermal brine in this industry could be realistically determined. During the visit, discussions were held with Harold Griffith, Tri/Valley's Director of Engineering, from whom much useful information was gathered.

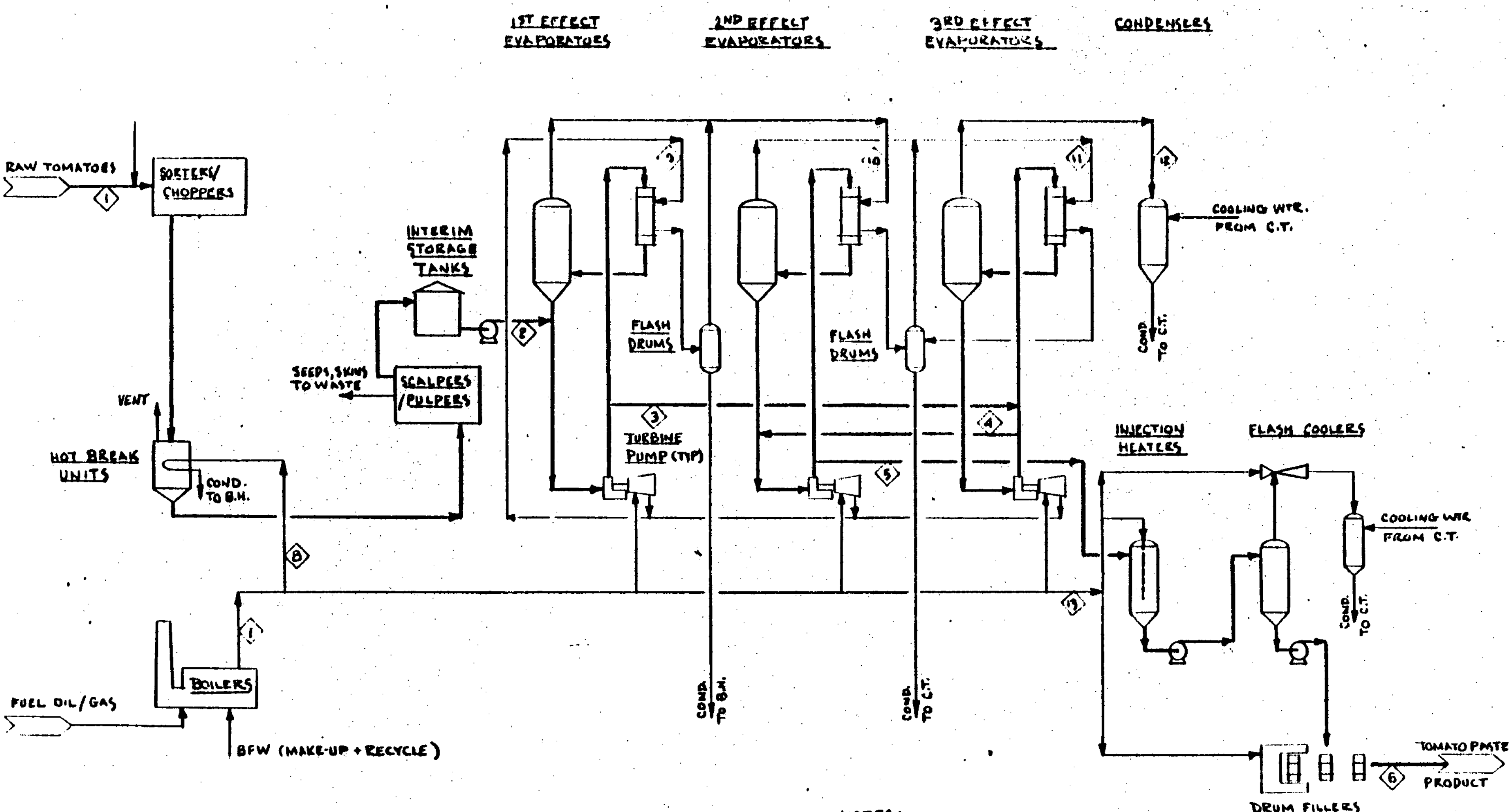
Tri/Valley's Volta plant began operations in 1973. It has the capacity to convert up to 200 tons/hr of tomatoes into a 300% solids tomato paste. The plant is operated only during the 70-day/year harvest season.

The facility cost $10 million. Of that, about $1 million was spent for steam generators, $2 million for the multiple-effect evaporation system, and $250,000 for a five-mile gas supply pipeline. A good description of this plant is given in the article "Astute Engineering Designs, The New Generation Plant"(31).

2.2.3 Tomato Paste Process

Tomatoes are processed at the Volta plant using a sequence of operations that are typical of most tomato paste facilities (refer to Figure 2-1):

1. Washing to remove dirt, etc.
2. Chopping to reduce size.
3. "Hot breaking" or cooking for brief time at 210°F to deactivate enzymes and separate the skins.
4. Scalping, pulping, and finishing to remove skins, seeds, etc.
5. Interim storage to provide operating flexibility.



NOTES:

	1	2	3	4	5	6	7	8	9
TEMPERATURE, °F									
PRESSURE, PSIA									
FLOW, LB/HR									
GPM									
WT% SOLIDS									

	10	11	12	13	14	15	16	17	18
TEMPERATURE, °F									
PRESSURE, PSIA									
FLOW, LB/HR									
GPM									
WT% SOLIDS									

FIG. 2-1

ERDA

NONELECTRIC USES OF GEOTHERMAL BRINE

PROCESS FLOW DIAGRAM
CONVENTIONAL - 200 TON/HR
TOMATO PASTE PLANT

by BECHTEL CORPORATION

JOB NO	DWG. NO	REV.
11840		3/3/77

6. Multiple effect evaporation to concentrate from 5 to 30 wt% solids.
7. Heating to 210°F by direct steam injection to sterilize the product.
8. Cooling to 80°F in vacuum coolers before filling 55-gallon drums with the tomato paste product.

Process steam for the plant is supplied by two 125,000 lb/hr boilers. Each boiler is rated at 150# pressure and can produce steam at 365°F. The boilers were originally designed to use natural gas as fuel, but have recently been modified to use oil as well. Most of the process steam is used in the hot break units (44%) and, after driving turbine evaporator-circulation pumps, in the multiple effect evaporator system (43%).

The hot break units are simply a number of vessels with internal coils for heating the tomato pulp. Steam is supplied directly from the boilers at 365°F, although, with increased heat transfer surfaces, lower temperature steam could be used.

The multiple-effect evaporator system consists of three 60 ton/hr parallel trains. Each train is made up of three Rossi-Catelli forced-circulation evaporators to give a three effect system. Tomato pulp at 5 wt% solids is fed to the first effect at about 200°F. Here, the pulp is concentrated to 7 wt% solids at approximately 210°F. The product is then discharged to the third effect where its concentration is increased to 13 wt% before being pumped, finally, to the second effect body. Product tomato pulp is discharged from the second effect at 30 wt% and 160°F for final sterilization and drum filling. The tomato pulp is routed from first to third to second effect to counter problems of high viscosity and low heat transfer coefficients at increasing paste solids concentrations. Ideally, a 25°F steam to product temperature differential is maintained in the first effect, while the pulp temperature is limited to a maximum of 210°F to prevent "burning" of the pulp. Condensate from the first and second effects is collected, flashed (to provide additional heat to respective downstream effect), and returned to the boilers. The evaporator system is constructed almost entirely of 316 stainless steel, as is most of the other process equipment in the plant.

After being concentrated to 30%, the tomato paste is quickly heated to 210°F by direct 365°F steam injection. This method of sterilization, though wasteful of steam, is simple and inexpensive. An alternate method would employ a scraped surface heat exchanger for the waste heating. In this way, condensate could be collected and recycled to the boiler for greater heat economy.

2.2.4 Tomato Paste Production Using Geothermal Brine

During the second quarter, an evaluation was started of a typical tomato paste plant using geothermal brine as its sole source of steam.

Process flow diagrams were prepared for 200 ton/hr retrofit and new paste plants using geothermal brine, as well as for the base case conventional plant using steam generated from fossil fueled boilers. These diagrams will be used to point out the differences between the conventional, retrofit, and new plant cases.

Using the modified version of the evaporator computer program, complete heat and material balances were prepared for each of the cases. For the retrofit and new plant cases, a total brine requirement was calculated using brines of varying temperatures (see Figure 2-2). These brine flows are sufficient to supply all the plant's steam requirements (evaporators, hot breaks, sterilizers, etc.).

2.2.5 Industry Discussions

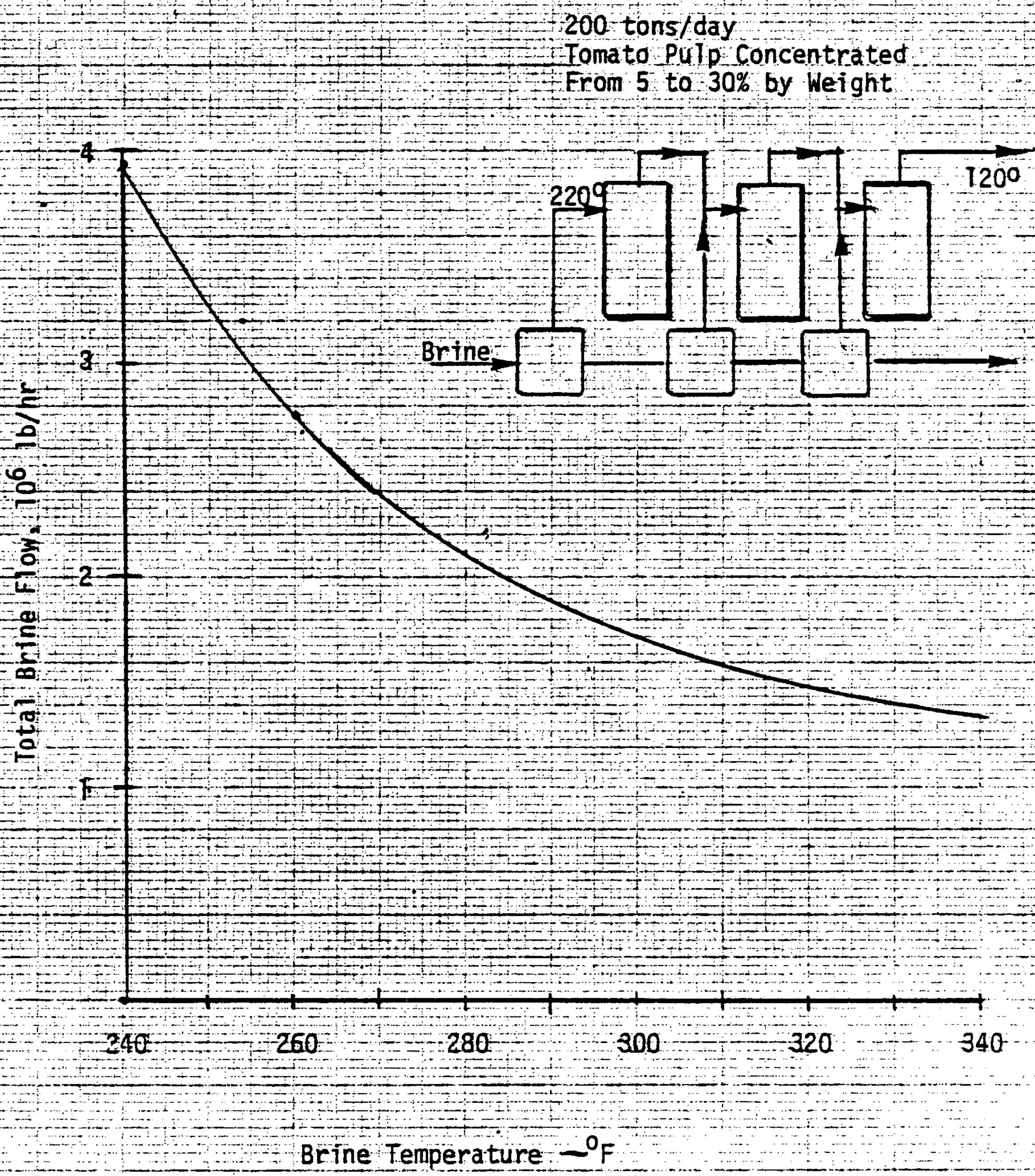
Harold Griffith of Tri/Valley Growers was enthusiastic about the possibilities of using geothermal brine for tomato pulp concentration. He stressed the need for, and Tri/Valley's interest in, new sources of energy. Tri/Valley, being very concerned about the possible future interruptions in their natural gas supply, has started modifying their boilers to burn oil. As this may be only a short term solution, other forms of energy, as well as energy conservation programs, are being investigated.

Viewing the future of the tomato paste industry, and the prospects for future plants in geothermal resource areas, Harold feels that there will be a need for new tomato paste plants. The demand for tomato paste products has been increasing at about 8%/year. His criteria for the location of future facilities are as follows:

Figure 2-2

Retrofit Tomato Paste Plant

Brine Flow vs. Brine Temperature



- Located in California. Over 90% of the tomatoes in the Western states are grown and processed in California.
- Inexpensive land. Tomato waste products and waste water would be used to upgrade the soil around the plant for future agricultural use.
- 75% of the tomatoes used in the facility should come from no further than 150 miles. This is to hold down transportation costs and reduce spoilage in transit.
- Readily available utilities. 400 - 800 gallons of water per ton of tomatoes is required.
- Readily available part and full time labor.

A different approach to tomato handling called "field cutting" has been considered by tomato processors. In this scheme, the tomatoes are picked and sliced in the field. The resulting slurry can then be transported over longer distances to the paste plant. The disadvantage is that the enzymes in the tomatoes, which at temperatures between 100 and 140^{o}F are active and eventually destroy the pectin in the fruit, would have to either be killed by heating ("hot breaking") before transporting, or deactiviated by shipping in refrigerated trucks. If "field cutting" was adopted, paste plants could be located further from sources of tomatoes.

Harold could foresee no major process problems in using geothermal brine for tomato paste concentration. However, when asked if some of the spent brine could be used to wash the incoming whole tomatoes (much water is used in this step), he replied that it would depend on the pH of the brine. High pH brine could tend to increase the tomato pH above its normal 4.5, where bacteria growth is promoted.

According to Mr. Griffith, Tri/Valley would be willing to consider participation in a future geothermal industrial demonstration facility.

Discussions were also held with various manufacturers of equipment for the Fruit and Vegetable industry. Among these were H. Sussman of APV and Allen Dal Porto of Fran Rica (distributor of Rossi-Catelli evaporators). They were able to give us valuable information on this industry.

2.2.6 Remaining Work

Remaining work on the evaluation of the Preserved Fruit and Vegetable Industry is summarized as follows:

- Final "polishing" of the process flow diagrams.
- Sizing of the equipment needed to adapt a tomato paste plant for geothermal use.
- Estimation of the cost of this equipment.
- Economic evaluation of the cases studied, including the required geothermal well/pipeline systems, to arrive at the cost of steam for each case.
- Economic impact of geothermal brine use on this industry.

2.3 Sugar and Confectionary Products Industry

Beet-sugar solution concentration (for the production of beet-sugar) was chosen as the example case for this industry which includes both beet and cane sugar solution concentration as users of multi-effect evaporation.

2.3.1 Beet-Sugar Industry

The beet-sugar industry converts approximately 26 million tons per year (1971) of raw sugar beets into various sugar products. Roughly 70% of these beets are processed in 39 beet-sugar factories located in the Western United States[10]. In 1971, the industry consumed a total of 83.3 x 10^{12} BTU's of energy, of which about 12.5 x 10^{12} BTU (15%) were used for multi-effect evaporator operations[34, 55]. Thus, in the Western United States, about 70% or 8.75 x 10^{12} BTU (1,800,000 BBL oil/yr equivalent) is used for evaporation. Natural gas (60%) and coal (38%) are used by the beet-sugar industry to produce the steam required for beet-sugar production. A listing of the companies that produce beet-sugar in the Western United States is given in Table 2-2.

2.3.2 Plant Visit

In February, a visit was made to the Spreckels Woodland, California beet-sugar factory. After an extensive tour of the facility, discussions were held with Martin Quinlan, the plant manager, who answered our questions about beet-sugar processing and the beet-sugar industry.

Table 2-2

Western U.S. Beet-Sugar Producers (10)

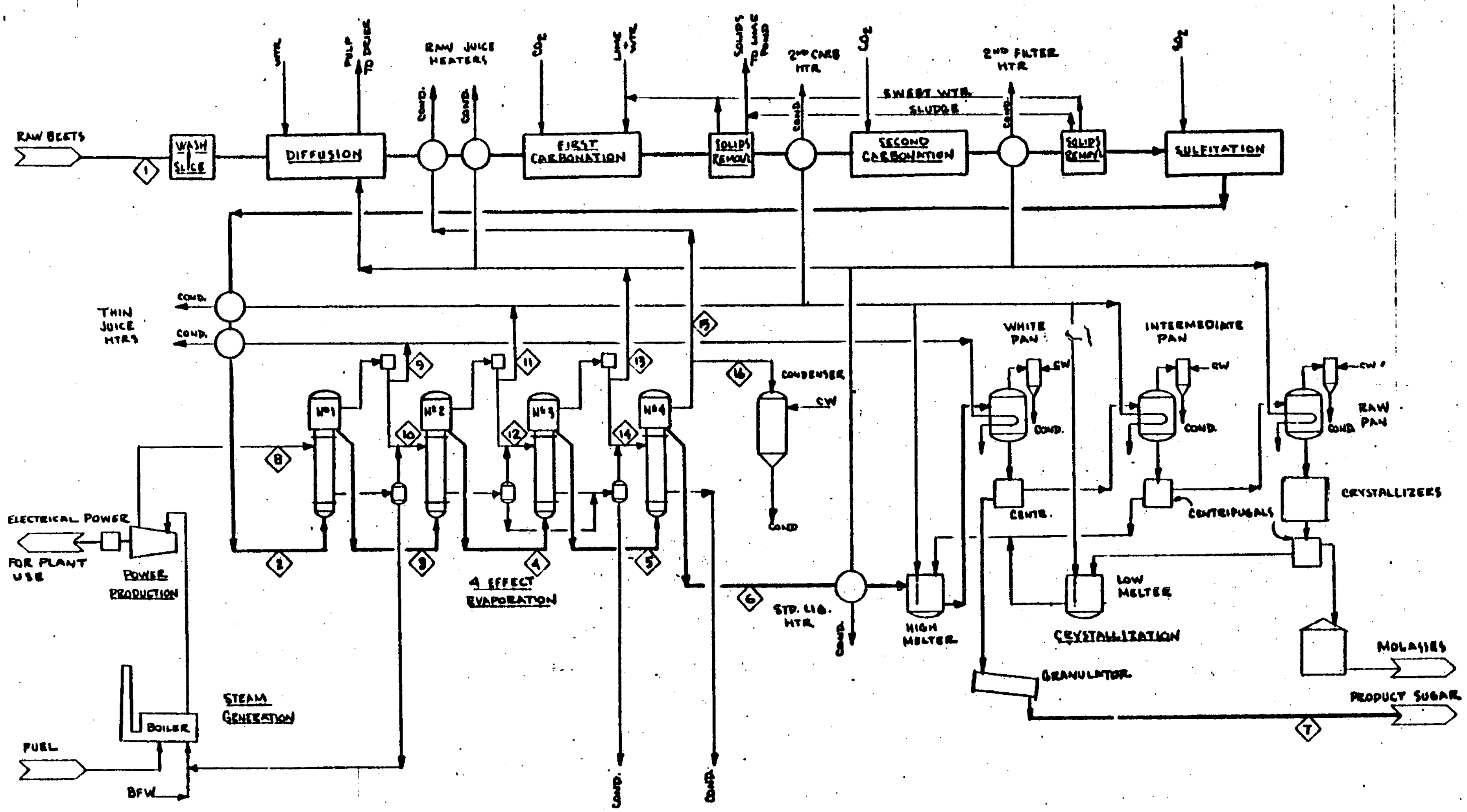
Firm	Factory Location
Amalgamated Sugar Company	Lewiston, Utah Paul, Idaho Twin Falls, Idaho Nampa, Idaho Nyssa, Oregon
American Crystal Sugar Company	Clarksburg, California Rocky Ford, Colorado
Great Western Sugar Company	Loveland, Colorado Greeley, Colorado Eaton, Colorado Longmont, Colorado Sterling, Colorado Fort Morgan, Colorado Billings, Montana Lovell, Wyoming Brighton, Colorado Ovid, Colorado
Holly Sugar Corporation	Hamilton City, California Santa Ana, California Worland, Wyoming Tracy, California Delta, Colorado Sidney, Montana Torrington, Wyoming Hardin, Montana Brawley, California
Spreckels Sugar Company, Division Amstar Corporation	Spreckels, California Manteca, California Woodland, California Mendota, California Chandler, Arizona
Utah-Idaho Sugar Company	Garland, Utah Idaho Falls, Idaho West Jordan, Utah Toppenish, Washington Moses Lake, Washington
Union Sugar Division, Consolidated Foods Corporation	Betteravia, California

The Spreckels Woodland factory was put into operation in 1937. As such, it is one of the more modern of beet sugar factories. It has a daily capacity of 3,600 tons of raw sugar beets, and employs about 350 people. Beets used in this plant come from as far away as Oregon and the Imperial Valley, as well as from local sources. The beets, once harvested, do not keep well; thus, the factory is operated seasonally. In California this can cover a good portion of the year (anywhere from six months up to as much as eleven months in some years).

2.3.3 Beet-Sugar Process

The process used at the Woodland factory is typical of most beet-sugar operations, and is similar to that shown in the flow diagram (Figure 2-3), except that the Steffen process for further recovery of sugar from molasses is used. Nearly every chemical engineering unit operation is used in converting sugar beets (8-16 wt% sugar) to pure refined sugar.

Sugar beet refining requires large amounts of steam (1,500 lbs of steam per ton of beets). The Woodland factory uses three-300# boilers to meet their steam requirement. Before being used for process heating, virtually all of the steam is used to drive seven turbines. Two of the turbines drive generators, which supply two-thirds of the factory's electric power requirement. The other turbines drive various large pumps and compressors. Most of the exhaust steam from these turbines is used in the first effect of their multiple-effect evaporator system, while the remainder is used directly for process heating, such as in some of the evaporator feed preheaters.



	1	2	3	4	5	6	7	8	9	10
TEMP., °F										
PRESS., PSIA										
FLOW, LB/HR										
GPM										
°BRIX										

	11	12	13	14	15	16	17	18	19	20
TEMP., °F										
PRESS., PSIA										
FLOW, LB/HR										
GPM										
°BRIX										

ERDA

NONELECTRIC USES OF GEOTHERMAL BRINE

PROCESS FLOW DIAGRAM
CONVENTIONAL – TON/DAY
BEET-SUGAR FACTORY

by BECHTEL CORPORATION

JOB No	DWG No	REV
11940		

FIG. 2-3

of the fuel requirement in a typical beet-sugar factory is for pulp drying.

2.3.4 Beet-Sugar Production Using Geothermal Brine

As part of the evaluation to determine the feasibility of using geothermal brine to supply steam for a beet-sugar factory, process flow diagrams were started this quarter. These flow diagrams represent retrofit and new beet-sugar plants designed to use geothermal brine for their entire steam requirements, as well as the base case conventional factory using steam generated in fossil fueled boilers. From these diagrams, differences between the three schemes will be seen.

Heat and material balances were started using industry data for the conventional plant case, and the evaporator computer program for the retrofit and optimized new plants.

2.3.5 Industry Discussions

Beet-sugar industry contact consisted mainly of discussions with officials of Spreckels Sugar. These include Martin Quinlan (Woodland Plant Manager), Temple Rowe (Director of Engineering), R. A. McGinnis (Retired, Editor of the comprehensive beet-sugar reference - "Beet-Sugar Technology"), and Fred Ballou (Retired Vice President).

After our tour of the Woodland factory, we discussed, with Martin Quinlan, the possibilities of using geothermal brine in the beet-sugar industry. He was quite receptive to the idea. Beet-sugar production is energy intensive (480,000 BTU/100 lb. sugar), and like others, the industry is being threatened with increasing fuel prices and fuel availability problems. They would, of course, welcome an inexpensive source of heat. Mr. Quinlan gave us what he considered is the criteria for locating any future beet sugar factory:

- Reasonable land cost
- Available labor
- Reliable water supply (2,000 gpm/4,000 T/D factory).
- Reliable source of power and steam. Reliability is important since the plant is very difficult to shutdown or startup.
- Access to raw materials (beets) is a factor, but freight costs, within reason, are of minor importance.

A new 4,000 T/D beet-sugar plant would cost in the neighborhood of $50-60 million.

Temple Rowe, in our discussions with him, was also generally enthusiastic about the possibilities of geothermal use. Some of the more pertinent points of the discussion are given, in brief, as follows:

General

- Some factories potentially could operate up to 300 days/year by using beets grown in distant areas. However, increased transportation costs would have to be offset by lower operating costs to make this economical.

- Transportation charges (by rail) range from $5-10/ton beets.
- Can tolerate a "reasonable amount" of evaporator delta T's and vapor drawoff temperatures.

Participation in Geothermal Development

- A pilot plant demonstration would be a good way to convince Spreckels of the feasibility of using geothermal brine for sugar beet processing.
- Temple would be interested in discussing further the application of geothermal energy after we obtain some results from our analysis.

Both Mr. McGinnis and Mr. Ballou contributed several useful comments.

2.3.6 Remaining Work

Work remaining on the evaluation of the Sugar and Confectionary Products Industry includes the following:

- Completion of heat and material balances.
- Sizing of the equipment needed to modify a beet-sugar plant for geothermal brine use.
- Estimation of the cost of this equipment.

- Economic evaluation of the cases studied, including required geothermal systems, to arrive at the cost of steam for each case.
- Economic impact of geothermal brine use on this industry.

2.4 Chemicals Industry

Salt (sodium chloride) production by evaporation was chosen as the example case for the chemical industry. Users of multi-effect evaporation/crystallization in this industry include, in addition to sodium chloride concentration, inorganic salts production, and caustic soda concentration in chlorine-caustic production.

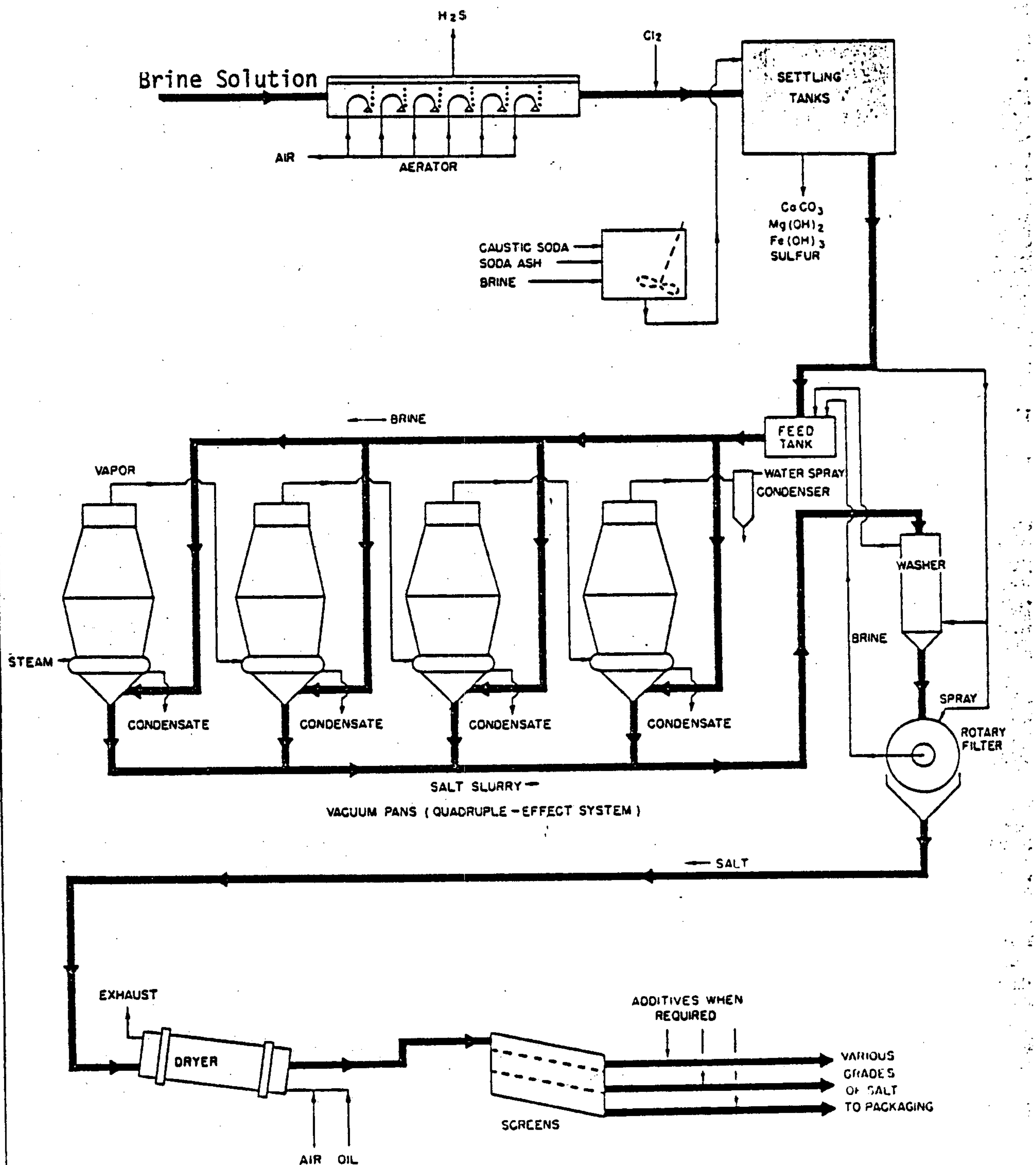
2.4.1 Salt Industry

The salt industry produces over 45 million tons per year (1972) of sodium chloride, most of which is used by the chemical industry itself (see Table 2-3). About 4.5 million tons/year (10%) of the salt is produced using multi-effect evaporation/crystallization - the remainder being produced by various other processes[34, 46, 47]. "Evaporated" salt is produced in 29 plants located in 11 states. Four of these plants are in the Western United States [47].

Table 2-3

Uses of Salt in the U. S.[47]

	Percent
Chlor-Alkali Industry	45
Soda Ash	13
Food Processing	6
Other Chemicals	4
Feed Dealers and Mixers	4
Industrial	1
Miscellaneous	27



FLOW DIAGRAM
TYPICAL SALT PLANT

2.4.2 Salt Process

The production of salt by multi-effect evaporation begins by pumping a saturated brine, obtained from an impure salt deposit, to an aerator to remove most of any hydrogen sulfide that may be present. Addition of small amounts of chlorine completes the H_2S removal by oxidation. The brine is then pumped to settling tanks where it is further treated with caustic soda and soda ash to precipitate out calcium, magnesium, and ferric ions. The clear overflow from the settling tanks is pumped to the multiple effect evaporators where the salt is crystallized out of the saturated solution. The resulting slurry is washed to remove calcium sulfate fines by hydraulic classification, and then filtered - the mother liquor filtrate being returned to the evaporators. Moist salt crystals from the filters are dried to a moisture content of .05 wt% or less in a fossil fueled rotary drum dryer, and then screened to yield the various product salt grades (see Figure 2-4).

The multiple effect evaporator/crystallizer operation typically consists of a quadruple effect system. Brine, saturated with salt at about 25 wt%, is fed in parallel to each effect. As water is evaporated in each unit, salt crystals are formed, and discharged, finally, as a 25 wt% solids solution of salt crystals and saturated brine. Steam, exhausted from power producing turbines at 15-40 psia, is used to drive the evaporators. Normally, a vacuum of 25-27 in. Hg is maintained in the last effect.

In the salt industry, the most frequently used evaporator/crystallizers are internally agitated short-tube calandria units (typically with tubes @

2½" diameter x 5'), and the more recent long-tube forced-circulation units (typically with tubes @ 1½" diameter x 20').

Because of the inherent low profit margin of salt production, salt plants are large, capacities range up to 1000 tons/day.

2.4.3 Remaining Work

Work remaining on the evaluation of the chemicals industry includes the following:

- Development of the process flow diagrams, and heat and material balances for the conventional, retrofit, and new plant cases.
- Sizing of the equipment needed to modify a salt plant for geothermal brine use.
- Estimation of the cost of this equipment.
- Economic evaluation of the cases studied, including the required geothermal systems, to arrive at the cost of steam for each case.
- Economic impact of geothermal brine use on this industry.
- Discussions with industry and a plant visit to obtain information and to assess industry reaction to geothermal use.

- Brief evaluation of inorganic salts and chlorine-caustic industries to roughly determine their prospects for geothermal use.

2.5 Other Areas of Application

This section discusses other industries - Pulp and Paper, Dairy, and Waste Concentration, that are potential candidates for geothermal use. They will not be evaluated in detail because their multi-effect evaporator systems were similar to one of the selected candidate industries, or there was less likelihood of integrating the geothermal system with the overall plant steam system.

2.5.1 Pulp and Paper Industry

That segment of the Pulp and Paper Industry (SIC Industry Groups 261, 262) which includes pulp mill, as well as combined pulp-paper mill operations, is a potential candidate for geothermal brine use. This industry uses multi-effect evaporation with up to seven effects to concentrate black liquor from kraft pulping operations.

The Pulp and Paper Industry is a major energy consumer. In 1971, almost 400 x 10^{12} BTU's were consumed in pulp, and integrated pulp/paper mills (over 35% of this energy is produced internally from waste products). Roughly 15% of the total energy is consumed by mills in the Western United States. Since black liquor multi-effect evaporator operations use about 15% of the energy required in an integrated pulp/paper mill, nearly 9 x 10^{12} BTU's (1,900,000 BBL oil/yr) are consumed by multi-effect evaporation of black liquor in western mills[11, 34]. A number of these mills are located near known geothermal sources (see Figure 2-5).

Both pulp, and pulp/paper mills are highly integrated facilities. Heat from the combustion of black liquor and bark is used to generate steam at 450-600 psi. This steam, after passing through a turbine to produce electrical power, is exhausted at two pressures and used in a number of process heating operations. The low pressure (40-50 psia) portion of the exhaust steam is used in the black liquor evaporators. The combination of steam pressures and multiple process heating systems adds a degree of complexity, as compared to the selected candidate industries, when conversion to geothermal brine use is considered. Unlike beet-sugar production, where the required process heating steam is drawn off between evaporator units, or tomato pulp concentration, where all process steam is used at low pressure, pulp/paper mills would require, in a geothermal plant, a combination of high pressure recovery boiler steam (for power production), intermediate pressure turbine-exhaust steam, and low pressure geothermal steam. Because these steam systems are so highly integrated, there may be some reluctance by the industry to consider geothermal brine use, especially for existing plants.

The feasibility of using geothermal heat in the Pulp and Paper Industry has been discussed by others. A March 1975 study, "Geothermal Resource Utilization, Paper and Cane Sugar Industries", looks at the use of geopressure resources by the Paper Industry[54]. An integrated pulp/paper mill in New Zealand has been using geothermal steam for some of its operations, including a black liquor pre-evaporator, since 1960[28].

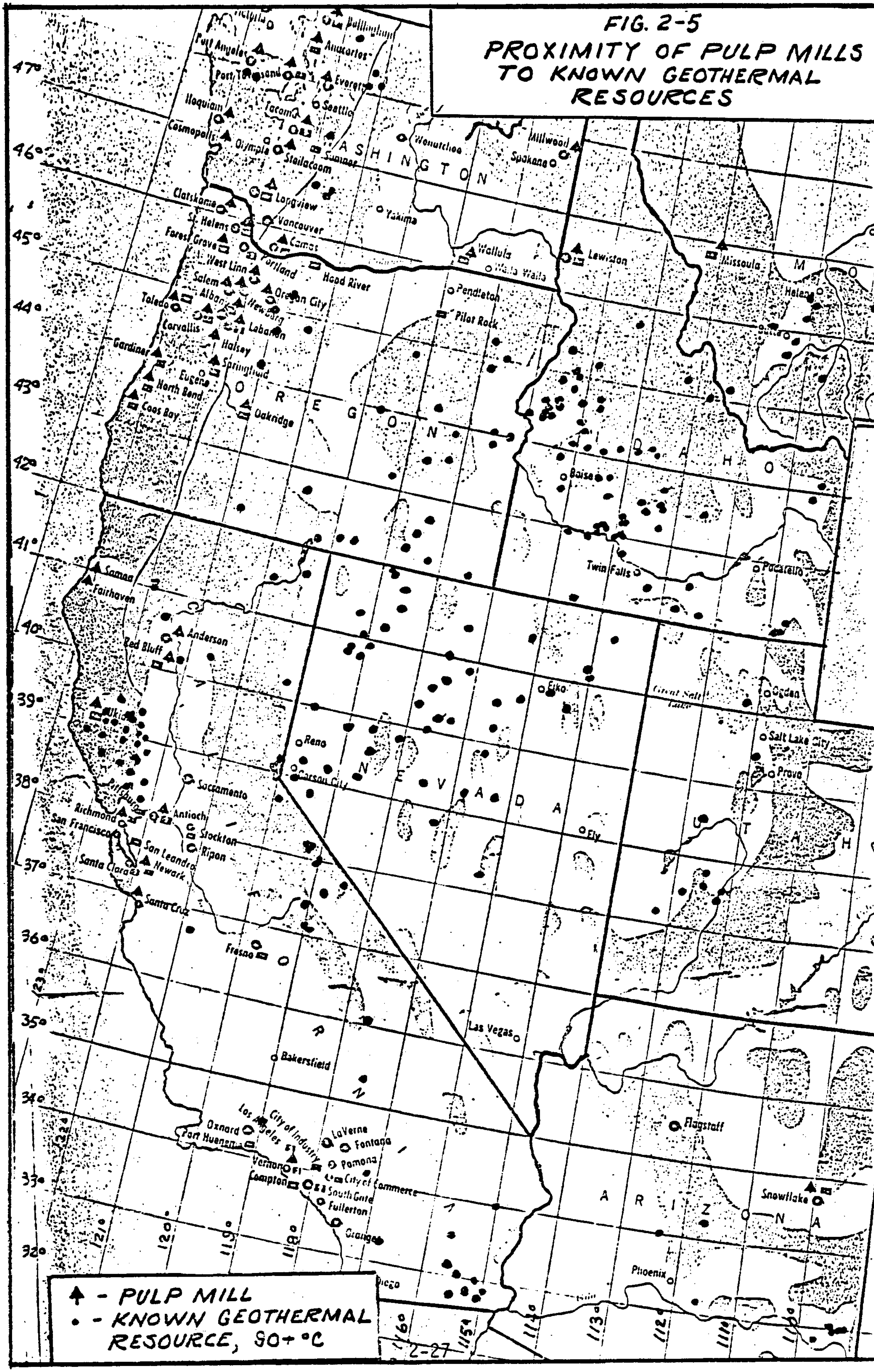


FIG. 2-5
PROXIMITY OF PULP MILLS TO KNOWN GEOTHERMAL RESOURCES

Future work on this industry includes a tentative plant visit, and a survey of industry reaction to geothermal use.

2.5.2 Dairy Industry

The Dairy Industry (SIC Industry Group 202) uses multi-effect evaporation to produce skim milk, condensed milk, evaporated milk, whey, and dry milk. There are many facilities located in the Western United States. Some are near known or potential geothermal resources. As such, this industry is a potential candidate industry. In 1971, 22.5 x 10^{12} BTU's (4,600,000 BBL oil/yr. equiv.) were consumed by this segment of the Dairy Industry[34]. Of this, 10 x 10^{12} BTU's are used in multi-effect evaporator operations[55]. Since about 13% of these milk products are produced in the West, 1.3 x 10^{12} BTU's (266,000 BBL oil/yr. equiv.) are used for evaporation in Western geothermal regions.

From two to four effect evaporator systems are typically used by the Dairy Industry. These systems are similar in operating conditions to those used in the Preserved Fruits and Vegetables Industry.

Future work in this area will include a survey of industry reaction to geothermal use.

2.5.3 Waste Concentration

Although it cannot be classified as an SIC industry, that broad category of operations generally described as waste concentration has many uses for multi-effect evaporators. Waste concentration for recovery, reuse, or disposal of waste materials is a potential candidate for geothermal brine use.

Some examples of waste concentration operations that use multi-effect evaporation are:

- Recovery of ferrous sulfate from pickling liquors.
- Recovery of alumina from spent liquor for reuse.
- Recovery of salts in cooling tower blowdown for disposal.

The operating conditions of these evaporation processes are similar to those used in the Chemical Industry.

Because of increasing economic incentives, and more stringent pollution standards, a greater number of facilities will be concentrating their waste products. In many cases multi-effect evaporation will be used.

Future work on this category will include a listing of processes that now use, or potentially could use multi-effect evaporation to concentrate their waste products.

2.6 Implementation Program

As part of an implementation program, during the last quarter discussions were held with equipment suppliers, evaporation/crystallization users, and Lawrence Berkeley Laboratory personnel who have made an industry survey for utilizing low temperature geothermal brines. The following paragraphs present the results of these discussions with the manufacturers and LBL. The discussions with users are included in the respective sections on application (2.3, 2.4, and 2.5).

Along with Rossi-Catelli and APV (see Section 2.2.5), we talked with the following manufacturers:

- Swenson (R. Bennet, L. Diestelow)
- Goslin (C. Cook)
- Ecodyne (T. Chirico)
- HPD (P. Cheng, J. Karoly)

HPD people were particularly enthusiastic, and stated that they would like to become involved in future geothermal/evaporation development programs, especially in the actual testing of equipment, as they are equipped with extensive pilot facilities.

In addition to equipment manufacturers, there was a lengthy discussion with Jim Davey, Manager of the Non-electric Geothermal Utilization Program at Lawrence Berkeley Labs. During the last year he has contacted over a hundered individuals at various industries in order to acquaint them with the potentials of using low-temperature geothermal brines. The following is a summary of his most relevant comments:

- General: Jim is presently issuing a report on his findings. He summarized the report saying that all of the industries contacted are interested in utilizing more efficient energy processes. However, there appears to be a tremendous inadequacy in their knowledge of the applications of geothermal brines. In addition, they recognize there is a large risk associated with geothermal brines which makes industry reluctant to convert to this process.

- Pulp and Paper Industry: He has contacted Crown Zellerbach and Weyerhaeuser. Weyerhaeuser has over the last five years been exploring the potentials of geothermal energy. They have drilled a well for geothermal brine for use in one of their pulp and paper mills. They spent approximately $100,000 for development of a geothermal well, but ended with a dry hole.

- Sugar Industry: He has talked to Union Sugar, Holly Sugar and Spreckels Sugar. Spreckels built a plant in Arizona in which a well yielding hot water was obtained. Since the water was to be used for cooling, it has to be cooled in a cooling tower prior to utilization in the plant. This factory is an excellent candidate application for low temperature brines as it is located within the immediate area of geothermal activity.

- Food Processing: Many canneries were contacted for applications of geothermal. However, most of the heat requirements in canneries is for sterilization, so it is not applicable to the process we are investigating. Stanislaus Food does some tomato processing and may be a worthwhile contact. However, they are a small company.

- <u>Chemical Process Industry</u>: This is a large area of application including the evaporative process but not many contacts were made. He had not made any contacts in the area of chlorine-caustic production or waste pollution controls.

- <u>State and Local Agencies</u>: For the Imperial Valley, Jeff Weggins is an excellent contact as he is their coordinator of geothermal activities. In Idaho, the Chief of the Bureau of Minerals and Energy for the State of Idaho, Mr. Arthur Zierold, has been contacted and is familiar with local applications. The Idaho National Labs with Jeff Kunze is the best contact. Idaho is an excellent source of low temperature geothermal energy. Presently, 280^{o}F brine is being obtained there from 500 foot wells.

2.7 Computer Program

The multi-effect evaporation heat and material balance computer program has been modified for each specific application considered. This was done to eliminate the convergence problems encountered in the more general version. The result has been increased flexibility in the evaporator configurations that are being considered.

Where information has been available, a subroutine to estimate the overall heat transfer coefficients has been included. This has been done for the sugar beet industry.

The existing programs cover the multiple effect forward feed evaporator system with vapor drawoffs (sugar-beet industry) and a three effect mixed feed evaporator system (tomato paste industry). Future modifications will include the multiple effect parallel feed arrangement used in the sodium chloride industry.

2.8 Brine Supply Economics

From various sources, recent information on the economics of geothermal well/pipeline systems has been obtained this last quarter.

Jim Davey of LBL provided us with a set of his unpublished charts, "Energy Economics for Each Geothermal Production Well", which show the cost of various low temperature geothermal brines. His calculations showed this brine to be valued at approximately $1.50/million BTU's. This figure is based upon year round operation with 360^{o}F brine. It should be noted that natural gas and fossil fuels are in the category of $2.00 to $2.50 per million BTU's at present prices. His calculated cost for brine would increase for lower brine temperatures (such as we are studying) but would decrease for a more efficient heat extraction process as utilized in our process.

An updated report by T. Larson, of U. C., Riverside titled "The Costs of Geothermal Energy Development"(49), examines the economics of developing and maintaining a geothermal field and 200 MW power plant in the Imperial Valley. Much of the data and many of the variables used such as brine temperature, flow rate, and drilling costs can be applied to our non-electric use study.

A section of the final technical report on the Susanville Energy Project, titled "An Introduction to Engineering and Economic Modeling"(51), by B. B. Basse described a model for estimating the costs of geothermal energy for industry. Formulas are given that can be used to calculate well and pipeline costs based on a number of variables.

Also, during the second quarter, work was started on a general economic analysis of industrial plants using geothermal derived steam vs. similar plants using steam generated from fossil fuels. Part of this analysis includes estimating well/pipeline system costs. Some of the more significant assumptions are:

- Well depth required
- Well flow rates possible
- Well life
- Number of reinjection wells required
- Pipeline length
- Exploration costs

Still to be done is the firming up of the assumptions used in this analysis so that the effect of the more important parameters on well/pipeline total costs can be shown.

Section 3

Future Work

Bechtel's effort for the next quarter (April through June 1977) will concentrate on the following areas:

- Completion of Process Flow Diagrams - Most of the remaining work is in the development of Chemical Industry (salt manufacturing) flow diagrams.

- Completion of Conceptual Engineering - This includes work on all three of the candidate industries - mainly sizing of the additional equipment needed to retrofit a plant for geothermal use.

- Completion of Economic Analysis - Calculations for the cost of steam for conventional, retrofit, and new plants will be finalized.

- Begin Comparison to Alternate Methods - The practical and economic advantages of the feed-and-bleed process will be assessed by comparison with other processes for the industrial utilization of geothermal heat.

- Begin Economic Impact Study - An estimate of industry-wide economic impact of the use of geothermal heat will be started.

- <u>Begin R&D, Implementation Plans</u> - After pointing out potential problem areas, a research and development program will be outlined to solve these problems, or to minimize their impact on the proposed industrial application of geothermal heat. Along with this, in order to establish a cooperative demonstration program with a number of potential users of geothermal heat, a plan of action will be developed together with a suggested schedule and a rough cost estimate of the program.

- <u>Completion of Environmental Study</u> - The environmental effects of using geothermal steam vs. steam derived from fossil fuels will be looked at.

REFERENCES

1. R. N. Poulter, ed., *Posts' 1973 Pulp and Paper Directory* (San Francisco, Ca., Miller Freeman).

2. K. N. Britt, ed., *Handbook of Pulp and Paper Technology* (New York, Van Nostrand Reinhold Co., 1970).

3. J. N. Stephenson, ed., *Pulp and Paper Manufacture,* Vol. 1 (New York, McGraw-Hill, 1950).

4. J. P. Casey, *Pulp and Paper,* Vol. 1 (London, Interscience Publishers Ltd., 1960).

5. E. P. Gyftopoulos, et al, *Potential Fuel Effectiveness in Industry* (Cambridge, Mass., Ballinger Publishing Company, 1974).

6. R. N. Shreve, *Chemical Process Industries,* 3rd ed. (New York, McGraw-Hill, 1967)

7. *Multiflash Feed-and-Breed Coupling for the Evaporation and Crystallization Industry,* Proposal prepared for ERDA, Division of Geothermal Energy, (San Francisco, Ca., Bechtel Corporation, 1976).

8. H. F. J. Wenzl, *Kraft Pulping, Theory and Practice* (New York, Lockwood Publishing Co., 1967).

9. ______________, *Sulphite Pulping Technology* (New York, Lockwood Trade Journal Company, 1965).

10. R. A. McGinnis, ed., *Beet-Sugar Technology,* 2nd ed. (Ft. Collins, Co., Beet Sugar Development Foundation, 1971).

11. The Conference Board, *Energy Consumption in Manufacturing* (Cambridge, Mass., Ballinger Publishing Company, 1974).

12. *American Beet Sugar Companies Directory, 1975-1976* (Washington, D.C., U. S. Beet Sugar Association).

13. "A Partial List of APV Evaporator Installations," private communication with H. Susmann of APV, November 1976.

14. "Canning Industry Background," private communication with E. Yates of the Canners League of California, November 1976.

15. *Dairy Plants Surveyed and Approved for USDA Grading Service* (Washington, D.C., Bulletin USDA, Dairy Division, 1976).

16. "APV Flow Diagram of Tree Top Apple Juice Plant, Evaporator Section," private communication with H. Susmann of APV, November 1976.

17. *Processing Plants Under Contract for USDA Inspection* (Washington, D. C., USDA, Fruit and Vegetable Division, Bulletin, 1976).

18. "Tomato Processing Background," private communication with A. Grinkevich of Hunt-Wesson, November 1976.

19. *Directory of the Canning, Freezing and Preserving Industry*, 6th ed. (Westminster, Md., E. E. Judge and Sons)

20. M. E. Parker, *Elements of Food Engineering*, Vol. 3 (New York, Reinhold Publishing Company, 1954)

21. "Inorganic Salt Evaporation," private communication with R. Bennet of Swenson, November 1976.

22. "List of Chlorine Plants," from files of G. Klingman, Bechtel Corp., November 1976.

23. "Chlor-Alkali Plant Design," from files of G. Klingman, Bechtel Corporation, November 1976.

24. E. R. Berman, *Geothermal Energy* (Park Ridge, N.J., Noyes Data Corporation, 1975).

25. Stanford Research Institute, *Patterns of Energy Consumption in the United States*, for Office of Science and Technology, Washington, D. C., January 1972.

26. Lawrence Livermore Laboratory, *UCRL-51926, Present Status and Future Prospects for Nonelectric Uses of Geothermal Resources*, for ERDA, October 1975.

27. D. N. Anderson, L. H. Axtell, "Geothermal Overviews of the Western United States, 1972," (Davis, Ca., Geothermal Resources Council).

28. P. J. Lienau, J. W. Lund, eds., *Multipurpose Use of Geothermal Energy* (Klamath Falls, Ore., Geo-Heat Utilization Center, Oregon Institute of Technology, October 1974).

29. D. F. White, D. L. Williams, eds., "Assessment of Geothermal Resources of the United States, 1975," Geological Survey Circular 726 by Department of the Interior for ERDA.

30. "Tour Fact Sheet" (Ontario, Ca., Sunkist Growers, Orange Products Division, May 1975).

31. H. E. Griffith, C. R. Havighorst, "Astute Engineering Designs, The New Generation Plant," Food Engineering, January 1976.

32. *Dairy Products Annual Summary 1975*, (Washington, D.C., USDA Crop Reporting Service, June 1976).

33. *Canned Food Pack Statistics, 1975-76* (Washington, D.C., National Canners Association, October 1976).

34. "1972 Cenus of Manufacturers," Industry Series MC72(2)-20B, 20C, 20F,26A, and 28A, (Washington, D. C., U.S. Dept. of Commerce, 1975).

35. "1972 Cenus of Manufacturers," Area Series MC72(3)-3, 5, 6, 12, 13, 27, 29, 32, 38, 48, and 51, (Washington, D. C., U.S. Dept of Commerce, 1975).

36. H. C. H. Armstead, "Geothermal Economics," from pp. 161-174 of *Geothermal Energy; Review of Research and Development*, UNESCO, 1973.

37. "Tomato Paste Processing," private communication with Allen Dal Porto of Fran Rica, November 1976.

38. D. Q. Kern, *Process Heat Transfer* (New York, McGraw-Hill, 1950).

39. J. F. Kunze, A. S. Richardson, *National Program Definition Study for the Non-electrical Utilization of Geothermal Energy* (ANCR-1214) (Idaho Falls, Idaho, Idaho National Engineering Laboratory, June 1975).

40. "East Mesa Well 6-2 Brine Composition," unpublished paper, Bechtel Corp., 1976.

41. T. D. Palmer, "Salton Sea Geothermal Field — Chemical Analysis of Geothermal Brines," Memo GG75-24, (Livermore, Ca., Lawrence Livermore Laboratory, May 9, 1975).

42. *Characteristics of Geothermal Wells Located in the Salton Sea Geothermal Field, Imperial County, Calif.*, Report UCRL-51976 (Livermore, Calif., Lawrence Livermore Laboratory, December 15, 1975).

43. H. C. Helgeson, "Geologic and Thermodynamic Characteristics of the Salton Sea Geothermal System," American Journal of Science, 266, 129-166, March 1968.

44. "Cost of Wells at East Mesa," private communication between A. Rogers and S. Suemoto, 1976.

45. "Fossil Fuels Costs," Chemical Week, November 10, 1976.

46. D. W. Kaufmann, ed., Sodium Chloride, The Production and Properties of Salt and Brine, ACS Monograph No. 145 (New York, Hafner Publishing Company, 1971).

47. F. A. Lowenheim, M. K. Moran, Faith, Keyes and Clarks Industrial Chemicals, 4th ed., (New York, Wiley and Sons, 1975).

48. "Pipeline Economics," Oil & Gas Journal, August 23, 1976.

49. T. Larson, "The Costs of Geothermal Energy Development" (Riverside, California, Dry Lands Research Institute, U. C. Riverside, January 1977).

50. "Energy Economics for Each Geothermal Production Well," from unpublished paper by J. Davey of Lawrence Berkeley Labs, Berkeley, California, 1977.

51. B. B. Basse, "The Thermal Systems Model," Susanville Geothermal Energy Project, pp X-1 through X-8, for ERDA, July 13, 1976.

52. L. H. Godwin, et al, "Classification of Public Lands Valuable for Geothermal Steam and Associated Geothermal Resources," Geological Survey Circular 647 by Department of the Interior, 1971.

53. A. S. Hester, "Salt Manufacture," Industrial and Engineering Chemistry, Vol. 47, No. 4, April 1955.

54. "Geothermal Resource Utilization, Paper and Cane Sugar Industries," by DSS Engineers, Inc. for Lawrence Livermore Laboratory, March 1975.

55. H. G. Schwartzberg, "Energy Requirements for Liquid Food Concentration," Food Technology, March 1977.

56. D. K. Tressler, M. A. Joslyn, Fruit and Vegetable Juice Processing Technology, (Westport, Conn., AVI Publishing Company, Inc., 1961).