TECHNICAL REPORT

FOR THE PERIOD

SEPTEMBER 29 THROUGH DECEMBER 31, 1976

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

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CONTENTS

<u>Section</u>		<u>Page</u>
1	INTRODUCTION	1-1
	1.1 Summary of Work	1-2
	1.2 Preliminary Conclusions	1-4
2	DISCUSSION OF RESULTS	2-1
	2.1 Candidate Industries	2-1
	2.2 Available Process Information	2-4
	2.3 Computer Program	2-22
	2.4 Computer Results	2-33
	2.5 Geothermal Sources	2-47
	2.6 Well and Pipeline Costs	2-47
3	FUTURE WORK	3-1
	REFERENCES	R-1

TABLES

<u>Table</u>		<u>Page</u>
2-1	Major Industry Summary	2-2
2-2	Wood Pulp Mills	2-5
2-3	Sugar Beet Refineries	2-3
2-4a	Food Processing -- Tomato Processing Plants	2-7
2-4b	Food Processing -- Fruit Juice Concentrating Plants	2-8
2-4c	Food Processing -- Dry Milk Plants	2-9
2-5	Inorganic Salts Refineries	2-10
2-6	Chlorine-Caustic Plants	2-11
2-7	Waste Disposal/Recovery Operations	2-12
2-8	Wood Pulp Industry	2-13
2-9	Sugar Beet Industry	2-14
2-10a	Tomato Processing Plants	2-15
2-10b	Fruit Juice Concentrating Plants	2-17
2-10c	Dry Milk Plants	2-18
2-11	Inorganic Salts Industry	2-19
2-12	Chlorine-Caustic Industry	2-20
2-13	Waste Disposal/Recovery Operations	2-21
2-14	Evaporator Heat and Material Balance Program	2-35
2-15	Case No. 1 -- Conventional Steam Supply, Five-Effect System	2-36
2-16	Case No. 2 -- Geothermal Feed-and-Bleed, Five-Effect System	2-39
2-17	Case No. 3 -- Geothermal Feed-and-Bleed, Four-Effect System	2-42
2-18	Case No. 4 -- Geothermal Feed-and-Bleed, Three-Effect System	2-45
2-19	Composition of Geothermal Brines Used as Basis for This Study	2-48

ILLUSTRATIONS

<u>Figure</u>	<u>Page</u>
1-1 Proximity of Wood Pulp Mills to U.S. Hydrothermal Convection Systems with Indicated Subsurface Temperatures between 90° and 150°C	1-5
1-2 Proximity of Sugar Beet Refineries to U.S. Hydrothermal Convection Systems with Indicated Subsurface Temperatures between 90° and 150°C	1-6
1-3 Proximity of Feed Processing Plants to U.S. Hydrothermal Convection Systems with Indicated Subsurface Temperatures between 90° and 150°C	1-7
2-1 Forward Feed Model	2-24
2-2 Model for the I th Effect	2-25
2-3 Flow Diagram for Forward Feed System	2-26
2-4 Hydrothermal Convection Systems with Indicated Subsurface Temperatures between 90° and 150°C	2-49

Section 1

INTRODUCTION

In October of 1976, Bechtel Corp. was awarded a contract by ERDA (Division of Geothermal Energy) to determine the technical and economic feasibility of using geothermal brine in place of steam from conventional sources for industrial multieffect 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 initial quarterly report outlining work performed on this contract during the period of October through December 1976.

The report includes:

- A listing of industries that show the most promise as potential geothermal brine users
- A summary of available process information for these industries
- A description of a multieffect heat and material balance-optimization computer program
- Geothermal brine source location data
- Initial information about geothermal well and pipeline economics

Preliminary conclusions are also discussed and work to be performed during the next quarter is outlined.

1.1 SUMMARY OF WORK

The actual work performed during October through December is summarized in Subsections 1.1.1 through 1.1.5 and discussed in detail in Section 2.

1.1.1 Candidate Industries

A search of the literature and conversations with vendors and people in relevant industries indicate that a number of industries use multieffect evaporation and crystallization in some phase of their operations and are located in the general area of geothermal sources. These industries, as listed below, qualify as potential users of geothermal steam:

Most Promising

- Wood pulping — concentration of black liquor
- Sugar beet refining — concentration of sugar solution
- Food and dairy processing — concentration of tomato juice, fruit juice, milk, cheese whey

Some Possibility (especially in future plants)

- Inorganic salt refining — concentration of the ore and crystallization of the salt
- Chlorine-caustic production — concentration of caustic
- Waste disposal and recovery — concentration of aqueous wastes

1.1.2 Available Process Information

To aid in determining whether or not coupling geothermal energy with multieffect evaporation and crystallization processes is technically and economically practical, flow diagrams, heat and material balances, and equipment specifications must first be developed of evaporator

and crystallizer operations in the candidate industries. This requires gathering information such as the following:

- Plant location, capacity, and steam use
- Evaporator and crystallizer section characteristics
 - Equipment configuration
 - Process flows, temperatures, and pressures
 - Product stream physical properties; inlet and outlet solids
 - Heat transfer coefficients
 - Equipment types and sizes

Much of this information for the three most promising candidate industries has been collected or is readily available from known sources.

1.1.3 Multieffect Evaporator Heat and Material Balance-Optimization Program

To help evaluate and compare multieffect evaporator operations, a computer program was developed. This program, which is designed to make heat and material balances for multieffect evaporator systems of various configurations, will be used to optimize new and retrofit geothermal steam evaporator systems so that they can be compared to present evaporator operations using conventionally generated steam.

1.1.4 Geothermal Sources

A fairly concise reference (Geological Survey Circular 726, 1976) gives the exact location of hydrothermal convection systems in the United States. This information enabled Bechtel to choose evaporation and crystallization industries located in the same areas.

The two types of geothermal brines that will serve as the study basis have been tentatively selected.

1.1.5 Well Drilling and Pipeline Costs

Some preliminary studies have been made on the costs of drilling geothermal wells and constructing the required delivery and reinjection pipelines.³⁶ Both capital and recurring costs are being studied so that the cost of geothermal steam at the point of use can be determined. Published costs of geothermal steam for existing exploited fields range from \$0.15 to \$0.20 per million Btu at point of use. This compares with \$2.00 to \$2.50 per million Btu for steam from fossil fuels (1976 basis).⁴⁵

1.2 PRELIMINARY CONCLUSIONS

Preliminary conclusions drawn from the work performed October through December 1976 are discussed in Subsections 1.2.1 through 1.2.3.

1.2.1 Evaporation Steam Requirements

Investigation of the three most promising candidate industries indicates that a large portion of each industry's steam requirement is used in its multieffect evaporation operation. A pulp mill (producing pulp only as product) uses 20 percent of its generated steam for multieffect evaporation of black liquor. A sugar beet refinery uses essentially all of its steam for its multieffect evaporators (a portion of this steam is drawn off between evaporators for process heating). Approximately 50 percent of a tomato paste plant's steam requirement is used for evaporation. Dry milk and juice concentration plants also use a large portion of steam for evaporation.

1.2.2 Location of Candidate Industries

One of the bases for picking the candidate industries was their proximity to *known* geothermal resources, as shown in Figures 1-1, 1-2, and 1-3. However, initial investigation shows that few, if any, existing plants of the candidate industries (or any other multieffect evaporator users) are close enough to presently known sources to make economical use of

Figure 1-1. PROXIMITY OF WOOD PULP MILLS TO U.S. HYDROTHERMAL CONVECTION SYSTEMS WITH INDICATED SUBSURFACE TEMPERATURES BETWEEN 90° AND 150°C

Δ - WOOD PULP MILLS IN WESTERN U.S.
 • - GEOTHERMAL SOURCE

Figure 1-2. PROXIMITY OF SUGAR BEET REFINERIES TO U.S. HYDROTHERMAL CONVECTION SYSTEMS WITH INDICATED SUBSURFACE TEMPERATURES BETWEEN 90° AND 150°C

O – SUGAR BEET REFINERIES IN WESTERN U.S.
 • – GEOTHERMAL SOURCE

Figure 1-3. PROXIMITY OF FOOD PROCESSING PLANTS TO U.S. HYDROTHERMAL CONVECTION SYSTEMS WITH INDICATED SUBSURFACE TEMPERATURES BETWEEN 90° AND 150°C

T - TOMATO PROCESSING PLANTS IN WESTERN U.S.
 J - JUICE CONCENTRATING PLANTS IN WESTERN U.S.
 D - INSPECTED DRY MILK PLANTS IN WESTERN U.S.
 • - GEOTHERMAL SOURCE

geothermal heat. An estimate must be made of the extent of the unproven but probable geothermal system locations so that a greater possibility will exist for using geothermal steam in retrofitted plants.

1.2.3 Industry Acceptance

The energy crisis and the rapidly rising cost of fossil fuels provide a strong incentive for developing alternative sources of energy. Many industries have begun to place increasing emphasis on conservation with various programs including the use of special boilers for the combustion of process wastes. Geothermal energy provides a welcome supplement to existing sources of heat.

As the study under this contract proceeds, conceptual cost estimates will be developed in sufficient detail to permit decisions to be made on the basis of economics. Costs will result from changes to piping and equipment as well as from geothermal wells and pipelines mentioned above.

The obvious application of the techniques under study in this contract is in retrofitting existing plants. It must be emphasized, however, that many of the sugar and pulp mills and food processing plants in existence today are very old and are becoming obsolete. When they are replaced, the feed-and-bleed design can be readily incorporated at minimal cost. In addition, the availability of low-cost geothermal heat will be one of the factors to consider in locating new plants.

In discussions with industry during the later stages of this contract, this aspect will be thoroughly explored. The energy savings of the feed-and-bleed process together with the ready availability of geothermal heat in a number of locations will be emphasized in an attempt to stimulate industry cooperation in this project.

Section 2

DISCUSSION OF RESULTS

This section discusses the bases for the results summarized in Section 1.

2.1 CANDIDATE INDUSTRIES

The industries most likely to benefit from using geothermal steam in their evaporation and crystallization operations were chosen based on the following criteria:

- Use of multieffect evaporation and crystallization with low level steam ($<280^{\circ}\text{F}$) in some phase of operations. A listing of all major industries is shown in Table 2-1. A brief review of each process established whether or not this criterion was met 6, 11, 34
- Significant user of energy in general, and in particular for evaporation and crystallization operations. A significant user was arbitrarily defined as one consuming more than 50×10^{12} Btu/yr of total energy (refer to Table 2-1). As noted in Subsection 1.2.1, all of the most promising industries use a large fraction of their total steam requirement for evaporation 5, 6, 7, 8, 10, 31, 37
- Location in the same geographic area as the geothermal sources. From various industry sources, plant locations of the most promising candidate industries have been identified in these areas, as shown on location maps in Figures 1-1, 1-2, and 1-3 1, 12, 15, 19, 29
- Sufficient information available to adequately define these industries. Most of the required data on the candidate industries are now available or can easily be obtained

Table 2-1

MAJOR INDUSTRY SUMMARY

Industry	1967 Energy Consumption (10 ¹² Btu/yr)	Uses multi- stage evaporation or crystallization w/low level heat (<300°F)	Located in vicinity of geothermal sources
Food			
• Meatpacking	84	No	—
• Fluid milk	64	No	—
• Dry milk	27	Yes	Yes
• Canned fruit and vegetables	48	Yes	Yes
• Frozen fruit and vegetables	27	Yes	Yes
• Beet sugar	72	Yes	Yes
• Cane sugar	32	Yes	Very few
• Animal feeds	49	No	—
• Bakery products	49	No	—
Paper			
• Pulp mills	2,156 ⁽¹⁾	Yes	Yes ⁽²⁾
• Fiberbox	30	No	—
• Building paper and board	40	No	—
Chemicals			
• Alkalis and chlorine	268	Yes ⁽³⁾	Few
• Industrial gases	65	No	—
• Organic cyclic intermediates	132	No	—
• Industrial organic chemicals	858	Not signif.	—
• Inorganic chemicals	536 ⁽⁴⁾	Yes	Few ⁽⁵⁾
• Plastic and resins	130	Not signif.	—
• Synthetic rubber	61	Not signif.	—
• Manmade fibers	152	Not signif.	—
• Petroleum refining	2,300	No	—
Stone, Clay, and Glass			
• Glass	239	No	—
• Cement	463	No	—
• Brick and clay	97	No	—
• Ready-mix concrete	37	No	—
• Lime	78	No	—

Table 2-1 (Cont.)

MAJOR INDUSTRY SUMMARY

Industry	1967 Energy Consumption (10 ¹² Btu/yr)	Uses multi- stage evaporation or crystallization w/low level heat (<300°F)	Located in vicinity of geothermal sources
Primary Metals			
• Steel	3,007	No	—
• Electrometallic products	76	No	—
• Iron and steel castings	99	No	—
• Copper rolling	32	No	—
• Nonferrous wire	25	No	—
• Iron and steel forgings	53	No	—
• Aluminum	636	Yes (6)	No

Notes:

1. 1971 data
2. Percent of energy consumption by area:
NE — 13 percent
NC — 14 percent
S — 57 percent
W — 16 percent
3. Caustic soda concentration in diaphragm cell electrolytic caustic-chlorine process.
4. Not including uranium enrichment plants.
5. Evaporation of potassium brine by Trona process or crystallization of KCl by U.S. potash process (dry).
6. Alumina spent liquor concentration.

2.2 AVAILABLE PROCESS INFORMATION

This study requires obtaining enough information on the most promising candidate industries to develop flow diagrams, heat and material balances, and economics of the respective evaporator and crystallizer operations. These data, in addition to present plant locations and information of geothermal wells (location, capacity, costs, etc.), will help determine the feasibility of coupling geothermal steam with multieffect evaporator operations (using Bechtel's multiflash feed-and-bleed system). Industry data now on hand and those still lacking are summarized in Tables 2-2 through 2-7. People contacted in the various industries are listed in Tables 2-8 through 2-13.

TABLE 2-2
WOOD PULP MILLS⁽⁴⁾

STATUS of INFORMATION					AVAILABLE INFORMATION ⁽²⁾			
					GOOD	ADEQUATE	NOT ENOUGH	NONE
• PLANT DATA								
	LOCATIONS				1.			
	CAPACITIES					1.		
	STEAM USE					1., 5.		
• PROCESS DATA (TYPICAL PLANT) ⁽¹⁾						(3)		
	flow diagram					7.		
	flows					7.		
	TEMPERATURES					7.		
	PRESSURES					7.		
	% SOLIDS IN/OUT					7., 8.		
	PHYSICAL PROPERTIES					7., 8.		
	HT COEFFICIENTS					7.		
	Number of effects					7., 8.		
	Boiling Point Rise					8.		
• EQUIPMENT DATA (TYPICAL PLANT) ⁽¹⁾								
	EVAP./CRYS. TYPE					4., 3.		
	" " SIZES						3.	
• INDUSTRY DATA (GENERAL)						11., 34		
NOTES — (1) EVAPORATOR / CRYSTALLIZER OPERATION ONLY.								
(2) Numbers refer to reference								
(3) THESE DATA ORIGINALLY from "Heat Transfer" by Keen. It remains to be determined if the data are typical of today's mills.								
(4) DIRECTED mainly towards KRAFT MILLS since ~60% PULP made by this process. See ref 2 for sulfite pulping, ref 4 for Semichemical.								

TABLE 2-3
SUGAR BEET REFINERIES

STATUS of INFORMATION					AVAILABLE INFORMATION ⁽³⁾			
					GOOD	ADEQUATE	NOT ENOUGH	NONE
• PLANT DATA								
	LOCATIONS				12, 10.			
	CAPACITIES				12, 10.			
	STEAM USE					10 ⁽²⁾		
• PROCESS DATA (TYPICAL PLANT) ⁽¹⁾								
	flow diagram					10.		
	flows					10.		
	TEMPERATURES					10.		
	PRESSURES					10.		
	% SOLIDS IN/OUT					10.		
	PHYSICAL PROPERTIES					10.		
	HT COEFFICIENTS					10.		
	Number of effects					10.		
• EQUIPMENT DATA (TYPICAL PLANT) ⁽¹⁾								
	EVAP./CRYS. TYPE					10.		
	" " SIZES					10.		
• INDUSTRY DATA (GENERAL)						34.	6.	
NOTES — (1) EVAPORATOR / CRYSTALLIZER OPERATION ONLY.								
(2) see table 11-2, 3 - ref 10.								
(3) numbers refer to reference.								

FOOD PROCESSING

TOMATO PROCESSING PLANTS

2-7

TABLE 2-4(B)

FOOD PROCESSING

FRUIT JUICE CONCENTRATING PLANTS

STATUS OF INFORMATION					AVAILABLE INFORMATION (2)			
					GOOD	ADEQUATE	NOT ENOUGH	NONE
• PLANT DATA								
	LOCATIONS				19		13, 30	
	CAPACITIES						30.	
	STEAM USE						16	
• PROCESS DATA (TYPICAL PLANT) (1)								
	flow diagram					(4)		
	flows					16		
	TEMPERATURES					16, 30		
	PRESSURES					16		
	% SOLIDS IN/OUT					16		
	PHYSICAL PROPERTIES					16		
	HT COEFFICIENTS					(3)		
	Number of effects					15		
• EQUIPMENT DATA (TYPICAL PLANT) (1)								
	EVAP./CRYS. TYPE						16	
	" " SIZES						16.	
• INDUSTRY DATA (GENERAL)								
							11, 34	
NOTES — (1) EVAPORATOR / CRYSTALLIZER OPERATION ONLY.								
(2) NUMBERS REFER TO REFERENCE.								
(3) Can get from APV.								
(4) APV flow diagram of Apple juice evaporation.								

TABLE 24(C)

FOOD PROCESSING
DRY MILK PLANTS

STATUS OF INFORMATION					AVAILABLE INFORMATION (2)			
					GOOD	ADEQUATE	NOT ENOUGH	NONE (3)
• PLANT DATA								
	LOCATIONS					15.	13.	
	CAPACITIES							✓
	STEAM USE							✓
• PROCESS DATA (TYPICAL PLANT) (1)								
	flow diagram							✓
	flows							✓
	TEMPERATURES							✓
	PRESSURES							✓
	% SOLIDS IN/OUT							✓
	PHYSICAL PROPERTIES							✓
	HT COEFFICIENTS							✓
	Number of effects						20.	
• EQUIPMENT DATA (TYPICAL PLANT) (1)								
	EVAP./CRYS. TYPE						20.	
	" " SIZES							✓
• INDUSTRY DATA (GENERAL)						32,34		
NOTES — (1) EVAPORATOR / CRYSTALLIZER OPERATION ONLY.								
(2) NUMBERS REFER TO REFERENCE.								
(3) MUCH INFORMATION, NOW LACKING, IS AVAILABLE FROM ESTABLISHED INDUSTRY CONTACTS.								

TABLE 2-5

INORGANIC SALTS REFINERIES

STATUS of INFORMATION					AVAILABLE INFORMATION ⁽²⁾			
					Good	ADEQUATE	NOT ENOUGH	NONE ⁽³⁾
• PLANT DATA								
	LOCATIONS						21.	
	CAPACITIES							✓
	STEAM USE							✓
• PROCESS DATA (TYPICAL PLANT) ⁽¹⁾								
	flow diagram						6.	
	flows							✓
	TEMPERATURES							✓
	PRESSURES							✓
	% SOLIDS IN/OUT							✓
	PHYSICAL PROPERTIES							✓
	HT COEFFICIENTS							✓
	Number of effects						6.	
• EQUIPMENT DATA (TYPICAL PLANT) ⁽¹⁾								
	EVAP./CRYS. TYPE							✓
	" " SIZES							✓
• INDUSTRY DATA (GENERAL)						11,34		
NOTES — (1) EVAPORATOR / CRYSTALLIZER OPERATION ONLY.								
(2) NUMBERS REFER TO REFERENCE.								
(3) REQUIRED INFORMATION to be gathered later in the program.								

TABLE 2-6

CHLORINE-CAUSTIC PLANTS

STATUS of INFORMATION	AVAILABLE INFORMATION (2)			
	Good	ADEQUATE	NOT ENOUGH	NONE
• PLANT DATA				
LOCATIONS	22.			
CAPACITIES	22.			
STEAM USE		23, 6.		
• PROCESS DATA (TYPICAL PLANT) (1)				
flow diagram		23		
flows		↓		
TEMPERATURES		↓		
PRESSURES		↓		
% SOLIDS IN/OUT		↓		
PHYSICAL PROPERTIES		↓		
HT COEFFICIENTS		↓		
Number of effects		↓		
• EQUIPMENT DATA (TYPICAL PLANT) (1)				
EVAP./CRYS. TYPE		23.		
" " SIZES		↓		
• INDUSTRY DATA (GENERAL)		11, 6, 34		
NOTES — (1) EVAPORATOR / CRYSTALLIZER OPERATION ONLY.				
(2) NUMBERS REFER TO REFERENCE.				

TABLE 2-7

WASTE DISPOSAL / RECOVERY OPERATIONS

STATUS of INFORMATION					AVAILABLE INFORMATION ⁽²⁾			
					Good	ADEQUATE	NOT ENOUGH	NONE ⁽³⁾
• PLANT DATA								
	LOCATIONS							/
	CAPACITIES							//
	STEAM USE							//
• PROCESS DATA (TYPICAL PLANT) ⁽¹⁾								
	flow diagram							/
	flows							//
	TEMPERATURES							//
	PRESSURES							//
	% SOLIDS IN/OUT							//
	PHYSICAL PROPERTIES							//
	HT COEFFICIENTS							//
	Number of effects							//
• EQUIPMENT DATA (TYPICAL PLANT) ⁽¹⁾								
	EVAP./CRYS. TYPE							//
	" " SIZES							//
• INDUSTRY DATA (GENERAL)								
NOTES — (1) EVAPORATOR / CRYSTALLIZER OPERATION ONLY.								
(2) numbers refer to reference.								
(3) Required information to be gathered later in the program.								

WOOD PULP INDUSTRY

TABLE 2-8

SUMMARY OF CONTACTS THROUGH 12/28/76

[illegible]

2-13

SUGAR BEET INDUSTRY

TABLE 2-9

SUMMARY OF CONTACTS THROUGH 12/28/76

[illegible]

TOMATO PROCESSING PLANTS (FOOD PROCESSING)

TABLE 2-10(A)
SHEET 1/2

SUMMARY OF CONTACTS THROUGH 12/28/76

#	FIRM OR AGENCY	INDIVIDUAL CONTACTED & POSITION	DATES CONTACTED	COMMENTS
1	BLAW KNOX (EVAPORATORS) N.Y. (716) 895-2100	HARLAN ENGLANDER, ENGIN.	11/10	CAN FURNISH STEAM RATES FOR B-K INSTALLATIONS IN THE FOOD INDUSTRY.
2	USDA WEST. REG. LAB., BERKELEY 486-3160	DR. CHAS. HUXSOLL	11/11	REF. TO JACK RALLS (NAT. CANNERS ASSOC.) & CANNERS LEAGUE OF CALIF.
3	NAT. CANNERS ASSOC. WESTERN REG. LAB., BERKELEY 843-9762	DR. JACK RALLS & LARRY LEWIS	11/12	WOULD SEND CANNERS DIRECTORY IF THEY COULD FIND ONE. REF. TO LARRY VAN MEIR (NAT. CANNERS ASSOC.)
2-15 4	APV (EVAPORATORS) PALO ALTO, 326-6875	HERB SUSMANN WEST. REG. SALES MGR.	11/12	GAVE PARTIAL LISTING OF APV EVAPORATOR INSTALLATIONS & REF. TO SEVERAL PEOPLE IN INDUSTRY.
5	USDA FRUIT & VEG. DIV (PROCESSED FOOD INSP. DEPT.) SAN JOSE, (408) 275-7468	INFORMATION CLERK	11/17	SENT BULLETIN OF FOOD PROCESSING PLANTS UNDER USDA INSPECTION.
6	CANNERS LEAGUE OF CALIF SACRAMENTO (916) 444-9260	ED YATES	11/17	EXPRESSED INTEREST IN STUDY. REF - HARRY HATCH (CONTADINA), ALEX GRINKOVICH (HUNT-WESSON).
7	FEDERAL ENERGY ADMIN INFO. LIBRARY, S.F. 556-7328	CHRIS SWORE	11/18	REF. LANDY ALTMAN (USDA), BRUCE HANNON (UNIV. ILL.)

TOMATO PROCESSING PLANTS

TABLE 2-10(A)

SHEET 2/2

SUMMARY OF CONTACTS THROUGH 12/28/76

#	FIRM OR AGENCY	INDIVIDUAL CONTACTED & POSITION	DATES CONTACTED	Comments
8	NATIONAL CANNERS ASSOC. WASH., DC, (202) 331-5997	DR LARRY VAN MEIR	11/19	REF. a DIRECTORY OF CANNING PLANTS (ORDERED 11/19), JIM WASHBURN (CALIF. CANNERS & GROWERS, BILL ALLENWELT (TRI VALLEY GROWERS)
9	HUNT-WESSON, Fullerton, (714) 871-2100	Alex GRINKEVICH	11/19	OUTLINED TYPICAL PLANT FLOW. REF. FRAN RICA EVAPORATORS
10	CALIF. CANNERS & GROWERS, SF. 981-0101	JIM WASHBURN	11/19	REF. WALT DOUCETT, Director of Engineering (CALIF. CANNERS) (408) 736-5431.
11	FRAN RICA (EVAPORATORS) Stockton, (209) 948-2811	Allen DAL PORTO	11/19	VERY GOOD SOURCE OF INFO ON TOMATO PROCESSING. Sent literature on plant H&M BAL'S.

FRUIT JUICE CONCENTRATING PLANTS (FOOD PROCESSING)

TABLE 2-10(B)

SUMMARY OF CONTACTS THROUGH 12/28/76

[illegible]

2-17

DRY MILK PLANTS (FOOD PROCESSING)

TABLE 2-10(c)

SUMMARY OF CONTACTS THROUGH 12/28/76

#	FIRM OR AGENCY	INDIVIDUAL CONTACTED & POSITION	DATES CONTACTED	COMMENTS
1	FOREMOST R&D Center, Dublin, Ca. 828-1440	GAYLORD PALMER	11/11	REF. JOE MALDARI (FOREMOST)
2	FORMOST HDQ'S SF, 983-8450	JOE MALDARI, ENGINEERING MGR	11/11	REF. OTHO MURRAY (FORMOST), MILK INDUSTRY FOUNDATION, WASH. D.C.
3	FOREMOST, Lemoore, Ca. (209) 924-5625	OTHO MURRAY Reg. PRODUCTION MGR	11/11	REF. AM. DRY MILK INSTITUTE, CHI. DRE GAVE LIST OF MILK PLANTS IN CALIF.
4	MILK INDUSTRY FOUNDATION, WASH. D.C. (202) 296-4250	MR. TIPTON	11/15	REF. USDA bul., "MANUFACTURED DAIRY PRODUCTS, NY CONSULTING FIRM (will send us the name)
5	Am. Dry Milk Institute, Chi., IL (312) 782-4888	DR. WARREN CLARK DIRECTOR	11/15	GAVE LIST OF DRY MILK PLANT EVAPORATOR MFRS. REF. USDA bul ON INSPECTED MILK PLANTS (REC'D 11/17).

2-18

INORGANIC SALTS INDUSTRY

TABLE 2-11.

SUMMARY OF CONTACTS THROUGH 12/28/76

[illegible]

CHLORINE-CAUSTIC INDUSTRY

TABLE 2-12

SUMMARY OF CONTACTS THROUGH 12/28/76

#	FIRM OR AGENCY	INDIVIDUAL CONTACTED & POSITION	DATES CONTACTED	Comments
1	BECHTEL	GIL KLINGMAN	11/12	Some background in the industry
<p>Note: FURTHER CONTACTS to be made later in the program.</p>				

2-20

WASTE DISPOSAL / RECOVERY OPERATIONS

TABLE 2-13

SUMMARY OF CONTACTS THROUGH 12/28/76

[illegible]

2.3 COMPUTER PROGRAM

A computer program is being developed to calculate heat and material balances for multiple effect evaporator systems. The program will ultimately handle both forward and reverse feed arrangements with conventional steam supply or geothermal feed-and-bleed heat supply. To date, the program is operational for conventional and geothermal steam supplies using a forward feed arrangement.

2.3.1 Calculations

The capabilities of the program at present are summarized below for the forward feed arrangement.

Input Data

1. Feed flow rate and temperature
2. Product flow rate and temperature
3. Number of effects
4. Value of UA for each evaporator, where U is the heat transfer coefficient and A is the heat transfer area
5. Steam supply temperature for a conventional plant design or the brine supply temperature for a geothermal plant design (this serves as a starting point for the calculation and is subsequently adjusted by the computer)
6. Options allow the program to calculate the amount of vapor to withdraw from the various effects for preheating the feed prior to the first effect

Output Data

1. For conventional plant designs, the required steam temperature and flow rate; for feed-and-bleed plant designs, the brine flow rate and interstage temperatures
2. The temperatures of the steam and vapor for each effect
3. The flows of steam and vapor and the amount of flash for each effect
4. Optional output gives the amount of vapor from each effect for preheating the feed

The basic forward feed arrangement for the computer model is shown as a three-effect system in Figure 2-1. The model for any intermediate effect in an N-effect system is shown in Figure 2-2. At present the program operates in a conversational mode in which adjustments are made by the operator until convergence is obtained for a given problem. A general logic diagram of the calculational procedure is shown in Figure 2-3.

2.3.2 System Optimization

Several designs, using various evaporator surface areas and arrangements, may be compared on the basis of equipment and operating costs by using the program to calculate energy requirements for each design. These costs may be plotted versus evaporator area, and the most economical selection of a plant design can be determined by examination of these costs.

Retrofitting an existing plant with geothermal steam is a matter of evaluating the system performance with existing equipment. This will enable the designer to determine the economic advantages of using geothermal steam versus the conventional design.

2.3.3 Discussion of Operation of the Program

The present version (see Program Listing following) of the program needs additional work on convergence criteria. The present version is operated in a conversational mode because of the sensitivity of convergence criteria to adjusted values within the iterative process. It is anticipated that the conversational aspects of the program can be deleted when the sensitivity is better defined. The automatic convergence of the results will, of course, be effective only in certain ranges of plant types and configurations inasmuch as excessive flexibility would require a very complex computer program.

LEGEND:

AS - AUXILIARY PLANT STEAM FROM VAPOR DRAWOFF,
NOT USED WITH GEOTHERMAL DESIGN
B - BRINE
BF - BRINE FLASH
C - CONDENSATE
E - EVAPORATOR
F - FEED

FC - FLASHED CONDENSATE
FT - FLASH TANK
P - PRODUCT
PH - PREHEATER
PS - STEAM TO PREHEATER
S - STEAM
V - VAPOR

Figure 2-1. FORWARD FEED MODEL

LEGEND:

- TG(I) — BRINE TEMPERATURE INTO FLASH CHAMBER
- TG(I+1) — BRINE TEMPERATURE OUT OF FLASH CHAMBER
- TS(I) — SATURATION TEMPERATURE OF STEAM
- TFV(I) — VAPOR TEMPERATURE FROM EVAPORATOR
- BPEV(I) — BOILING POINT ELEVATION OF VAPOR
- BPEG(I) — BOILING POINT ELEVATION OF FLASHED BRINE
- MS(I) — STEAM FLOW TO EVAPORATOR
- MFV(I) — VAPOR FLOW FROM EVAPORATOR
- MFL(I) — LIQUID FEED FLOW TO EVAPORATOR
- MFL — TOTAL FEED FLOW TO SYSTEM
- MFVD(I) — VAPOR DRAOFF FOR AUXILIARY USE
- MFVL(I) — VAPOR DRAOFF FOR FEED HEATING
- UA(I) — HEAT TRANSFER COEFFICIENT TIMES SURFACE AREA FOR EVAPORATOR
- TFL(I) — TEMPERATURE OF FEED FROM THE PREHEATER CAUSED BY STEAM DRAOFF FROM EVAPORATOR

NOTE: SUBSCRIPTS I, I+1, AND I-1 REFER TO THE EFFECT NUMBER

Figure 2-2. MODEL FOR THE Ith EFFECT

Figure 2-3. FLOW DIAGRAM FOR FORWARD FEED SYSTEM

PROGRAM LISTING

LIST

```
10 DATA 1
20 DATA 4,1,229000,80,49600
30 DATA 147,.9
40 DATA 10,1,1,1,1
50 DATA 300
60 DATA .95,0
70 DATA 1.673E6,0,1.49E6,0,1.55E6,0
80 DATA 1.863E6,0,.13,.6
490 READ X1
500 READ N,X,M3,T2(N+1),M3(N+1)
510 READ T1(N),C1
520 IF X<.5 GOTO 540
530 READ D
531 FOR I=1 TO N
532 READ X2(I)
533 NEXT I
540 READ T1
541 IF X1<.5 GOTO 550
542 READ C2,M6
550 M1=M3-M3(N+1)
560 FOR I=1 TO N
570 READ U(I),X(I)
580 NEXT I
590 READ C4,C5
770 IF X1>.5 GOTO 780
772 PRINT "CONVENTIONAL STEAM SUPPLY DESIGN"
774 GOTO 800
780 PRINT "GEOTHERMAL STEAM SUPPLY"
800 PRINT "DATA"
810 PRINT "NO. OF EFFECTS",N
820 IF X>.5 GOTO 850
830 PRINT "NO FEED PREHEAT VAPOR DRAOFF"
840 GOTO 860
850 PRINT "MULTIPLE EFFECT PREHEAT: TEMP APPROACH=",D
860 PRINT "LIQUID FLOW:","IN","OUT"
865 PRINT "",M3,M3(N+1)
870 PRINT "LIQUID TEMP:","IN","OUT"
875 PRINT "",T2(N+1),T1(N)
880 PRINT "LIQUID FEED SPEC HT",C1
885 IF X1<.5 GOTO 915
890 PRINT "BRINE TEMP",T1
900 PRINT "BRINE SPEC HT",C2
910 PRINT "BRINE FIRST STG FLASH DRAOFF",M6
914 GOTO 920
915 PRINT "STEAM TEMP",T1
920 PRINT "EFFECT","UA","FRAC VAP OFF","PREHEAT: 0-N,1-Y"
930 FOR I=1 TO N
940 PRINT I,U(I),X(I),X2(I)
950 NEXT I
960 IF X1>.5 GOTO 990
962 K=.5
965 M4=1.333*M1/(N-1)
970 GOTO 1000
```

```

990 M4=1333*M1/((N-1)*C2*(T1-T1(N)))
992 K=1
1000 I=N
1010 T=I+1
1020 GOSUB 6000
1030 B(I)=B
1040 T3(I+1)=T1(I)-B(I)
1050 T=T3(I+1)
1060 GOSUB 7400
1070 L(I+1)=L
1100 T3(I)=T1(I)+(T1-T1(N))/(2*N)
1101 Z2=0
1102 IF Z1<100 GO TO 1108
1103 PRINT "LOOP 1100 DID NOT CONVERGE"
1105 STOP
1108 Z1=Z1+1
1110 T=T3(I)
1112 IF Z2<200 GOTO 1118
1114 PRINT "LOOP 1110 DID NOT CONVERGE"
1115 STOP
1118 Z2=Z2+1
1120 GOSUB 7000
1130 B1(I)=B1
1131 T=I
1140 GOSUB 6000
1150 B(I-1)=B
1160 T=T1(I)
1170 GOSUB 6800
1180 C(I)=C
1190 GOSUB 6400
1200 L1(I)=L1
1210 IF I>1 GOTO 1500
1220 IF I>.5 GOTO 2000
1225 PRINT "ERROR: I<1"
1230 STOP
1300 M2=0
1310 FOR J=1 TO N
1320 M2=M(J)+M2
1330 NEXT J
1340 GOTO 1350
1350 GOTO 8000
1351 IF X1>.5 GOTO 1360
1352 T1=T1(N)+(T1-T1(N))*(M1/M2)
1353 GOTO 1370
1360 PRINT "MFV",M1,"MFVCAL",M2,"MG",M4
1361 INPUT M4
1370 I=N
1380 GOTO 1100
1500 Q(I)=U(I)*(T3(I)-T1(I))
1510 M3(I)=M3(I+1)
1520 T1(I-1)=T3(I)+B(I-1)
1530 M(I)=(Q(I)+M3(I)*C(I)*(T1(I-1)-T1(I)))/L1(I)
1540 IF ABS(M3(I+1)+M(I)-M3(I))/M(I)<.001 GOTO 1570
1550 M3(I)=M3(I+1)+M(I)
1560 GOTO 1530

```

```

1570 T=T3(I)
1580 GOSUB 7400
1590 L(I)=L
1600 M6(I)=Q(I)/L(I)
1605 IF X1<.5 GOTO 1680
1610 IF I<N GOTO 1620
1615 GOTO 1680
1620 T=T3(I)
1630 GOSUB 7000
1640 B1(I)=B1
1650 T(I+1)=T3(I)+B1(I)
1660 T(I+2)=T3(I+1)+B1(I+1)
1670 M4(I+1)=M4*C2*(T(I+1)-T(I+2))/L(I+1)
1680 IF X2(I)<.5 GOTO 1760
1690 IF T1(I)-B(I)<=T2(I+1)+D GOTO 1760
1700 T2(I)=T1(I)-B(I)-D
1710 M1(I)=M3*C1*(T2(I)-T2(I+1))/L(I+1)
1720 IF M1(I)<=M(I)*(1-X(I))*K GOTO 1780
1730 M1(I)=M(I)*(1-X(I))*K
1740 T2(I)=T2(I+1)+M1(I)*L(I+1)/(M3*C1)
1750 GOTO 1780
1760 M1(I)=0
1770 T2(I)=T2(I+1)
1780 M5(I)=M(I)*X(I)
1790 IF I<N GOTO 1796
1795 GOTO 1890
1796 IF X1>.5 GOTO 1800
1797 M4(I+1)=0
1800 M5=M4(I+1)+(1-X(I))*M(I)-M1(I)
1810 IF M5/M6(I+1)>1.02 GOTO 1860
1820 IF M5/M6(I+1)<.98 GOTO 1860
1830 GOTO 1890
1840 M=1
1850 GOTO 1870
1860 M=1
1870 T3(I)=T1(I)+(T3(I)-T1(I))*(M6(I+1)/M5)^M
1880 GOTO 1110
1890 I=I-1
1900 GOTO 1100
2000 M3(I)=M3(I+1)
2010 Q(I)=U(I)*(T3(I)-T1(I))
2020 IF X2(I)>.5 GOTO 2060
2030 T2(I)=T2(I+1)
2040 M1(I)=0
2050 GOTO 2090
2060 IF T3(I+1)<=T2(I+1)+D GOTO 2030
2070 T2(I)=T3(I+1)-D
2080 M1(I)=M3*C1*(T2(I)-T2(I+1))/L(I+1)
2090 M(I)=(Q(I)-M3(I)*C1*(T1(I)-T2(I)))/L1(I)
2091 IF M(I)>0 GOTO 2100
2092 T3(I)=T3(I)+1
2093 GOTO 2000
2100 IF ABS(M3(I+1)+M(I)-M3(I))/M(I) <.001 GOTO 2125
2110 M3(I)=M3(I+1)+M(I)
2120 GOTO 2090
2125 M5(I)=M(I)*X(I)

```

```

2130 IF M1(I)>=M(I)*(1-X(I))*K GOTO 2150
2140 GOTO 2161
2150 M1(I)=M(I)*(1-X(I))*K
2160 T2(I)=T2(I+1)+M1(I)*L(I+1)/(M3*C1)
2161 IF X1>.5 GOTO 2170
2162 M4(I+1)=0
2163 GOTO 2230
2170 T=T3(I)
2180 GOSUB 7000
2190 B1(I)=B1
2200 T(I+1)=T3(I)+B1(I)
2210 T(I+2)=T3(I+1)+B1(I+1)
2220 M4(I+1)=M4*C2*(T(I+1)-T(I+2))/L(I+1)
2230 M5=M4(I+1)+(1-X(I))*M(I)-M1(I)
2240 IF M5/M6(I+1)>1.02 GOTO 2290
2250 IF M5/M6(I+1)<.98 GOTO 2290
2260 GOTO 2320
2270 M=1
2280 GOTO 2300
2290 M=1
2300 T3(I)=T1(I)+(T3(I)-T1(I))*(M6(I+1)/M5)^M
2310 GOTO 1110
2320 T=T3(I)
2330 GOSUB 7400
2340 L(I)=L
2350 M6(I)=Q(I)/L(I)+M6
2351 IF X1>.5 GOTO 2360
2352 GOTO 2500
2360 T(I)=T(I+1)+M6(I)*L(I)/(M4*C2)
2370 M4(I)=M6(I)
2380 IF T(I)/T1>1.02 GOTO 2440
2390 IF T(I)/T1<.98 GOTO 2440
2400 GOTO 1300
2440 PRINT "TACT",T1,"TCAL",T(I)
2441 PRINT "TSN",T3(N)
2442 PRINT"ENTER NEW VALUE FOR TSN"
2443 INPUT T3(N)
2450 I=N
2460 GOTO 1110
2500 IF T3(I)/T1>1.02 GOTO 2530
2510 IF T3(I)/T1<.98 GOTO 2530
2520 GOTO 1300
2530 T3(N)=T3(N)-(T3(I)-T1)/(N+1)
2540 GOTO 2450
6000 REM SUB BPEV
6100 C6=((C5-C4)/(M3-M3(N+1)))*(M3-M3(T))+C4
6110 IF C6>.3 GOTO 6140
6120 B=(2/.3)*C6
6130 GOTO 6210
6140 IF C6>.5 GOTO 6170
6150 B=2+(2.5/.2)*(C6-.3)
6160 GOTO 6210
6170 IF C6>.6 GOTO 6200
6180 B=4.5+(2/.1)*(C6-.5)
6190 GOTO 6210
6200 B=6.5+(3/.1)*(C6-.6)
6210 RETURN

```

```

6400 REM SUB LAMV
6410 L1=1074.85-.3506*T-.00067*T^2
6420 RETURN
6800 REM SUB CPI
6810 C=1
6820 RETURN
7000 REM SUB BPEG
7002 C3=.03
7010 T0=(T-32)/1.8+273
7020 B1=565.757/T0-9.81559+1.54739*LOG(T0)
7030 B1=B1-(337.178/T0-6.41981+.922753*LOG(T0))*(19.819*C3/(1-C3))
7040 B1=B1+(32.681/T0-.55368+.079022*LOG(T0))*(19.819*C3/(1-C3))^2
7050 B1=B1*(19.819*C3/(1-C3))
7060 B1=B1/(266919.6/T0^2-379.669/T0+.334169)
7070 RETURN
7400 REM SUB LAMS
7410 L=1074.85-.3506*T-.00067*T^2
7420 RETURN
8000 GOTO 8010
8010 PRINT "EFFECT","TS","TFV","MFV","VAP/OFF"
8020 FOR I=1 TO N
8030 PRINT I,T3(I),T1(I),M(I),X(I)*M(I)
8040 NEXT I
8050 PRINT "MFV-REQ","MFV-CAL"
8060 PRINT M1,M2
8070 IF X1>.5 GOTO 8125
8071 PRINT "ANY CHANGES?"
8072 INPUT A$
8073 IF A$="N" GOTO 8350
8080 PRINT "CHANGE STEAM TEMP?"
8090 INPUT A$
8100 IF A$="N" GOTO 8120
8110 INPUT T1
8120 GOTO 8210
8125 PRINT "BRINE:","FLOW","TEMP"
8126 PRINT "",M4,T1
8127 PRINT "ANY CHANGES?"
8128 INPUT A$
8129 IF A$="N" GOTO 8350
8130 PRINT "CHANGE BRINE TEMP?"
8140 INPUT A$
8150 IF A$="N" GOTO 8170
8160 INPUT T1
8170 PRINT "CHANGE BRINE FLOW?"
8180 INPUT A$
8190 IF A$="N" GOTO 8210
8200 INPUT M4
8210 PRINT "CHANGE UA`S?"
8220 INPUT A$
8230 IF A$="N" GOTO 8270
8240 FOR I=1 TO N
8250 INPUT U(I)
8260 NEXT I
8270 PRINT "CHANGE VAP FRAC`S?"
8280 INPUT A$
8290 IF A$="N" GOTO 8330

```

```

8300 FOR I=1 TO N
8310 INPUT X(I)
8320 NEXT I
8330 I=N
8335 Z1=0
8340 GOTO 1100
8350 PRINT "FULL PRINTOUT?"
8360 INPUT A$
8370 IF A$="N" GOTO 9999
8800 PRINT"FORWARD FEED MULTIPLE EFFECT EVAPORATORS"
8995 PRINT"....."
9000 FOR I=1 TO N
9010 PRINT "EFFECT NO.",I
9020 PRINT"....."
9030 PRINT"TEMPERATURES"
9035 IF X1<.5 GOTO 9060
9040 PRINT"BRINE","TIN","TOUT","BPR"
9050 PRINT " ",T(I),T(I+1),B1(I)
9060 PRINT "STEAM",T3(I)
9070 PRINT "VAPOR","TOUT","BPR"
9080 PRINT " ",T1(I),B(I)
9090 PRINT "LIQUID","TIN","TOUT"
9100 PRINT " ",T2(I+1),T2(I)
9110 PRINT"....."
9120 PRINT"FLOWRATES"
9125 IF X1<.5 GOTO 9150
9130 PRINT"BRINE","TOTAL","FLASH"
9140 PRINT " ",M4,M4(I)
9150 PRINT "STEAM",M6(I)
9160 PRINT "VAPOR","TOT VAP","AUX VAP","PRE HT"
9170 PRINT " ",M(I),M5(I),M1(I)
9180 PRINT "LIQUID","FD IN","FD OUT","FLASH"
9185 IF I>1 GOTO 9190
9186 PRINT " ",M3(I),M3(I+1)
9187 GOTO 9200
9190 PRINT " ",M3(I),M3(I+1),M(I)-Q(I)/L1(I)
9200 PRINT"....."
9210 PRINT "THERMAL DATA"
9220 PRINT "DUTY","UA","LAMV","LAMS"
9230 PRINT Q(I),U(I),L1(I),L(I)
9240 PRINT"....."
9250 NEXT I
9999 END

```

*

2.4 COMPUTER RESULTS

This subsection contains the computer runs for a typical plant under consideration in the present study. A computer printout is shown for each example. The terms used in these printouts are explained in Table 2-14. Computer outputs for each effect and the sample cases are shown in Tables 2-15 through 2-18.

2.4.1 Case No. 1

This example (Table 2-15) shows a calculation for an existing sugar beet processing plant using a five-effect evaporator system with six evaporator shells (the first effect consists of two evaporators in parallel). The printout evaluates the existing plant operation with a conventional steam supply system. The auxiliary vapor includes vapor for preheating the feed and is not shown separately.³⁸

2.4.2 Case No. 2

This printout (Table 2-16) shows the same plant fitted with a geothermal feed-and-bleed system. Auxiliary plant steam is not included in this balance because it will be provided directly from the brine flash chambers as required. The latter calculation is not included in the program. Note that the distribution of UA values is different from the conventional design. This is accomplished by connecting the last two evaporators in parallel and the first four in series, thereby increasing the values of UA toward the cold end of the forward feed system. This arrangement better suits the feed-and-bleed system than does the decreasing UA value used in conventional plant design. The optimum system may involve reducing the number of effects to allow increased heat transfer surface at the cold end. This alternative is investigated in Cases 3 and 4.

2.4.3 Case No. 3

This printout (Table 2-17) shows that by connecting the last three evaporator shells in parallel while keeping the first three connected in series (as in Case No. 2), the number of effects is reduced to four but the heat transfer area in the cold end of the system is increased.

2.4.4 Case No. 4

The printout for this case (Table 2-18) illustrates that connecting the last three evaporators in parallel and the middle two in parallel with the first one as a single evaporator results in a three-effect system.

These examples indicate that for a plant retrofit, it may be more economical to reduce the number of effects in order to increase the surface area on the colder end of the system. In the above examples, the four-effect system requires the least amount of geothermal brine. This is an area that will require further investigation when specific plants are analyzed.

Table 2-14

EVAPORATOR HEAT AND MATERIAL BALANCE PROGRAM
(Explanation of Printout)

Temperature in °F

Brine	Inlet and outlet temperature. Refers to the flash stage associated with the effect in consideration, with BPR = boiling point rise of brine
Steam	Inlet temperature to the evaporator. This is the saturation temperature of the steam
Vapor	Outlet temperature from evaporator, with BPR = boiling point rise of feed
Liquid	Temperature in and out of preheater. These temperatures refer to preheating the feed to the first effect attributed to vapor extracted from the effect in consideration

Flowrates in lb/hr

Brine	Total brine flow (assumed constant); vapor flashed from the stage
Steam	Flow of steam to evaporator
Vapor	Amount of vapor out of evaporator; vapor extracted for auxiliary plant uses (not including preheat); vapor extracted for preheating the feed to the first effect; feed in and out of the evaporator

Thermal Data

Duty	Quantity of heat supplied to the evaporator by the steam, Btu/hr
UA	Product of heat transfer coefficient and surface area for evaporator, Btu/hr °F
LAMV	Latent heat of vapor, Btu/lb
LAMS	Latent heat of steam, Btu/lb

Table 2-15

CASE NO. 1 — CONVENTIONAL STEAM SUPPLY, FIVE-EFFECT SYSTEM

CONVENTIONAL STEAM SUPPLY DESIGN
DATA

NO. OF EFFECTS 5

NO FEED PREHEAT VAPOR DRAOFF

LIQUID FLOW: IN 229000 OUT 49600

LIQUID TEMP: IN 251 OUT 147

LIQUID FEED SPEC HT .9

STEAM TEMP 274

EFFECT	UA	FRAC VAP OFF	PREHEAT: 0-N,1-Y
1	3160000	.508	0
2	1550000	.206	0
3	1320000	.188	0
4	1090000	.395	0
5	483000	0	0

FORWARD FEED MULTIPLE EFFECT EVAPORATORS

EFFECT NO. 1

TEMPERATURES

STEAM	TOUT	BPR
VAPOR	279.4197	2.43215
LIQUID	251	251

FLOWRATES

STEAM	TOT VAP	AUX VAP	PRE HT
VAPOR	69113.57	33660.31	0
LIQUID	228324.7	162068.4	FLASH

THERMAL DATA

DUTY	UA	LAMV	LAMS
6.39007e 07	3160000	938.9622	924.5749

.....
EFFECT NO.

2

.....
TEMPERATURES

STEAM

256.7659

VAPOR

TOUT

BPR

237.1695

3.574653

LIQUID

TIN

TOUT

251

251

.....
FLOWRATES

STEAM

32290.6

VAPOR

TOT VAP

AUX VAP

PRE HT

35580.78

7329.64

0

LIQUID

FD IN

FD OUT

FLASH

162068.4

126506.2

3742.223

.....
THERMAL DATA

DUTY

UA

LAMV

LAMS

3.03743e 07

1550000

954.0113

940.6557

.....
EFFECT NO.

3

.....
TEMPERATURES

STEAM

233.5949

VAPOR

TOUT

BPR

213.2068

4.653705

LIQUID

TIN

TOUT

251

251

.....
FLOWRATES

STEAM

28139.39

VAPOR

TOT VAP

AUX VAP

PRE HT

30881.17

5805.66

0

LIQUID

FD IN

FD OUT

FLASH

126506.2

95643.38

3126.34

.....
THERMAL DATA

DUTY

UA

LAMV

LAMS

2.69123e 07

1320000

969.6434

956.392

.....
EFFECT NO. 4
.....

TEMPERATURES

STEAM 208.5531
VAPOR TOUT BPR
186.2427 5.545198
LIQUID TIN TOUT
251 251

.....
FLOWRATES

STEAM 25003.67
VAPOR TOT VAP AUX VAP PRE HT
27270.5 10771.85 0
LIQUID FD IN FD OUT FLASH
95643.38 68392.71 2614.723

.....
THERMAL DATA

DUTY UA LAMV LAMS
2.43183e 07 1090000 986.3135 972.5901

.....
EFFECT NO. 5
.....

TEMPERATURES

STEAM 180.6975
VAPOR TOUT BPR
147 6.5
LIQUID TIN TOUT
251 251

.....
FLOWRATES

STEAM 16446.58
VAPOR TOT VAP AUX VAP PRE HT
18793.77 0 0
LIQUID FD IN FD OUT FLASH
68392.71 49600 2660.411

.....
THERMAL DATA

DUTY UA LAMV LAMS
1.62759e 07 483000 1008.834 989.6209
.....

Table 2-16

CASE NO. 2 - GEOTHERMAL FEED-AND-BLEED, FIVE-EFFECT SYSTEM

GEOTHERMAL STEAM SUPPLY
DATA

NO. OF EFFECTS	5		
MULTIPLE EFFECT PREHEAT: TEMP APPROACH=			10
LIQUID FLOW: IN	229000	OUT	49600
LIQUID TEMP: IN	80	OUT	147
LIQUID FEED SPEC HT			.9
BRINE TEMP	300		
BRINE SPEC HT	.95		
BRINE FIRST STG FLASH DRAOFF		0	
EFFECT	UA	FRAC VAP OFF	PREHEAT: 0-N,1-Y
1	1673000	0	1
2	1490000	0	1
3	1550000	0	1
4	1320000	0	1
5	1173000	0	1

FORWARD FEED MULTIPLE EFFECT EVAPORATORS

EFFECT NO. 1

TEMPERATURES

BRINE	TIN	297.7901	TOUT	275.1579	BPR	.5482367
STEAM		274.6096				
VAPOR	TOUT	264.971	BPR	1.202956		
LIQUID	TIN	239.5227	TOUT	253.768		

FLOWRATES

BRINE	TOTAL	750000	FLASH	17375.74		
STEAM		17375.74				
VAPOR	TOT VAP	14815.14	AUX VAP	0	PRE HT	3137.526
LIQUID	FD IN	225601.3	FD OUT	210787.9	FLASH	

THERMAL DATA

DUTY	UA	1673000	LAMV	934.9107	LAMS	928.0469
	1.61255e 07					

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.....
EFFECT NO.                2
.....
TEMPERATURES
BRINE          TIN        TOUT        BPR
                275.1579    264.2973    .5292605
                263.768
STEAM          TOUT        BPR
VAPOR          251.1783    1.655656
LIQUID         TIN        TOUT
                219.4258    239.5227
.....

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.....
FLOWRATES
BRINE          TOTAL        FLASH
                750000      8269.416
STEAM          20046.46
VAPOR         TOT VAP        AUX VAP        PRE HT
                22938.69      0          4379.997
LIQUID         FD IN        FD OUT        FLASH
                210787.9     187854      3078.108
.....

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.....
THERMAL DATA
DUTY          UA          LAMV          LAMS
1.87586e 07   1490000     944.5162     935.7587
.....

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.....
EFFECT NO.                3
.....
TEMPERATURES
BRINE          TIN        TOUT        BPR
                264.2973    250.0277    .505037
                249.5227
STEAM          TOUT        BPR
VAPOR          231.7474    2.32152
LIQUID         TIN        TOUT
                185         219.4258
.....

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```

.....
FLOWRATES
BRINE          TOTAL        FLASH
                750000      10751.39
STEAM          29135.14
VAPOR         TOT VAP        AUX VAP        PRE HT
                32582.89      0          7397.372
LIQUID         FD IN        FD OUT        FLASH
                187854      155284.2    3811.739
.....

```

```

.....
THERMAL DATA
DUTY          UA          LAMV          LAMS
2.75517e 07   1550000     957.6158     945.6521
.....

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.....
EFFECT NO. 4
.....

TEMPERATURES

BRINE	TIN	250.0277	TOUT	229.8981	BPR	.4722276
STEAM		229.4258				
VAPOR	TOUT	200.4975	BPR	5.49753		
LIQUID	TIN	130.5	TOUT	185		

.....
FLOWRATES

BRINE	TOTAL	750000	FLASH	14953.24		
STEAM		39811.82				
VAPOR	TOT VAP	44023.14	AUX VAP	0	PRE HT	11449.93
LIQUID	FD IN	155284.2	FD OUT	111304.6	FLASH	4963.685

.....
THERMAL DATA

DUTY	UA	1320000	LAMV	977.6221	LAMS	959.147
	3.81854e 07					

.....
EFFECT NO. 5
.....

TEMPERATURES

BRINE	TIN	229.8981	TOUT	195.4197	BPR	.41969
STEAM		195				
VAPOR	TOUT	147	BPR	6.5		
LIQUID	TIN	80	TOUT	130.5		

.....
FLOWRATES

BRINE	TOTAL	750000	FLASH	25041.48		
STEAM		57394.13				
VAPOR	TOT VAP	61713.36	AUX VAP	0	PRE HT	10280.93
LIQUID	FD IN	111304.6	FD OUT	49600	FLASH	5902.382

.....
THERMAL DATA

DUTY	UA	1173000	LAMV	1008.834	LAMS	981.0062
	5.63040e 07					

Table 2-17

CASE NO. 3 - GEOTHERMAL FEED-AND-BLEED, FOUR-EFFECT SYSTEM

GEOTHERMAL STEAM SUPPLY
DATA

NO. OF EFFECTS	4		
MULTIPLE EFFECT PREHEAT: TEMP APPROACH=	10		
LIQUID FLOW:	IN	OUT	
	229000	49600	
LIQUID TEMP:	IN	OUT	
	80	147	
LIQUID FEED SPEC HT		.9	
BRINE TEMP	300		
BRINE SPEC HT	.95		
BRINE FIRST STG FLASH DRAFF		0	
EFFECT	UA	FRAC VAP OFF	PREHEAT: 0-N,1-Y
1	1673000	0	1
2	1490000	0	1
3	1550000	0	1
4	1863000	0	1

FORWARD FEED MULTIPLE EFFECT EVAPORATORS

EFFECT NO. 1

TEMPERATURES

BRINE	TIN	TOUT	BPR
	300.09	254.7972	.5130442
STEAM	254.2842		
VAPOR	TOUT	BPR	
	237.5667	1.406646	
LIQUID	TIN	TOUT	
	202.8183	226.1601	

FLOWRATES

BRINE	TOTAL	FLASH	
	650000	29678.5	
STEAM	29678.5		
VAPOR	TOT VAP	AUX VAP	PRE HT
	26863.38	0	5039.076
LIQUID	FD IN	FD OUT	FLASH
	228663.3	201803.1	

THERMAL DATA

DUTY	UA	LAMV	LAMS
2.79683e 07	1673000	953.7457	942.3755

.....
EFFECT NO. 2
.....

TEMPERATURES

BRINE	TIN	254.7972	TOUT	236.6431	BPR	.4830445
STEAM		236.1601				
VAPOR	TOUT	214.7703	BPR	1.951936		
LIQUID	TIN	170	TOUT	202.8183		

.....

FLOWRATES

BRINE	TOTAL	650000	FLASH	11742.25		
STEAM		33383.57				
VAPOR	TOT VAP	37651.69	AUX VAP	0	PRE HT	6973.838
LIQUID	FD IN	201803.1	FD OUT	164171.7	FLASH	4749.297

.....

THERMAL DATA

DUTY	UA	1490000	LAMV	968.6469	LAMS	954.6853
	3.18708e 07					

.....

EFFECT NO. 3
.....

TEMPERATURES

BRINE	TIN	236.6431	TOUT	213.2646	BPR	.4463093
STEAM		212.8183				
VAPOR	TOUT	184.5484	BPR	4.548429		
LIQUID	TIN	130.5	TOUT	170		

.....

FLOWRATES

BRINE	TOTAL	650000	FLASH	14884.37		
STEAM		45178.66				
VAPOR	TOT VAP	49405.98	AUX VAP	0	PRE HT	8222.899
LIQUID	FD IN	164171.7	FD OUT	114810.6	FLASH	5025.25

.....

THERMAL DATA

DUTY	UA	1550000	LAMV	987.3284	LAMS	969.8905
	4.38184e 07					

```

.....
EFFECT NO.                4
.....
TEMPERATURES
BRINE      TIN      213.2646      TOUT      180.3982      BPR      .3982232
           180
STEAM
VAPOR      TOUT      147      BPR      6.5
LIQUID      TIN      80      TOUT      130.5
.....
FLOWRATES
BRINE      TOTAL      650000      FLASH      20499.31
STEAM      62097.87
VAPOR      TOT VAP      65213.87      AUX VAP      0      PRE HT      10280.93
LIQUID      FD IN      114810.6      FD OUT      49600      FLASH      4273.21
.....
THERMAL DATA
DUTY      UA      6.14790e 07      1863000      LAMV      1008.834      LAMS      990.034
.....

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ready
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Table 2-18

CASE NO. 4 - GEOTHERMAL FEED-AND-BLEED, THREE-EFFECT SYSTEM

GEOTHERMAL STEAM SUPPLY

DATA

NO. OF EFFECTS	3			
MULTIPLE EFFECT PREHEAT: TEMP APPROACH=				10
LIQUID FLOW:	IN		OUT	
		229000	49600	
LIQUID TEMP:	IN		OUT	
		80	147	
LIQUID FEED SPEC HT			.9	
BRINE TEMP		300		
BRINE SPEC HT		.95		
BRINE FIRST STG FLASH DRAFF			0	
EFFECT	UA		FRAC VAP OFF	PREHEAT: 0-N,1-Y
1	1673000		0	1
2	2635000		0	1
3	1863000		0	1

FORWARD FEED MULTIPLE EFFECT EVAPORATORS

EFFECT NO.

1

TEMPERATURES

BRINE	TIN	TOUT	BPR
	300.3386	238.0231	.4852795
STEAM			
VAPOR	TOUT	BPR	
	210.9988	1.400751	
LIQUID	TIN	TOUT	
	175	199.598	

FLOWRATES

BRINE	TOTAL	FLASH	
	750000	46552.14	
STEAM			
VAPOR	TOT VAP	AUX VAP	PRE HT
	43293.33	0	5216.064
LIQUID	FD IN	FD OUT	FLASH
	230007.6	186719.2	

THERMAL DATA

DUTY	UA	LAMV	LAMS
4.43998e 07	1673000	971.0451	953.765

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.....
EFFECT NO.                2
.....
TEMPERATURES
BRINE      TIN      TOUT      BPR
           238.0231  210.0394  .4414078
           209.598
STEAM
VAPOR      TOUT      BPR
           188.0786  3.078627
LIQUID      TIN      TOUT
           130.5     175
.....
FLOWRATES
BRINE      TOTAL      FLASH
           750000     20514.17
STEAM      58341.21
VAPOR      TOT VAP      AUX VAP      PRE HT
           61898.78      0             9291.7
LIQUID      FD IN      FD OUT      FLASH
           186719.2     124853.1  4343.88
.....
THERMAL DATA
DUTY      UA      LAMV      LAMS
           5.67036e 07  2635000  985.2093  971.9309
.....
EFFECT NO.                3
.....
TEMPERATURES
BRINE      TIN      TOUT      BPR
           210.0394  185.4053  .4052839
           185
STEAM
VAPOR      TOUT      BPR
           147       6.5
LIQUID      TIN      TOUT
           80       130.5
.....
FLOWRATES
BRINE      TOTAL      FLASH
           750000     17781.96
STEAM      71722.21
VAPOR      TOT VAP      AUX VAP      PRE HT
           75257.98      0             10280.93
LIQUID      FD IN      FD OUT      FLASH
           124853.1     49600     5083.884
.....
THERMAL DATA
DUTY      UA      LAMV      LAMS
           7.07940e 07  1863000  1008.834  987.0583
.....

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2.5 GEOTHERMAL SOURCES

Locations of known geothermal sources in the United States are based mainly on a geological survey circular, "Assessment of Geothermal Resources of the United States - 1975," by the U.S. Department of the Interior. The circular contains, along with geothermal source locations (see Figure 2-4), a tabulation of system temperatures (surface and subsurface) and reservoir assumptions (volume and heat content).²⁹

The composition of two types of geothermal brines (see Table 2-19) was tentatively selected on the basis of published data and personal experience.^{40, 41, 42, 43}

2.6 WELL AND PIPELINE COSTS

Some preliminary investigations have been made of the economics of geothermal delivery systems. The economic evaluation is based on the determination of the various relevant individual system costs as listed:

- Capital Costs
 - Exploration
 - Drilling
 - Wellhead equipment
 - Delivery and reinjection piping
- Recurring Costs
 - Interest on capital expenditure
 - Depreciation
 - Maintenance
 - Bore replacements
 - Salaries and overhead

Most of these items have been relatively well documented in the literature and so a reasonable estimate of the cost (at the point of use) of geothermal steam by the candidate industries should be possible.³⁶

Table 2-19

COMPOSITION OF GEOTHERMAL BRINES USED AS BASIS FOR THIS STUDY
(TENTATIVE)

Component	Ion Concentration (ppm by wt)	
	Low Salinity Brine	High Salinity Brine
Na	1,500	8,560
Ca	25	2,820
Mg	1.0	5.0
Ba	0.30	—
Sr	2.2	—
K	85	140
Cl	1,970	18,000
SO ₄	150	80
HCO ₃	610	650
SiO ₂	150	400
Fe	1.0	90
Mn	—	2.0
Sum of ions	4,495	30,792
CO ₂	3,000	200
H ₂ S	20	300
pH	6.2	6.7

Figure 2-4. HYDROTHERMAL CONVECTION SYSTEMS WITH INDICATED SUBSURFACE TEMPERATURES BETWEEN 90° AND 150°C

Section 3

FUTURE WORK

As outlined in the project schedule, Bechtel's work for the next quarter (January through March 1977) will concentrate on the following areas:

- Continuation of Industry Contacts. Further contacts with candidate industries, trade associations, and equipment manufacturers will be made to supplement the process information gathered to date and to develop industry acceptance of geothermal steam use
- Continuation of Flowsheet Development. From information now available, and with the aid of the newly developed evaporator heat and material balance program, detailed evaporator section flow diagrams will be drawn for the three most promising candidate industries
- Begin Conceptual Engineering. Details of existing plant evaporator equipment and optimum flow schemes for new and retrofitted plants will be finalized
- Start Considering Environmental Effects. Advantages and disadvantages of the use of geothermal steam in in evaporation and crystallization operations will be determined

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