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ETHANOL PRODUCTION FOR AUTOMOTIVE FUEL USAGE

Final Technical Report
July 1979 - August 1980

by

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ABSTRACT

Production of ethanol from potatoes, sugar beets, and wheat using geothermal resources in the Raft River area of Idaho was evaluated in this study. The south-central region of Idaho produces approximately 18 million bushels of wheat, 1.3 million tons of sugar beets, and 27 million cwt potatoes annually. A 20-million-gallon-per-year ethanol facility has been selected as the largest scale plant that can be supported with the current agricultural resources. The conceptual plant was designed to operate on each of these three feedstocks for a portion of the year, but could operate year-round on any of them.

The processing facility uses conventional alcohol technology and uses geothermal energy for all process heating. There are three feedstock preparation sections, although the liquefaction and saccharification steps for potatoes and wheat involve common equipment. The fermentation, distillation, and by-product handling sections are common to all three feedstocks.

Maximum geothermal fluid requirements are approximately 6,000 gpm. It is anticipated that this flow will be supplied by nine production wells located on private and BLM lands in the Raft River KGRA. The geothermal fluid will be flashed from 280°F in three stages to supply process steam at 250°F, 225°F, and 205°F for various process needs. Steam condensate plus liquid remaining after the third flash will be returned to receiving strata through six injection wells.

The capital cost estimated for this ethanol plant employing all three feedstocks is \$64 million. If only a single feedstock were used (for the same 20 million gallon per year plant) the capital costs are estimated at \$51.6 million, \$43.1 million, and \$40.4 million for sugar beets, potatoes, and wheat, respectively. The estimated capital cost for the geothermal system is \$21 million. Economic analyses which include escalation indicate the alcohol production cost is very sensitive to feedstock costs. The three feedstock concept is not economically attractive if significant amounts of expensive field run potatoes must be purchased. A wheat-only 20-million-gallon-per-year facility would yield a reasonable return on investment for a current alcohol selling price of less than \$1.75 per gallon. The cost of geothermal-derived steam is about \$3 per million Btu's, which is considerably less than purchased steam costs derived from oil or gas fuels.

The results of this evaluation study suggest that a commercial-scale geothermal-alcohol facility in the Raft River KGRA is technically feasible and could be economically attractive, given the current state and federal gasohol tax incentives. There are, however, institutional constraints which would make the

implementation of a 20 MM gpy plant difficult in the relatively undeveloped Raft River Valley. These constraints include limited manpower and community service resources, limited transportation access, a critical groundwater shortage, and a potential problem in obtaining rights to adequate geothermal resources. A smaller-scale facility (5 to 10 MM gpy) would be more appropriate for immediate implementation in this area.

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INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

The existence of extensive geothermal resources in the United States represents an untapped potential energy source to supplement available fossil fuels. High temperature geothermal resources (>350°F) will most likely be used to generate electricity. However, such high temperature resources are limited. Extensive studies by the U.S. Geological Survey and others have shown that lower temperature resources are much more abundant. These lower temperature geothermal resources are suitable for direct use. A number of direct applications for space heating and agriculture uses are currently in existence. These applications by their nature are limited to energy consumption at or near the geothermal source. For this study, the use of geothermal energy for the production of ethanol was evaluated. Geothermal resources are used to convert renewable resources to a mobile energy form to supplement our automotive fuel requirements.

This technical and economic evaluation of ethanol production using geothermal resources was initially directed to a site area adjacent to the Department of Energy Raft River Test Facility. The locations of the properties owned by Messrs. G. Crook, et al. and Frank Glover referred to in this study are shown in Figure 1-1. The site specific area was expanded during the study to encompass more promising geothermal resource zones in the Raft River Known Geothermal Resource Area (KGRA).

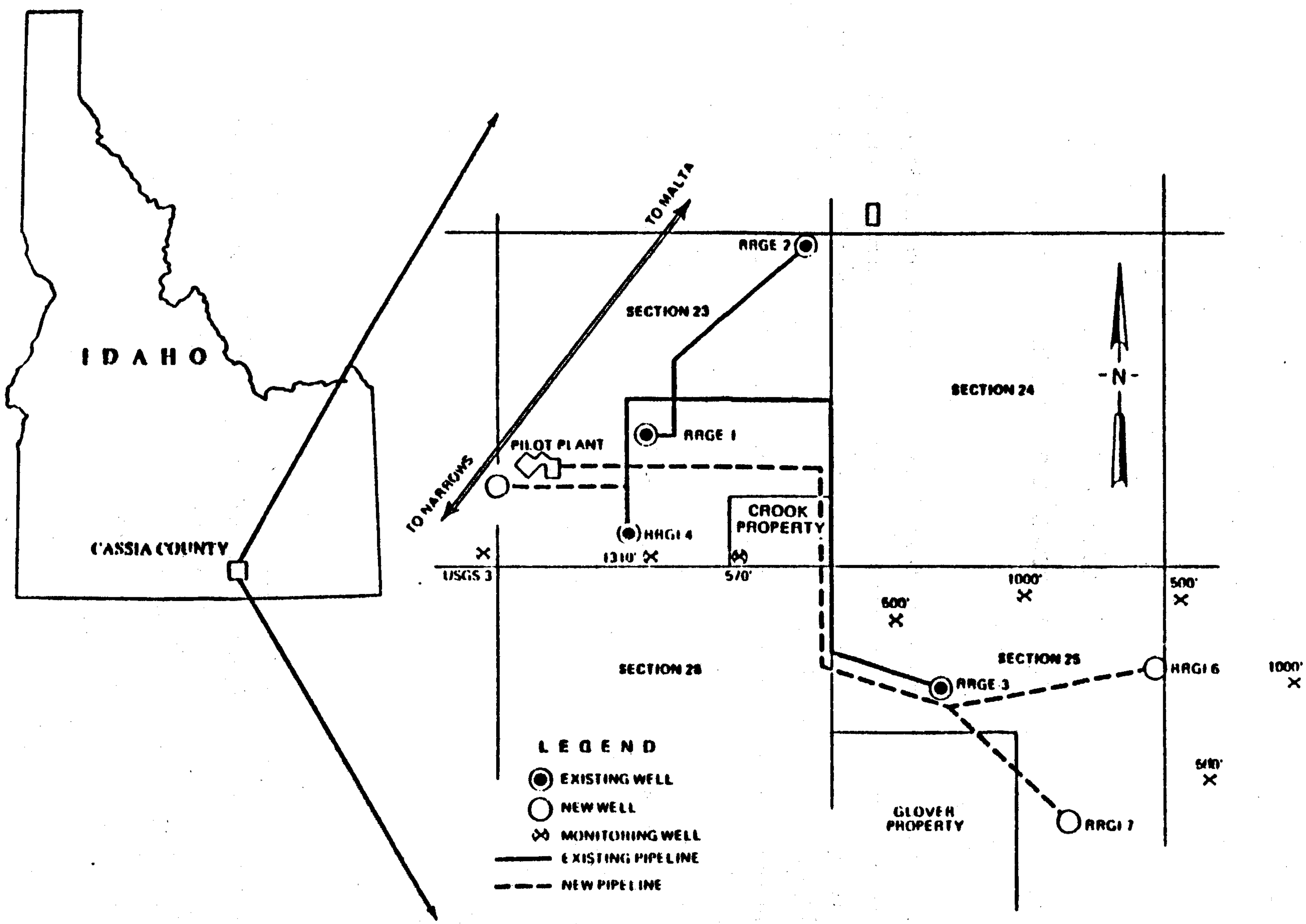

Figure 1-1 WELL & PIPELINE LOCATION – RAFT RIVER AREA

REF: (SEMI-ANNUAL PROGRESS REPORT FOR IDAHO GEOTHERMAL PROGRAM, 10/1/77 TO 3/31/78, E.G. & G IDAHO, INC., JULY 1978, TREE–1278)

This study was divided into nine major tasks to:

- Evaluate the availability of farm products in the Raft River region to produce ethanol
- Provide the necessary conversion process
- Establish the conditions and availability of the geothermal resource
- Provide an economic analysis
- Determine institutional requirements for commercial operation

The nine tasks, including all of the subtasks, are shown in Table 1-1.

The study was begun on July 2, 1979. This final report covers the work accomplished from the inception of the project to mid-May 1980 when the draft final report was delivered to DOE. Upon receipt of their comments in July, the final report was issued in August 1980. Section 2 describes work accomplished in Task 1. Sections 3 through 8 correspond to their respective task numbers, with Task 2 work (process flow diagrams) presented in Section 5.

1.2 SUMMARY

The Raft River KGRA in south-central Idaho is known to have extensive low salinity geothermal fluid. It has been established that this formation can yield 290°F (143°C) geothermal fluid at a well depth of 5000 feet (1500 m). Test wells drilled in the KGRA indicate that the temperature conditions, fluid properties and production flows appear to be compatible with the major energy needs of a commercial scale ethanol production facility.

The south-central agricultural region of Idaho is a major producer of wheat, sugar beets, and potatoes. Over the past few years, the total production of each crop in the counties around the KGRA has been sufficient to support

Table 1-1

SCOPE OF WORK

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Table 1-1 (Continued)

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- 7.1 Define Program Goals
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- 8.1 Feedstock Availability
- 8.2 Environmental Effects
- 8.3 Resources Leasehold Arrangement
- 8.4 Procedural Considerations

Task 9 — Final Report

a commercial-scale ethanol production facility. Based on discussions with property owners and farm groups, it appears that this region can support a 20-million-gallon-per-year ethanol production facility, and we selected this size facility at a specific site in the Raft River KGRA for our technical and economic evaluation.

Because of the feedstock supply-demand situation, we decided to use a multi-crop feedstock concept for the design of the production facility. The processing sequence described in this report is based on processing potatoes for five months, sugar beets for four months, and wheat for three months of the year. The plant has the theoretical capability of processing any one of the three feedstocks all year round, producing 20 million gallons per year. In each year, however, crop productions and prices would dictate the actual processing mix and run duration of each so that the feedstock having the lowest cost per gallon of ethanol production would be processed for the longest period. For example, if potatoes were too expensive, then the process run on wheat would be extended. Sugar beet acreage would have to be contracted a year in advance through the beet growers' association. Thus, the process run time on sugar beets would be essentially fixed before planting time.

Conventional technology was used in the design of both the alcohol production facility and the geothermal energy extraction system. This conventional technology approach was selected to facilitate rapid implementation of a commercial-scale geothermal-alcohol facility, thus avoiding new or unproven processes that would require substantial development efforts.

The geothermal energy system was designed to supply all of the process heating requirements. The maximum geothermal fluid requirement will be about 6,000 gpm at a well-head temperature of 280°F. This flow would be supplied by nine production wells, spaced on centers no closer than one-quarter mile to prevent mutual interference. A geothermal well layout developed by EG&G Idaho, Inc. suggests drilling wells along four identified or inferred fault zones would provide the best chance of successfully producing the geothermal fluid required by the facility.[1] Geothermal fluid gathered from the production wells would be piped to a three-stage flash system on the plant site. The fluid would be flashed successively to produce steam at 250°F, 225°F, and 200 to 205°F for various process needs. Geothermal steam condensate from the process, plus the remaining fluid from the third flash, would be filtered and pumped to six wells for injection into the formation. All process heating would be indirect except for direct steam injection in potato and wheat cooking.

The alcohol production scheme selected involves several basic steps:

- Feed preparation — primarily cleaning, size reduction, and slurry preparation
- Starch liquefaction and saccharification to produce fermentable sugars (except for beets)
- Batch fermentation of the sugar solutions to ethanol
- Alcohol recovery and dehydration by distillation
- Stillage separation and evaporation
- By-product solids drying

Sugar beets do not need to undergo a saccharification step. The beets do go through a slicing step and a hot water extraction step to separate the sugar from the beet solids (pulp). The resulting beet sugar solution would be concentrated by evaporation to 20 percent weight sugar prior to fermentation to correspond with the sugar content of the solutions resulting from potato and wheat processing.

Fermentation, distillation, and by-product handling sections of the plant would be common to all three feedstocks. The product alcohol would be virtually 200 proof. Dry by-product solids would be sold as an animal feed supplement.

Geothermal energy requirements would average about 158 million Btu's per hour or about 62,000 Btu's per gallon of ethanol produced. Beet processing into ethanol is the most energy intensive of the three feedstock processing options. Process heat rejection also would be significant. A nonconsumptive cooling water system was incorporated in the conceptual design to minimize the plant's demand for water resources in this critical groundwater-short area. Cooling water from five 1,500 gpm capacity groundwater supply wells would be pumped through process coolers and then injected through three 2,500 gpm capacity wells into the shallow aquifer without consumptive use. Air coolers would be used where practicable to minimize the cooling water flow requirements.

The constructed capital cost of the 20-million-gallon-per-year, three feedstock ethanol production facility was estimated at $64 million (first quarter 1980 wage and price levels). Single feedstock plants of the same capacity were estimated at $51.6 million, $43.1 million, and $40.4 million, respectively for sugar beets, potatoes, and wheat. The capital cost of the geothermal facility was originally estimated as $18 million based on an optimistic drilling success rate in a quarter section (160 acres) plot close to the conceptual plant site. The estimate was revised to $21 million based on a well layout scheme (provided by EG&G) which disperses the nine production wells along known or inferred fault zones. Costs for four unsuccessful production wells were included in the revised estimate. The conceptual alcohol facility would be located on a 55-acre plant site to which the geothermal fluid would be pumped through a gathering network of buried insulated pipe.

Annual direct operating and maintenance costs, excluding feedstock, for the geothermal-alcohol facility were estimated at $12.7 million (first quarter 1980) or about 60¢ per gallon of alcohol produced. By-product solids sold at $100 per ton is equivalent to a 35.5¢ per gallon credit.

Feedstock prices will be the most significant factor influencing the cost of producing alcohol. Initial feedstock prices used in this study and approved by DOE were:

- Sugar beets at $25 per ton = $1.03 per gallon of alcohol produced
- Potatoes at $1.50 per cwt = $1.23 per gallon of alcohol produced
- Wheat at $4.20 per bushel = $1.41 per gallon of alcohol produced

On a 4/5/3 month feedstock processing basis, the current day cost of producing alcohol (excluding capital charges) at these optimistic feedstock prices would be $1.46 per gallon, including the by-product credit. In February 1980, DOE recommended what were considered more realistic feedstock costs:

- Sugar beets at $31 per ton = $1.28 per gallon of alcohol produced
- Potatoes at $3 per cwt = $2.45 per gallon of alcohol produced
- Wheat at $4 per bushel = $1.34 per gallon of alcohol produced

On the same feedstock processing basis, the cost of producing alcohol would exceed $2 per gallon. Doubling the potato cost has a dramatic impact on the direct cost of producing alcohol and emphasizes the importance of feedstock costs.

An economic analysis based on a 20-year plant life and a proposed financing scheme of 60/40 debt/equity, 12 percent interest on debt, and 15 percent return on equity yielded a $2.76 per gallon selling price (first quarter 1980) for alcohol with the DOE recommended feedstock costs. Allowing a differential escalation of 4 percent annually for feedstock costs and by-product credit, and 8 percent annually for all other costs and revenues, the first quarter 1980 selling price would be an unattractive $2.14 per gallon. For a 20-million-gallon-per-year plant processing only wheat, the comparable alcohol selling price would be only $1.63 per gallon. It was clear from the economic analysis, that the economic viability of this geothermal-alcohol facility depends principally on obtaining a feedstock mix at a moderate cost. Wheat and sugar beets are acceptable feedstocks at the above costs. Potatoes at $3 per cwt are not. A geothermal-alcohol venture group should consider processing only culls and potato wastes (for a shorter process run) or excluding potato processing entirely.

The geothermal energy cost for this size plant at Raft River is approximately $3 per million Btu's which compares quite favorably with the cost of process steam produced from fossil fuels (except perhaps coal).

A geothermal-alcohol project of this size in the lower Raft River Valley would provide significant economic benefits to the region through increased employment, an increased tax base, and local purchases of goods and services including agricultural crops. The facility would produce two beneficial products: (1) a fuel supplement to displace a substantial amount of gasoline derived from petroleum, and (2) animal feed supplements derived from feedstock residues which could be used to displace some animal feed concentrates.

Because of the relatively isolated, rural setting of the Raft River geothermal resource area, implementation of such a project would have some adverse socioeconomic impacts on the area. A significant increase in local population would occur during the construction and operation phases, placing demands on local community services which may not be met without the financial assistance of the project. Transportation access to the KGRA is limited and a substantial increase in road traffic on Highway 81 would result from construction and operation activities. Truck traffic would be especially heavy during the operating phase because of continuous feedstock hauling into the area and, to a lesser extent, product shipping out of the area. Both of these will represent substantial changes in the local environment and impacts of both can be mitigated somewhat by proper planning and implementation of the project. Environmental impacts on or near the plant site during construction and operation should not be consequential enough to render the project unacceptable.

A project venture group would also have some practical difficulties in securing consumptive water rights and rights to adequate geothermal resources. The Raft River basin is closed to further appropriation of groundwater. Although the operating geothermal-alcohol facility would be a net producer of water, geothermal well drilling and construction of the alcohol facility would require some consumptive use of groundwater. Acquisition of existing water rights permits for the same types of consumptive use would be necessary under the state's current water resources policies in the Raft River area. The venture group would have to acquire, by lease or purchase, the rights to adequate geothermal resources on both private and BLM lands and then obtain geothermal resource permits and water rights permits from the Idaho Department of Water Resources. These water-related institutional constraints should be prominent items for early investigation by any venture group interested in implementing a commercial-scale geothermal-alcohol project in the Raft River KGRA.

The results of this technical and economic evaluation indicate that a commercial-scale geothermal-alcohol demonstration project should be considered for implementation in the Raft River KGRA. Although a 20 MM gpy facility appears favorable from a technical (engineering) and economic standpoint, the institutional constraints — limited transportation access, low manpower and community services resources, and uncertain availability of consumptive water rights — may preclude the immediate implementation of a project this size. It appears that a smaller-scale demonstration facility (on the order of 5 to perhaps 10 MM gpy production capacity) would be more appropriate for the Raft River KGRA at this time. Wheat and perhaps sugar beets should be considered as candidate feedstock materials.

A smaller-scale facility at this stage of the geothermal resource development will not risk the possibility that the actual resource is not as extensive as now thought. Acquisition of sufficient water rights for a smaller-scale facility may be less difficult to achieve. In addition, the immediate impacts on the local region would be substantially lessened and would allow for a more orderly social and economic expansion of this rural area.

There are economic penalties in going to a smaller capacity plant. The capital investment per unit of alcohol production increases and the labor costs increase as the capacity decreases. A 10 MM gpy facility processing wheat all year round could probably produce alcohol selling at about $1.80 per gallon (current day). Under the same economic conditions used in this study, the selling price would be a little over $2 per gallon for a 5 MM gpy wheat-only facility.

Section 2

DEFINITION OF CURRENT ETHANOL PRODUCTION TECHNOLOGY

Beverage-grade ethanol has been produced for many years from a variety of agricultural products. In recent years, production of fuel-grade (180 or higher proof) ethanol from agricultural products has been increasing in the U.S. This section examines the status of production technology and defines the technology approaches used in the conceptual design of the alcohol facility.

2.1 FEEDSTOCK REQUIREMENT

Wheat, sugar beets, and potatoes were selected as the candidate raw materials for ethanol fermentation. Over the past few years (1975 - 1978), production of each of these crops in the counties around the Raft River Geothermal Project has been sufficient to support a "commercial-scale" ethanol production facility (20 million gallons per year or larger). The following shows the average annual production:

- Wheat (winter) — 10,000,000 bushels
- Wheat (spring) — 8,000,000 bushels
- Sugar beets — 1,300,000 tons
- Potatoes — 27,000,000 cwt

Tables 2-1, 2-2, and 2-3 summarize the approximate production by counties. These quantities cannot be considered as the resources available solely for ethanol production. One cannot introduce a new demand equivalent to the existing demand for these agricultural products without seriously upsetting the local market conditions. In order to obtain raw materials

Table 2-1 (Ref. 2)

RECENT WHEAT PRODUCTION IN SOUTH-CENTRAL IDAHO

COUNTY	WINTER WHEAT			SPRING WHEAT		
	Acreage Planted	Yield bu/ac	Production million bu	Acreage Planted	Yield bu/ac	Production million bu
Cassia	60,000	46	2.76	35,000	71	2.48
Jerome	15,000	76	1.14	16,000	69	1.10
Minidoka	10,000	70	.7	22,000	75	1.65
Twin Falls	20,000	66	1.32	20,000	76	1.52
Power	125,000	34	4.25	40,000	45	1.8
TOTALS	230,000	44.2 avg	10.17	133,000	64.3 avg	8.55

Table 2-2 (Ref. 2)

RECENT SUGAR BEET PRODUCTION IN SOUTH-CENTRAL IDAHO

COUNTY	Acreage Planted	Yield tons/ac	Production tons
Cassia	17,000	18	306,000
Jerome	5,000	18	40,000
Minidoka	30,000	18	540,000
Twin Falls	14,000	20	280,000
Power	8,000	16.5	132,000
TOTALS	74,000	18.1 avg	1,348,000

Table 2-3 (Ref. 2)

RECENT POTATO PRODUCTION IN SOUTH-CENTRAL IDAHO

COUNTY	Acreage Planted	Yield cwt/ac	Production cwt
Cassia	25,000	245	6,125,000
Jerome	15,000	265	3,975,000
Minidoka	35,000	235	8,225,000
Twin Falls	19,000	300	5,700,000
Power	16,000	235	3,760,000
TOTALS	110,000	252 avg	27,785,000

at a reasonable price, the total demand must be kept close to the achievable production in the area. About 40 percent of the total cropland in these five counties is used for these three crops. Other cropland acreage could be used to increase production, however, irrigation water is in limited supply, especially in the Raft River Valley. Rather than attempt to markedly increase the production of one of these potential feedstocks, the strategy should be to seek a fraction of each crop's annual production for feedstock and to work with the growers' associations to ensure that there will be adequate supplies for all the buyers.

This multi-crop feedstock concept has been adopted for this study. A 20 million gallon per year ethanol production capacity was selected as being the largest scale that can be supported by the agricultural resources of the south-central area. The facility would nominally process potatoes for five months, sugar beets for four months, and wheat for three months of the year. On this processing basis, the nominal annual feedstock requirements would be about:

- 300,000 tons of sugar beets
- 360,000 tons of potatoes
- 53,000 tons of wheat

In each year, crop productions and prices would dictate the actual processing mix and run duration so that the lowest cost (per gallon of production) feedstock would be purchased on the open market. Sugar beet acreage would be contracted a year in advance through the growers' association, so the process run on sugar beets would be fixed essentially before planting time.

Only agricultural resources in the south-central area of Idaho were considered. There is very little production of wheat, sugar beets and potatoes in the Utah counties just south of the Idaho-Utah state line. Truck shipment of these materials from other producing areas in Idaho and perhaps Oregon would add too much to the cost of the materials to be an economic alternative.

2.2 FEEDSTOCK PREPARATION

Feedstock preparation technology for wheat, sugar beets, and potatoes was discussed with conventional processors (millers, sugar factories, starch plants and dehydrators) with equipment vendors and with saccharification/fermentation experts.

For each of the three feedstocks there are basically two preparation approaches: 1) whole product processing and, (2) refined product preparation. The second, and more costly approach, produces clean substrate material which is theoretically amenable to continuous fermentation. Whole product processing is conducive only to batch fermentation. For wheat and potatoes, whole product processing schemes were chosen. Both require liquefaction and saccharification steps prior to fermentation. For the beet case, a partially refined product preparation scheme was selected, since there is little experience with fermentation of the whole beet (juice and pulp).

The preparation steps for wheat consist of cleaning, then dry grinding with no separation followed by mixing with water to a 30 percent starch-dry solids (DS) content which is suitable for fermentation to about a 10 percent ethanol solution. The pH of the slurry is adjusted to 6.5 in preparation for gelatinization and enzymatic liquefaction.

Potatoes are washed with water, drained and disintegrated without peeling. The ground potatoes are centrifuged to a DS content of 21 percent. The pH is adjusted to 6.5 as in wheat preparation prior to gelatinization and liquefaction.

Sugar beets are processed using conventional beet-sugar technology. The beets are washed with water, drained, sliced into thin strips (cossettes) and then the juice phase is extracted from the insoluble portion of the beets (pulp) in a hot water diffusion process. The thin juice contains about 14 percent sucrose and is partially concentrated before fermentation to ethanol. These feedstock preparations involve simple, well-established, physical processes.

The refined product approach involves conventional separation processes which produce high quality starch (wheat and potatoes) and low impurity, concentrated juice (beets). The major by-product materials are produced in the preparation steps rather than in the post-fermentation processing.

In order to minimize the cost of the three feedstock preparation sections in the facility, the simpler approach was selected for this study.

2.3 SACCHARIFICATION AND FERMENTATION

Both potato and wheat starches must be converted into fermentable sugars. Enzymatic schemes were selected for liquefaction and saccharification based on starch conversion literature and discussions with enzyme producers. The processing conditions selected are well-established and the amylase enzymes required are commercially available. Because of the relatively low temperature heat source available, a low temperature liquefying enzyme is required. Both enzymes would be purchased rather than complicating the process by attempting to produce the enzymes on-site.

Processing steps for wheat and potato starch are nearly identical so the same equipment can be used for both:

- Addition of the liquefying enzyme (alpha amylase) to the raw starch slurry
- Cooking the slurry to liberate the starch molecules (gelatinization) and to allow enzymatic breakdown of the starch bonds (liquefaction)
- Cooling the slurry and pH adjustment to 4.5
- Conversion of starch to glucose (saccharification) by addition of saccharifying enzyme (glucoamylase) and holding the solution for about 40 hours to complete the conversion

The saccharification step can be carried out simultaneously with fermentation with the penalty of a higher glucoamylase dose. A clean substrate is desirable.

Both batch fermentation and continuous fermentation schemes were considered in the process of selecting preparation steps for each feed material. Continuous fermentation offers the advantages of high fermentation rates (low residence time) and low yeast makeup requirements. It requires a clean substrate. Continuous fermentation is also more susceptible to contamination than the conventional batch process. The batch fermentation approach was chosen along with the whole product processing approach because of its relative simplicity and its proven reliability.

Batch fermentation consists of charging a fermentation tank with the sugar (glucose or sucrose) solution, addition of brewers yeast and nutrients, and holding the mash for about 48 hours to allow completion of the sugar conversion to ethanol. Cooling is required to remove the heat of reaction, maintaining the mash temperature at about 30°C. By-products of the reactions include yeast, carbon dioxide, fusel oils (high-molecular weight alcohols) and aldehydes.

After the fermentation period, the tank is emptied, cleaned and sterilized and is ready to receive another charge of sugar solution. Multiple fermentation tanks are employed to avoid enormous tank sizes and to reduce the total cycle time — fill, ferment, empty, and clean.

The sugar solution from beet processing has lower than the desired 20 percent sugar content for optimum fermentation and the subsequent distillation. Prior to fermentation, the beet juice will be concentrated to about 20 percent sugar to match the content of the other two processed feedstock solutions.

2.4 ANHYDROUS ETHANOL PRODUCTION

The possibility of producing a 190 proof ethanol for blending with gasoline was abandoned early in this study by mutual agreement with DOE's Technical Representative.

The following distillation methods for producing anhydrous (200 proof) ethanol were subsequently examined:

- Conventional low pressure stripping, rectification, and benzene-water-ethanol azeotropic distillation
- Vacuum distillation to avoid the water-ethanol azeotropic condition
- Extractive distillation with gasoline yielding a gasoline/alcohol mixture
- Distillation followed by vapor phase dehydration using adsorption agents

The last two schemes offer promise of significant energy savings, but are not yet commercially and economically proven processes. The ACR gasoline extraction process (proprietary) is, however, being installed in a commercial-scale plant due to start up this year. Vacuum distillation does not appear to yield real cost/energy savings because of the greater investment in distillation equipment. Katzen offers a dual-pressure distillation modification of the conventional process.[3] However, it requires a steam temperature (from coal-fired boilers) that is considerably higher than that available from the geothermal resources.

The more conventional scheme was therefore selected:

- A beer still producing a 73 mole percent ethanol overhead and a stillage bottoms product with fusel oils taken off as a side draw
- A benzene-water-ethanol azeotropic distillation with anhydrous ethanol as bottoms product. Water from the benzene stripper is essentially free of benzene and ethanol.

2.5 BY-PRODUCT PROCESSING

By-product type and quantities were considerations in the selection of the preparation schemes for each feedstock. Refined product preparation produces a number of different front-end by-products. With a multiple feedstock facility, the handling, storage and marketing of a number of different by-product materials may not be attractive, even if some high-value materials such as gluten are produced. Process complexity and low utilization of process equipment are real drawbacks.

The whole processing approach carries the non-fermentables (except for beet pulp) through the process to the beer still. The whole stillage from each feed material contains yeast, other insolubles and dissolved solids from which a single-type of by-product animal feed would be recovered. Its advantage is a single by-product recovery scheme that accommodates each feedstock.

Production of a wet by-product for animal feeding onsite was an option considered briefly. While it would produce a considerable energy savings by reducing drying requirements, the option adds complexity by introducing another industry into the area. The feedlot option may not be practical in the geothermal resource site area.

The by-product processing scheme selected involves:

- Centrifugal separation of whole stillage into a sludge and a thin liquor containing the dissolved solids
- Evaporation of the thin liquor to a syrup-like product
- Blending the syrup with the sludge and drying it with geothermal fluid as the heat source
- Grinding the dry solids for storage and sale as dry animal feed

Three separate dry products could be produced or they could be blended for sale as a single product.

Figures 2-1, 2-2, and 2-3 are block flow diagrams illustrating the processing steps selected for wheat, potatoes, and sugar beets, respectively. Feedstock preparation is different for each feed material. The starch cooking and saccharification steps are common to wheat and potatoes processing. Fermentation, alcohol recovery, by-product recovery and product storage steps are common to processing all three feed materials.

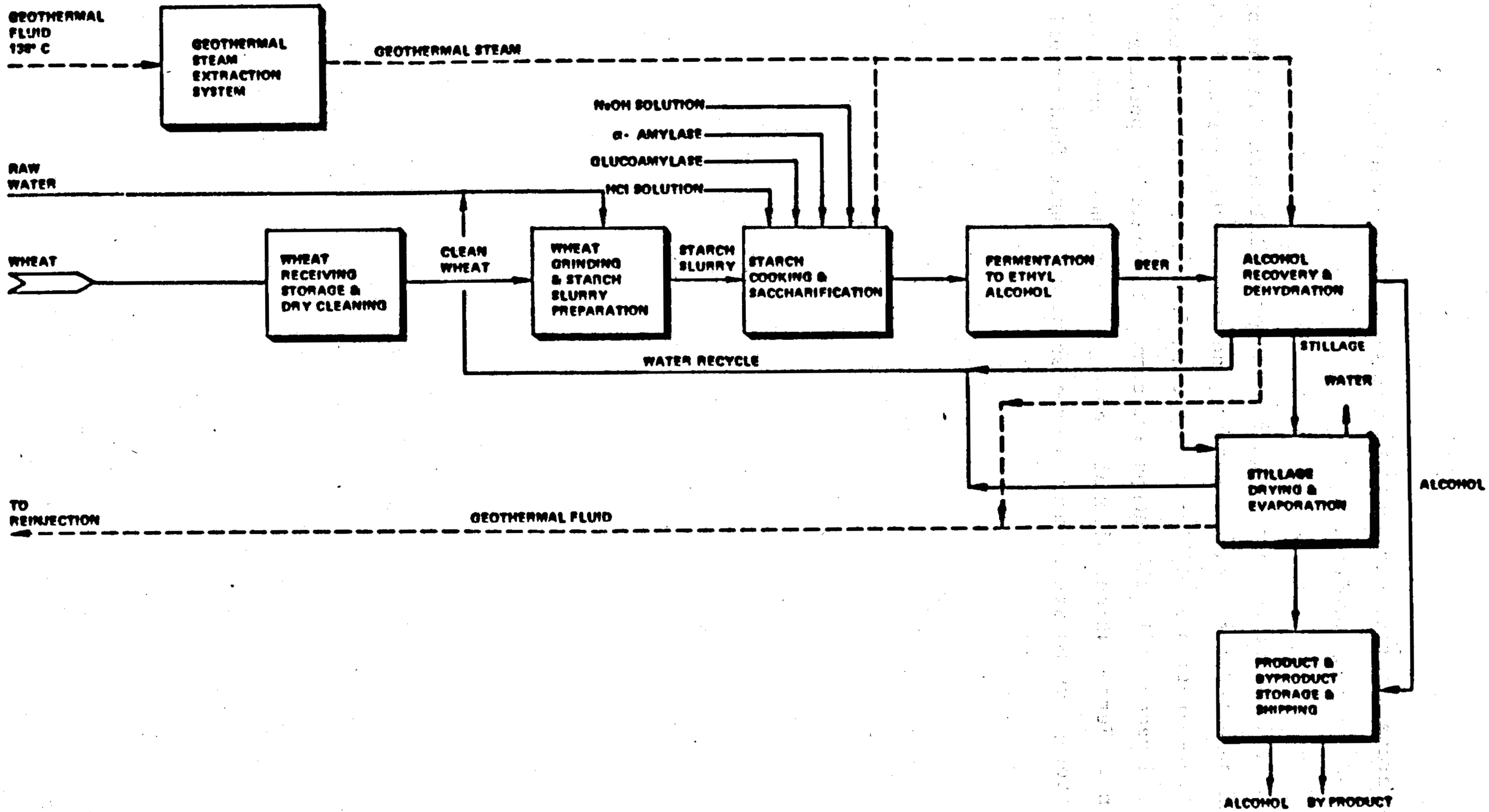

Figure 2-1. Block flow diagram — wheat processing.

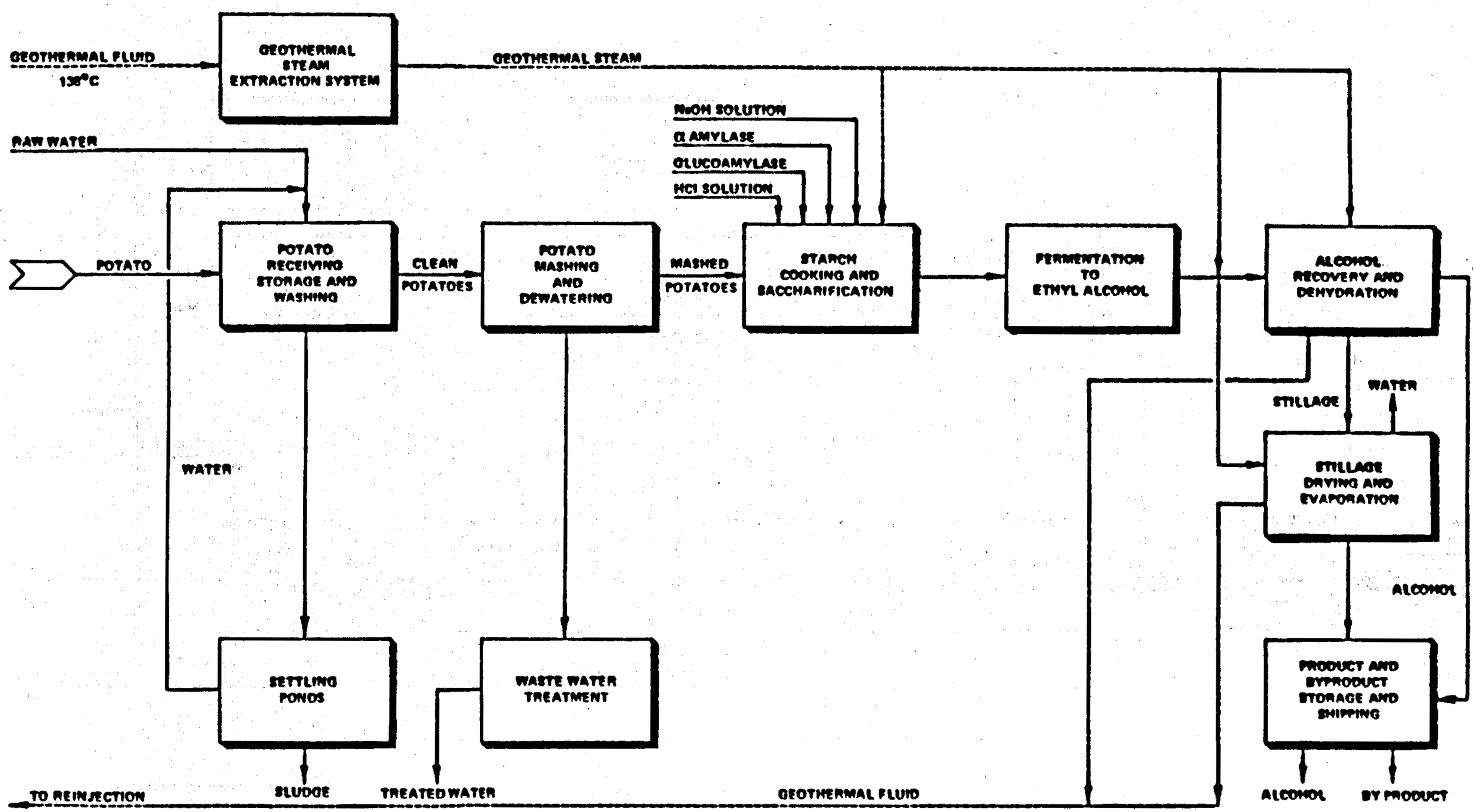

Figure 2-2. Block flow diagram — potato processing.

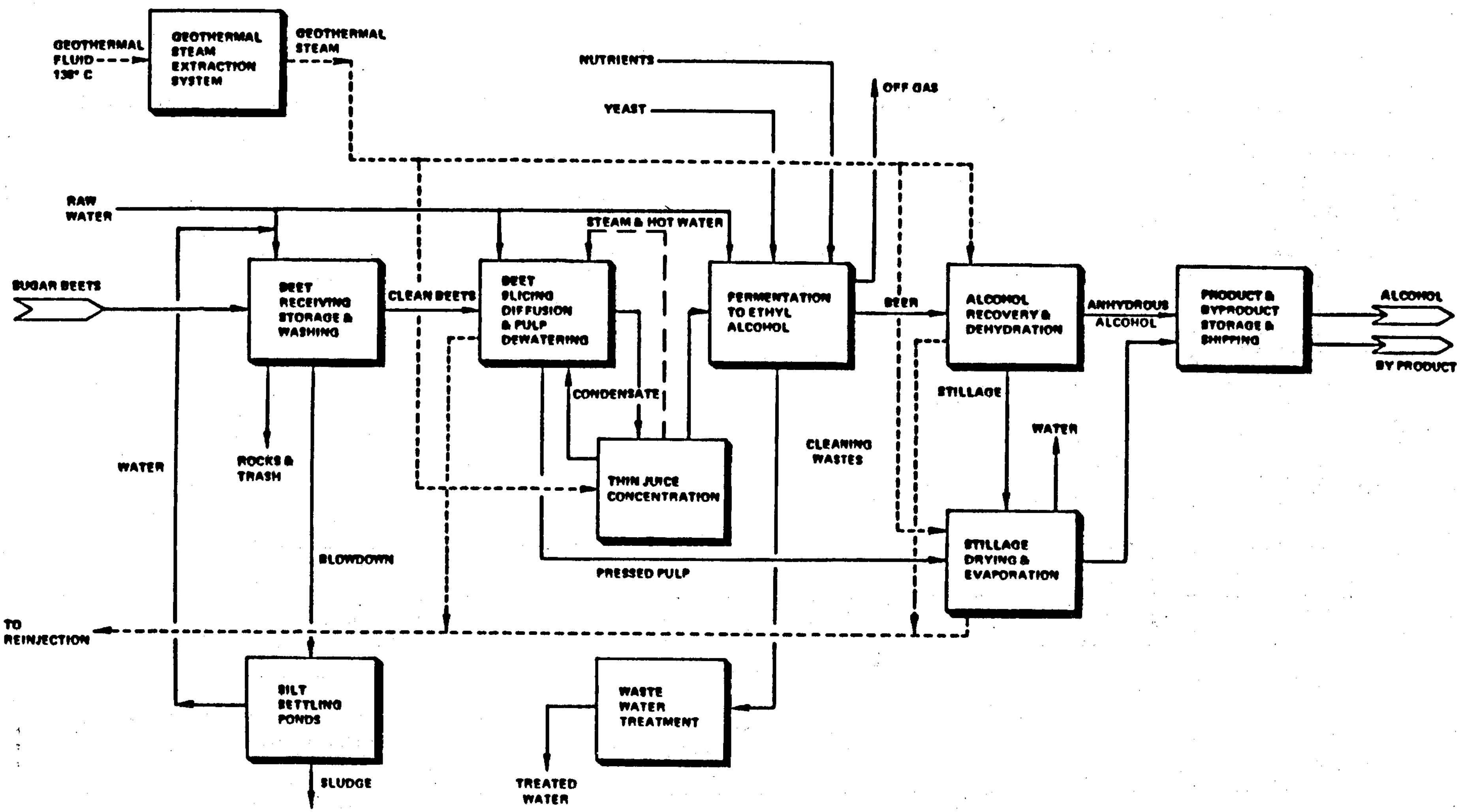

Figure 2-3. Block flow diagram — sugar beet processing.

Section 3

DEFINITION OF GEOTHERMAL RESOURCE REQUIREMENTS

The overall process heat requirements will dictate the geothermal fluid flow requirements. Process heat input temperatures are limited by the geothermal resource temperature. This section examines the process heat requirements and the extraction methods available to meet those requirements, giving due consideration to the constraints imposed because of the geothermal fluid properties.

3.1 PROCESS CONDITIONS

Process heat is required in the sugar beet preparation, the wheat and potato cooking, the alcohol recovery and the by-product recovery sections of the alcohol facility. Process heat balances indicated that the maximum input requirement would be slightly more than 200 million Btu's per hour — when processing sugar beets. More than one temperature level would be desirable with a fluid temperature range of 250°F minimum inlet and 200°F minimum exit from process users. The highest temperature requirement is for starch cooking (a consumptive use), although high temperatures in other services are desirable to avoid huge heat transfer surface areas. This heat can be supplied by geothermal fluid, in the form of fluid under pressure, steam produced by flashing, or a secondary working fluid.

The Raft River geothermal fluid is low in salinity, but it still has the potential to deposit scale on heat transfer surfaces under pressurized conditions. Some of the process equipment in the ethanol production plant incorporates heating surfaces, such as vessel jackets, that are extremely difficult to de-scale. As a result, the direct use of hot geothermal fluid was discarded.

Binary fluid systems would essentially require doubling the overall plant heat transfer surface, and were thus eliminated as being too expensive.

Multiple temperature steam heating systems are routinely used in chemical process plants. Heat transfer rates with condensing steam are uniformly high, and not susceptible to appreciable fouling. In addition, control of heat to individual users is simple and uses equipment already familiar to the industry. Balancing heat flow at the various temperature levels can be done in such a way as to minimize geothermal fluid flow.

In order to provide clean steam from flashing geothermal fluid, it is necessary to separate the fluid droplets containing dissolved solids. This can be accomplished by employing separation technology now used in salt evaporators. Separation efficiencies over 99.9 percent in this type of equipment is typical. Flash vessels using evaporator de-entrainment design criteria should be able to provide steam containing less than 10 mg/l dissolved solids from geothermal sources. A three-stage flash system was selected as best meeting the heat rate and temperature level needs of the multi-feedstock plant.

3.2 ESTABLISHMENT OF GEOTHERMAL WATER FLOW REQUIREMENTS

Using a multistage flashing system to provide heating steam to the process, the total geothermal fluid flow can be approximated by equation 3.1.

$$G = \frac{Q}{(h_1 - h_2)\ Cp} \tag{3.1}$$

Where

G = geothermal brine flow, lb/hr

Q = heat requirement, Btu/hr

h_1 = brine enthalpy at inlet to system, Btu/lb

h_2 = brine enthalpy at discharge conditions, Btu/lb

Cp = fluid heat capacity, Btu/lb ^oF

In practice, this equation is used to calculate the fluid flow into each flash vessel, allowing for the vapor production in upstream vessels. The minimum fluid flow is then found where the enthalpy change for fluid flowing from stage to stage exactly matches the heat requirement for users at that temperature level.

For the three steam temperature level system, the total geothermal fluid flow requirements would vary from a maximum of 5,900 gpm for sugar beet processing to a minimum of about 4,100 gpm for potato processing. Some steam users can accept two steam temperature levels to balance heat loads. Total vapor production would be less than 8 percent of the geothermal inlet fluid.

3.3 STUDY OF PHYSICAL AND CHEMICAL CONSTRAINTS

The expected range of geothermal fluid chemical properties is shown in Table 3-1.[4]

Scaling by calcium carbonate takes place in alkaline geothermal brine, such as at Raft River, when the brine pressure is dropped, allowing free carbon dioxide to be released. Deposition and fouling under these conditions can be dramatically severe, often causing plugging in process equipment and piping in a matter of days.[5] This phenomenon can be largely controlled by the addition of "threshold" type inhibitors to the brine, upstream of the flash point.[6] These inhibitors, typically organic phosphonates, acrylates, or polymers of maleic anhydride are added to the raw brine in concentration of 1 to 5 mg/l. A number of these compounds have been tested and found either biologically inert or FDA approved for use in drinking water.[7]

Both strontium sulfate and silica in the geothermal brine will exceed their solubility limits when the brine is cooled. This would tend to cause deposition in heat exchangers, especially if the fluid velocities

Table 3-1

EXPECTED GEOTHERMAL FLUID PROPERTIES

Constituent	Analysis Range, mg/l
Sodium	300 - 1000
Potassium	30 - 100
Calcium	30 - 130
Strontium	1 - 5
Magnesium	0.5 - 1.0
Lithium	1.0 - 3.5
Chloride	500 - 2000
Fluoride	4 - 6
Sulfate	30 - 50
Bicarbonate	25 - 50
Silica	125 - 150
pH	7.0 - 7.5

Potential scaling problems with this brine can be expected from three major species:

- Calcium carbonate
- Strontium sulfate
- Silica

are low and residence time unknown. The "threshold" inhibitors have shown some effectiveness for strontium sulfate, but will not prevent silica deposition. Fortunately, however, in a flashing brine situation, the release of carbon dioxide causes the brine pH to increase, thus increasing silica solubility. In addition, the kinetics of silica deposition are extremely slow. If a system is designed so that silica solubility is not greatly exceeded, and if residence time is kept short, say less than one hour from the flashing point to reinjection, silica deposition is very unlikely.

Non-condensible gases are present in the geothermal brine. Materials testing has shown there are trace amounts of hydrogen sulfide in the brines.[8] These are of sufficient quantity to cause corrosion problems with copper alloys. Mild steel and stainless steel (in vapor spaces) should be suitable materials of construction.

Section 4

CONCEPTUAL DESIGN OF GEOTHERMAL ENERGY GATHERING, TRANSFER, AND DISPOSAL SYSTEM

This section discusses the geothermal facilities required to support the alcohol production plant. The original concept involved an optimistic assessment which was revised, based on information supplied by EG&G Idaho, to reflect a more geologically probable production and injection well scheme for meeting the energy needs of the alcohol facility.

4.1 WELL FIELD DESIGN

Initial discussions with geologists, hydrologists, and engineers from EG&G concerning the Raft River geothermal area indicated that there is neither a general concensus on the extent of the moderate temperature resource nor any typical design conditions for production wells, including realistic operating lives.

There is major faulting in the Raft River area, so that it is very difficult to predict the results from exploratory drilling even if it occurs near an existing well. Existing production in the area is largely from wells intersecting fractures.

An optimistic view of the geothermal resource extent was taken for the preliminary well field design, which included well spacing on a ¼-mile grid close to the conceptual plant site which was assumed to be 160 acres in Section 25 (Frank Glover's property). Nine production wells were envisioned, each capable of producing an average of 700 gpm over their operating lives with 200 kW of pumping power available. The geothermal resource analysis performed by EG&G resulted in the well layout scheme indicated in Figure 4-1 in which nine production wells are located in four zones with significant potential for geothermal production. Costs for drilling a total of thirteen wells were included in the capital cost estimate. Four of these are assumed to be economically unproductive.

Average well depth is assumed to be 5900 ft with a 13 3/8-inch casing down to a depth of 1,400 feet where a 14-stage TRW-Reda pump is set. The pumps can develop a 500 psi head with a 300 hp motor. A replacement well is drilled once every five years. The low priority production well sites in Figure 4-1 are potential locations for replacement wells. The suggested well layout should be considered only conceptual in nature. Adequate exploratory drilling is mandatory to the successful placement of production wells.[1]

4.2 GEOTHERMAL WATER GATHERING SYSTEM

Because of the dispersed well layout, a substantial piping network will be needed to transfer the geothermal fluid to the energy extraction system at the conceptual plant site. The fluid gathering system (dotted lines in Figure 4-1) is composed of about 6 miles of insulated, buried pipe connecting the individual production wells in each zone which connects with main supply piping to the production plant. Schedule 40 carbon steel pipe is used in nominal sizes of 6 to 12 inches in diameter. The fluid gathering network is constructed by trenching below the frost line, then welding, spray insulating with 2 inches of urethane, and laying the pipe in the trench. The 48-inch deep trench is backfilled and compacted, and later the access ways are revegetated. Pipeways would cross both private and BLM lands. Right-of-ways are assumed to be leased from owners either under production leasehold agreements or simple right-of-way leaseholds where use of the properties are retained by the lessors.

The fluid temperature drop from heat loss in the fluid gathering network is expected to be low — on the order of 1 to 2^{o}C.

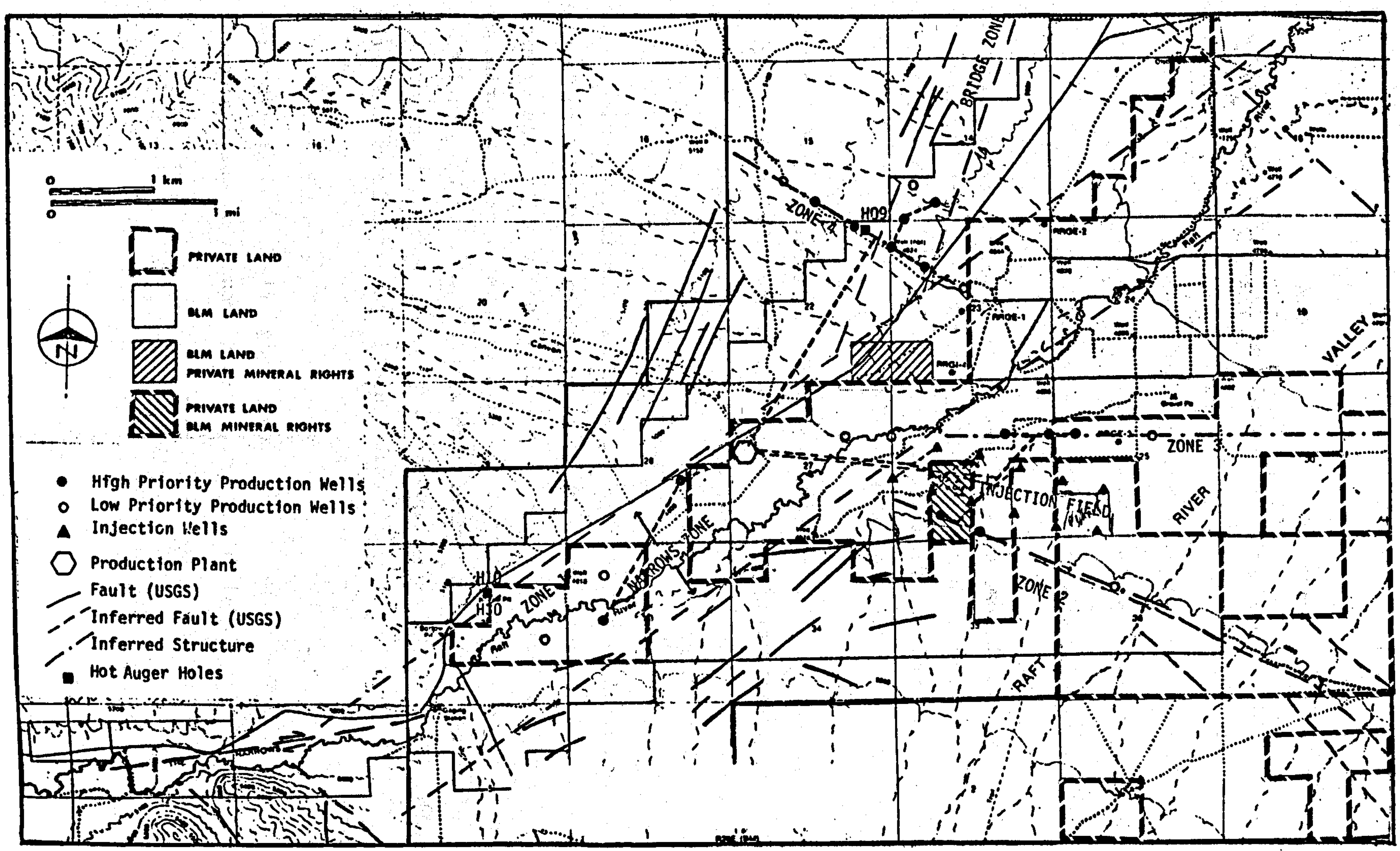

Figure 4-1. Location map of proposed well locations.(1)

4.3 ENERGY EXTRACTION SYSTEM

The geothermal energy supply system is designed to provide heat to the ethanol plant in such a way as to:

- Provide all heat users at the proper temperature level
- Avoid scaling of process heat transfer equipment
- Minimize geothermal brine flow requirements

This is done through the use of a multistage flash steam supply. In some cases, large heat users such as the multi-effect evaporators for beet juice and stillage concentration are designed to accept steam at two temperature levels in order to balance heat loads.

The multistage flash system provides steam at approximately 250°F, 225°F, and 205°F. By transferring the energy from geothermal brine to the process with steam, scaling of complex heat transfer surfaces in dryers, jacketed vessels, and evaporators is avoided.

The design of the geothermal energy extraction system is illustrated in Figure 4-2 and the overall geothermal flow diagram is presented in Section 6. Geothermal fluid from each well is pumped individually to the energy extraction system. Here, a scale control additive is metered into the brine by a positive displacement pump and mixed with a static mixer. The fluid then flows to the first flash vessel, where the pressure is reduced to produce steam at 250°F. The flow of geothermal fluid is adjusted to maintain the 250°F temperature.

The flashed liquid then flows to the second stage flash vessel, which is maintained at 225°F. A small amount of steam is vented to the atmosphere from the second stage for control purposes.

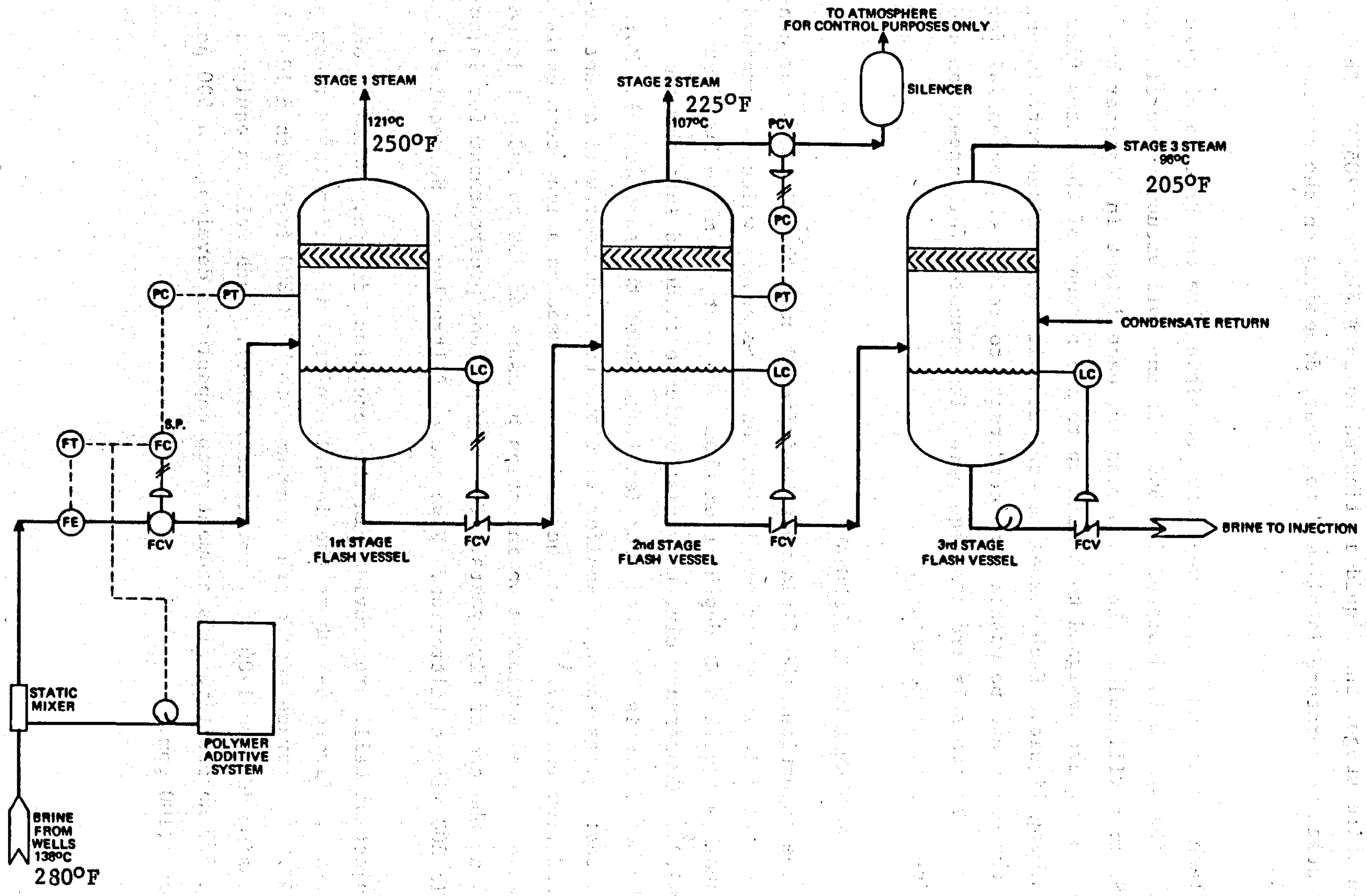

Figure 4-2. Geothermal steam extraction system.

In the third stage, the liquid is flashed to approximately 205°F. The third stage temperature is allowed to float, depending on the steam demands.

The flash vessels as well as major system piping are constructed of mild steel. The system is designed for 600 psig and full vacuum, according to ASME Section VIII code. The flash vessels, each 8 feet in diameter by 14 feet high, are designed to handle up to 125 percent of the rated flow of flashing liquid. Each vessel is equipped with a two-stage entrainment separator which can be washed with condensate to reduce the potential for plugging. The vessels are also equipped with manholes for inspection and cleaning access, if necessary.

4.4 GEOTHERMAL WATER DISPOSAL

For brine injection, the fluid must be injected such that it does not contaminate the drinking water and irrigation water supply which is obtained from shallow aquifers at depths from about 100 feet (30 m) to 500 feet (155 m).[4] Conservatively, the brine could be injected into the same aquifer the hot fluid is obtained from (at least about the same depth). More recent testing has shown an aquifer at 1,500 to 2,500 feet will accept reinjected flow readily.[9] Whether this can be used on a long-term basis is not known. It is estimated an injection pressure of 250 to 300 psi is required at the end of five years. The only present pretreatment for injection is 200 micron filtration. Five micron filtration may be required.

Six injection wells are provided in the conceptual design. Normally one is a spare. Figure 4-1 shows the location of the injection field recommended by EG&G.[1] Average well depth is assumed to be 3,800 feet with a 13 3/8-inch casing down to 1700 ft (similar to RRGI-6). Each well is equipped with a 500 hp positive displacement pump capable of developing a 500 psi head at 1,100 gpm.

An uninsulated 16-inch diameter line in the same trench as the main supply line from production zones 2 and 3 is used to transfer the cooled brine to the injection well distribution network. At the alcohol facility, the cooled brine plus steam condensate is withdrawn from the third flash stage and pumped through eight parallel multi-media filters for removal of suspended solids. After filtration, the fluid is routed through the underground transfer line to the individual reinjection wells. Section 6 includes a flow diagram of the overall geothermal system. Design fluid velocities in both the supply and reinjection piping are high to keep a low total fluid residence time in the system as an aid to preventing precipitation and scale deposition.

4.5 RESOURCE PROPERTY VARIATIONS

The overall energy requirements for processing the selected feedstocks into alcohol were considered during the conceptual design of the geothermal-alcohol facility. Both potatoes and wheat processing would require about 30 percent less total heat input than sugar beets processing, as discussed in Section 6. Drying the beet pulp accounts for most of the higher energy needs. The three feedstock concept was selected to provide flexibility in operation which could include dropping a feed material if it became too expensive and potentially eliminating by-product drying if a cattle feedlot operation were developed in conjunction with the geothermal-alcohol facility. The anticipated extent of the geothermal resource in the KGRA appears sufficient to accommodate the larger energy demand of the three feedstock concept.

4.6 SYSTEM OPTIMIZATION

The geothermal energy system represents the concept best suited to the needs of the alcohol production facility without compromising workability on either the geothermal or the alcohol production side. As indicated in subsection 3.1, the use of pressurized brine for heat input would represent least cost, but has the highest technical risk of fouling and scaling. The use of a secondary working fluid offers little technical advantage over the fluid flash system and would add significantly to the capital cost because of effective doubling of heat transfer surface.

The overall cost of geothermal energy is a strong function of the extracted energy per unit of fluid produced. Alcohol production from agricultural crops is characterized by relatively high temperature energy needs and little demand for low temperature heat sources. Thus, a 200+°F brine must be returned to the receiving strata. Options should be considered for increased geothermal energy use in conjunction with an alcohol production facility. Low temperature utilization in the KGRA has already been commercially demonstrated by Gary Crook. The Raft River Geothermal Project has examined numerous other "waste heat" utilization concepts. Section 7 indicates that co-users should be considered in any implementation plan.

Section 5

CONCEPTUAL DESIGN OF ALCOHOL FACILITY

This section incorporates the results of Task 2 — Process Flow Diagram Preparation as well as the results of Task 5. Process conditions for the three feedstocks were developed from in-house information, open literature, and discussions with processors, enzyme manufacturers and equipment vendors. Design bases were then established from which the conceptual design was prepared. As noted in Section 2, conventional technology was used throughout so that neither process development nor equipment development would be needed. The conceptual facility is designed to produce a nominal 20 million gallons per year of anhydrous ethanol using geothermal steam as the sole heat input. Other utility resources assumed to be available are:

• Electric power	4.16 kV, 3 Ø, 60 Hz
• Cooling water	70°F (max.) source from shallow groundwater wells*
• Potable water	60°F source from groundwater wells*

5.1 DESCRIPTION OF OVERALL FACILITY

The conceptual geothermal-alcohol facility is designed to operate 330 stream days per year for 20 years. The facility is divided into six process sections corresponding to the Section 100 through Section 600 drawings presented later in this section. Because three different feedstocks are to be processed, three separate sets of material balances and major equipment specifications are presented. Portions of the plant are common to all three feedstocks. Since simultaneous processing is not envisioned, common equipment was not duplicated.

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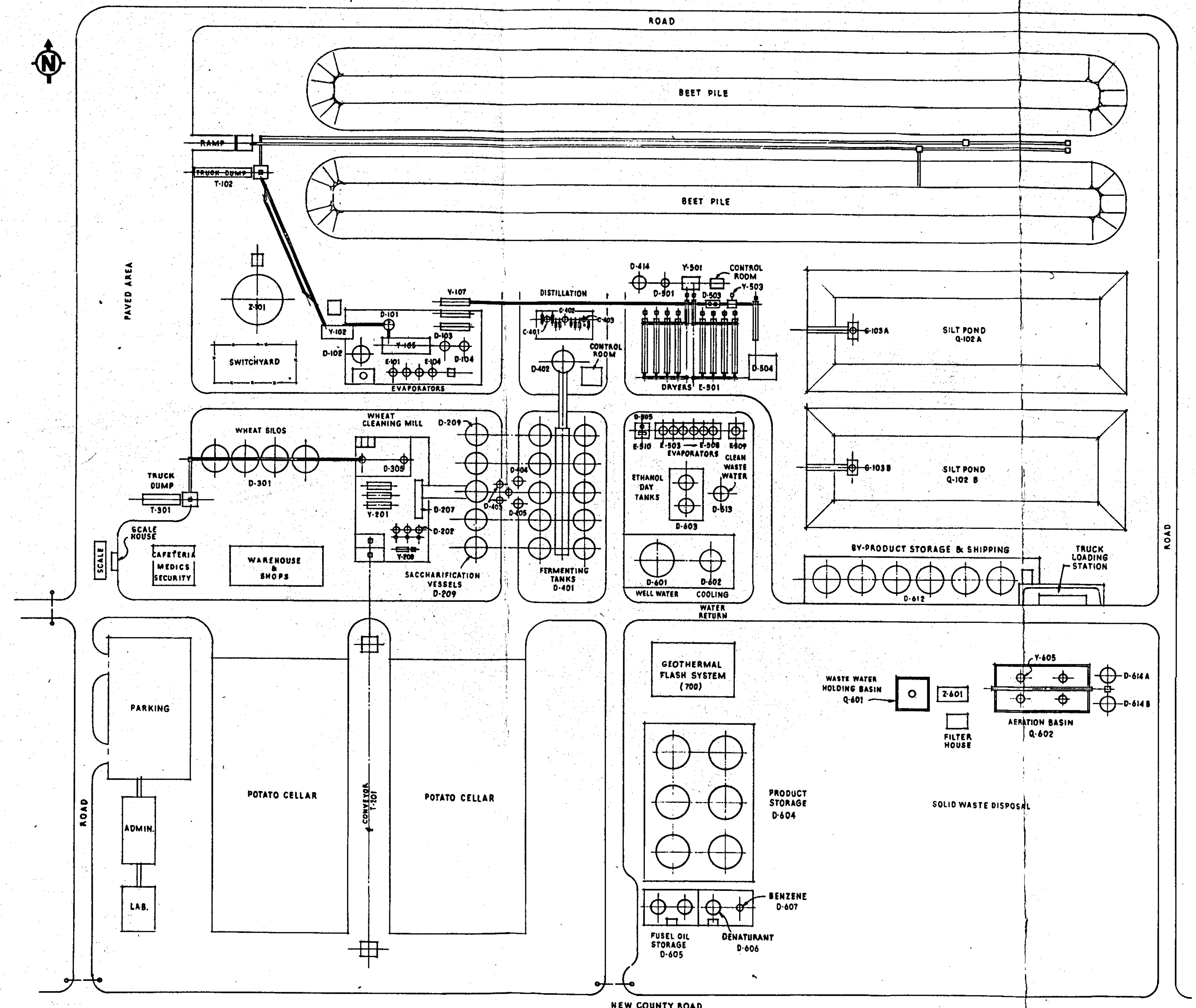
*Per discussions with Stanley Lloyd of Elba, Idaho — 55°F water available at 300-foot depth in well drilled north of Glover property (January 4, 1980).

A nominal processing sequence of 4 months on sugar beets, 5 months on potatoes, and 3 months on wheat is illustrated in the process descriptions. Sections 100, 400-A, and 500-A represent the plant operation when sugar beets are used as a feedstock. The design feed rate is about 110 tons per hour and the ethanol product yield is 2,556 gallons per hour (23.2 gallons per ton). Sections 200, 400-B, and 500-B represent the operation on potato feedstock. The design feed rate is about 2,173 cwt per hour and the ethanol yield is 2,554 gallons per hour (1.175 gallons per cwt). Sections 300, 400-C, and 500-C represent wheat operation. The ethanol yield is 2,558 gallons per hour with a design feed rate of about 892 bushels per hour (2.87 gallons per bushel). Section 600 includes the geothermal system, product storage, the cooling water system, and waste treatment common to all three feedstock operations.

Figure 5-1 represents a plot plan of the alcohol production facility, and Figure 5-2 gives a perspective view of the facility as it might appear in the Raft River KGRA. The conceptual plant occupies about 55 acres assumed to be private rather than federal land. Feed preparation facilities including on-site storage, Sections 100 through 300, occupy a considerable portion of the developed plant site. Major process equipment through the fermentation steps are housed in buildings for weather protection (not all of the building enclosures are shown). Product tankage and the by-product storage silos are somewhat isolated from the main processing areas for reasons of safety. It is anticipated that feedstock receiving and product shipping traffic would be handled through separate plant gates. The geothermal flash system is centrally located with respect to process steam users. Geothermal fluid piping is underground as are the major steam supply lines. All the hot side piping is insulated to minimize heat losses.

The foreground area is reserved for disposal of solid waste resulting from feedstock cleaning. The bulk of this waste will be silt dredged from the two silt ponds and will be a relatively inert material.



100 SERIES: BEET PROCESSING

- D-101 Clean Beet Bin
- D-102 Thin Juice Tank
- D-103 Dewatering Screen & Sump
- D-104 Press Water Tank
- Y-107 Pulp Press
- Z-101 Flume & Wash Water Clarifier

200 SERIES: POTATO PROCESSING

- D-202 Feed Bins
- D-207 Baffled Holding Tank
- Y-201 Potato Washer
- Y-203 Centrifuge

300 SERIES: WHEAT PROCESSING

- D-305 Crude Starch Slurry Mix Tank

400 SERIES: FERMENTATION

- C-401 Beer Still
- C-402 Azeotropic Distillation Column
- C-403 Hydrocarbon Stripper
- D-403 Yeast Vessels
- D-404 Sterilant Mixer Tank
- D-405 Cleaning Agent Mixer Tank
- D-414 Whole Stillage Tank

500 SERIES: BY-PRODUCTS

- D-501 Thin Stillage Tank
- D-503 Storage Bin
- D-504 Product Storage Bin
- D-505 Flash Vessel
- E-509 Air Cooled Condenser
- Y-501 Centrifuges
- Y-503 Cyclone

600 SERIES: OFF-SITE

- D-614 Gravity Clarifiers
- Y-605 Surface Aerators, Float Type
- Z-601 Dissolved Air Flotation Unit

50 0 50 100 150 200

SCALE IN FEET

Figure 5-1

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20 MM GAL / YR NOMINAL ETHANOL FACILITY
PLOT PLAN

13412 002

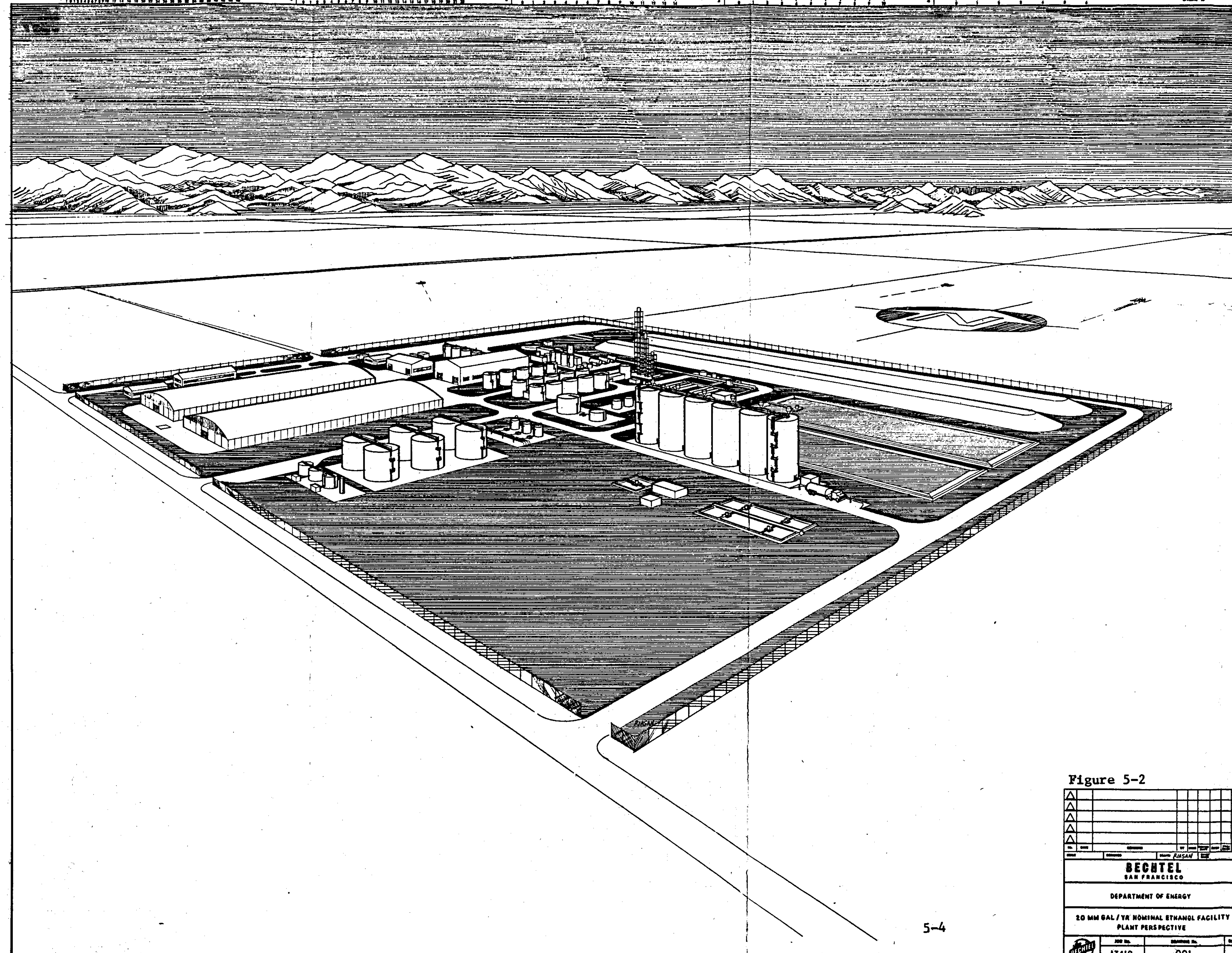

Figure 5-2

BECHTEL
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DEPARTMENT OF ENERGY

20 MM GAL / YR NOMINAL ETHANOL FACILITY
PLANT PERSPECTIVE

JOB No.	DRAWING No.	REV.
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The following subsections describe the process operations in the alcohol facility and include the design bases, material balances, and equipment specifications for each feedstock operation. Fermentation, alcohol recovery, and by-product recovery are presented as common operations for the three feedstocks.

5.2 BEET PROCESSING — SECTION 100

Section 100 covers beet processing steps up to fermentation, but the entire operation is summarized here.

Sugar beets are processed four continuous months each year, November through February, following three months of wheat processing. Three hundred ten thousand tons of field run beets are received by the plant for cleaning and processing. On-site storage capacity is about 80,000 tons, or about 30 days supply. About 21,000 tons of trash and silt are removed in cleaning the beets over the four-month period. The daily slice contains 421 tons of sugar of which 411 tons are extracted as a thin juice in the diffusion process. The thin juice (13.67 percent sugar) is concentrated to 19.1 percent sugar by evaporation. These 411 tons yield a net of 202.8 tons of ethanol at the end of batch fermentation of the juice concentrate. The beer, containing about 10 percent weight ethanol, is distilled to a 88 percent weight ethanol overhead product, then dehydrated to a 200 proof ethanol product in a benzene-water-ethanol column. Beet pulp from the diffusion step is dewatered and dried for by-product sale. The whole stillage from the beer still is evaporated to a syrup and dried with the beet pulp. Fusel oils (higher molecular weight alcohols) are also recovered as a by-product which are blended with the ethanol product.

5.2.1 Design Bases

The assumed composition of the sugar beets processed in the plant is presented in Table 5-1. Sixteen percent sugar is typical for beet varieties grown in the region.

Table 5-1

AVERAGE COMPOSITION OF SUGAR BEET (CLEAN)

Soluble dry matter	18.87%
Marc	5.00%
Water	76.13%
	100.00%

Juice Phase

Sucrose	16.00%
N-free organics (carbohydrates, acids, saponins)	1.20%
N-organics (betaine, amides, amino acids, purines, pyramidines, ammonia and nitrates)	1.17%
Inorganics (K, Ca, Mg, Na, PO_4, Cl, SO_4)	.50%
Water	76.13%

Marc Phase

Insoluble pectic material, proteins, saponins	1.25%
Cellulose, lignin, hemicelluloses	1.25%
Bound water	2.50%
	100.00%

The as-delivered beets are assumed to contain a total of seven percent (on a clean beet basis) foreign matter — rocks, trash and silt. In cleaning the beets, all foreign matter is removed and 0.1 percent of the soluble dry matter (half sucrose) is assumed to be lost in washing (or in storage).

Field run beets are processed 24 hours per day, seven days per week at a design stream factor of 90.4 percent — 2,823 tons per stream day or 2,552 tons per day on a calendar day basis. Figure 5-3 is a process flow diagram of the beet processing steps. Table 5-2 summarizes the principal design bases for each process step.

5.2.2 Beet Receiving and Storage

Sugar beets are shipped to the ethanol facility by end-dump tractor-trailers. The net load averages 25 tons. Trucks are weighed in (gross) and out (tare) to record the as-received tonnages. At the scale, trucks are directed to one of two dump stations: one for direct processing, and the other for transfer to storage. Five trucks per hour are routed to the direct processing station where a hydraulic dump platform elevates the trucks for discharge of the beets into the wet hopper.

At the other dump station, beets are dumped into a dry hopper and fed onto a pinch-roller trash screen which removes weeds and leaves. A traveling-stacker conveyor transfers the beets to one of two parallel storage piles. A transverse slewing boom is used to stack the beets up to a height of 20 feet and to a width of 120 feet. At full capacity, each pile will contain 40,000 tons. Transverse air ducts, spaced at 25-foot intervals, distribute ventilation air supplied by low pressure fans.

Beets are reclaimed at up to 150 tons per hour by front-end loaders working the toe of a pile. They load a moveable hopper positioned above the reclaim belt conveyor. The reclaim conveyor discharges into the wet dump hopper from which beets enter the flume system.

Table 5-2

PRINCIPAL DESIGN BASES — PROCESSING SUGAR BEETS

Elevation and Normal Atmospheric Pressure	4800 ft; 12.24 psia
Beet Receiving & Storage	
Receiving periods	daylight hours, 7 days per week
Carrier	25-ton net tractor-trailers (end dump)
Loads per day	113 average maximum for first 60 days
Direct process	1250 tpd
Reclaim from storage	1573 tpd
Maximum reclaim rate	150 tph
Beet Washing	
Flume water	2000 gal/ton of beets flumed (design)
Wash water	400 gal/ton of beets (design)
Direct recycle	60 percent (design)
Pond recycle	19 percent (maximum)
Lost to sludge	1 percent (minimum)
Beet Slicing	
Slicing capacity	1000 tpd per machine
Compressed air to slicers (cleaning)	30 lb/ton of beets sliced
Knife block cycle time	4 hours
Diffusion	
Average diffusion temp.	$70^{\circ}C + 273^{\circ} = 343^{\circ}K$
Draft	114 lb juice/100 lb cossettes
Length of cossettes	13 m/100 g cossettes
Diffuser constant	6.6×10^{-5}
Diffusion time	64 minutes
Sugar in pulp	0.353% wt (1.237% wt on pulp)
Sugar in sliced beets	15.95% wt
Diffuser capacity	3200 tpd
Diffusion steam	15,400 lb/hr @ $205^{\circ}F$

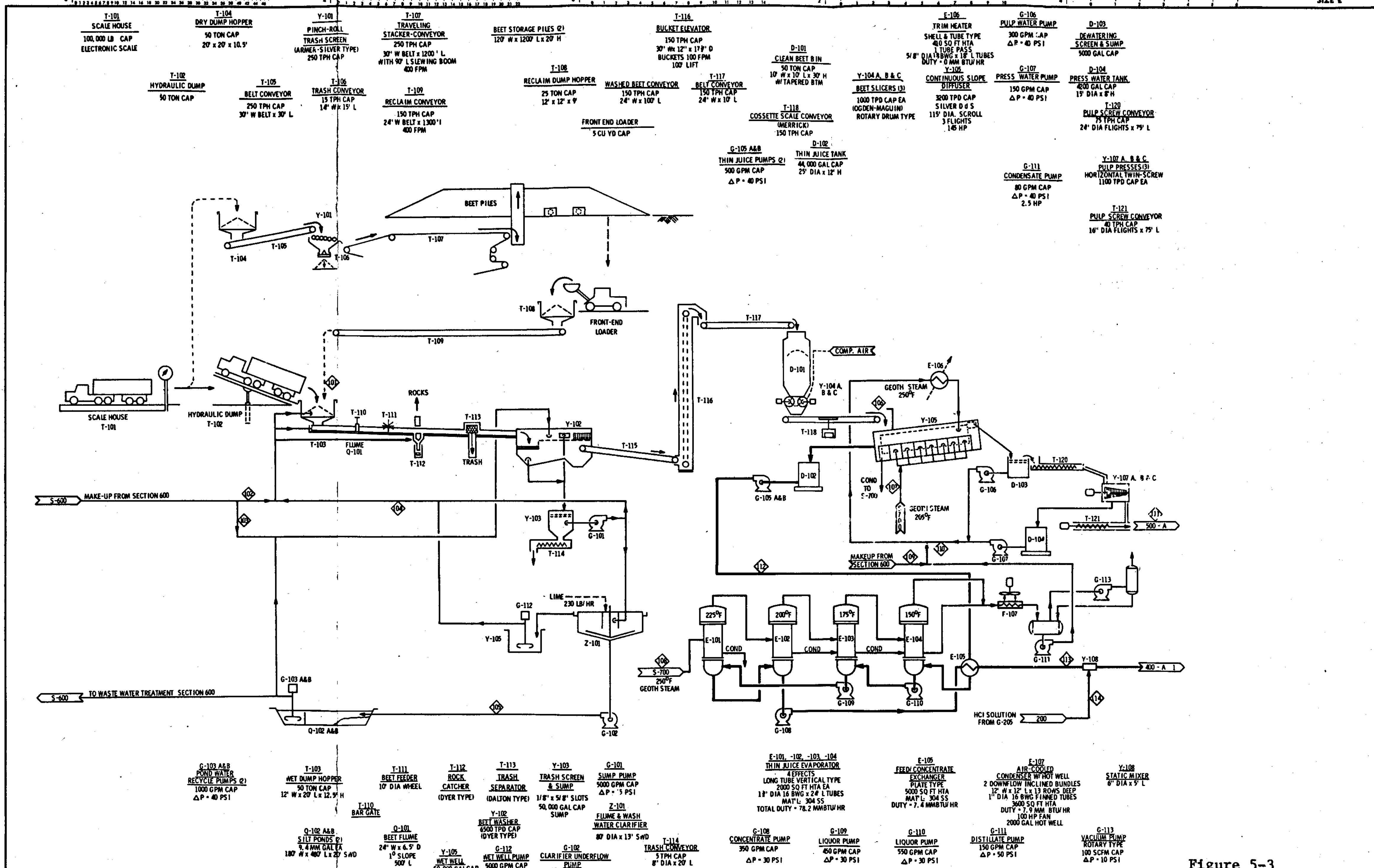
Table 5-2 (continued)

<u>Pulp Dewatering</u>

Raw pulp moisture	93% wt
Screened pulp moisture	85% wt
Pressed pulp moisture	80% wt
Sugar loss in pulp	1.237% wt on pulp
Press water return	80% on raw pulp

<u>Thin Juice Concentration</u>

Sucrose exit concentration	19.1% wt
Number of effects	4
Economy	3.2
Steam requirements	22,350 lb/hr @ 250°F



COMPONENT	(101) BEET FEED		(102) FLUME MAKE-UP LB/HR	(102) % WT	(103) WASH WTR MAKE-UP LB/HR	(103) % WT	(104) FLUME RECYCLE LB/HR	(104) % WT	(105) BLOWDOWN WATER LB/HR	(105) % WT	(106) SLICED BEETS LB/HR	(106) % WT	(107) STEAM TO DIFFUSER LB/HR	(107) % WT
SUGAR BEETS	(219,876)	(93.46)									(219,876)	(100.00)		
WATER	167,392	71.16	73,220	99.97	36,888	99.97	1,759,280	99.77	439,820	97.31	167,612	76.23	15,400	100.00
SUCROSE	35,180	14.95					1,556	0.09	389	0.09	35,070	15.95		
SOLIDS - SOLUBLE	6,310	2.68					1,556	0.09	389	0.09	6,200	2.82		
MARC/INSOLUBLES	10,994	4.67							230	0.05	10,994	5.00		
SILT & TRASH	15,391	6.34					352	0.02	10,994	2.43				
YEAST														
ETHANOL			25	0.03	13	0.03	608	0.03	152	0.03				
CARBON DIOXIDE														
FUSEL OIL														
ALDEHYDE														
NUTRIENTS														
HCl														
TOTAL	235,267	100.0	73,245	100.0	37,201	100.0	1,763,352	100.0	451,974	100.0	219,876	100.0	15,400	100.0

COMPONENT	(108) STEAM TO EVAPORATOR LB/HR	(108) % WT	(109) DIFFUSION WTR. MAKE-UP LB/HR	(109) % WT	(110) PULP WTR RETURN LB/HR	(110) % WT	(111) PRESSED PULP LB/HR	(111) % WT	(112) THIN JUICE FEED LB/HR	(112) % WT	(113) FERMENTER FEED LB/HR	(113) % WT	(114) 5% HCl SOLUTION LB/HR	(114) % WT
SUGAR BEETS														
WATER	22,352	100.00	22,267	99.6	197,959	97.00	50,183	79.997	211,222	84.17	139,696	77.86	456	95
SUCROSE					3,059	1.5	776	1.237	34,294	13.67	34,294	19.11		
SOLIDS - SOLUBLE					3,059	1.5	776	1.237	5,424	2.16	5,424	3.03		
MARC/INSOLUBLES							10,994	17.525						
SILT & TRASH														
YEAST														
ETHANOL			8	0.04	12	TR	2	0.004	12	TR	6	TR		
CARBON DIOXIDE														
FUSEL OIL														
ALDEHYDE														
NUTRIENTS														
HCl													24	5
TOTAL	22,352	100.0	22,275	100.0	204,089	100.0	62,731	100.0	250,952	100.0	179,420	100.0	480	100

Figure 5-3

ISSUED FOR REPORT

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DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
SUGAR BEET PROCESSING

13412 | 100 | 0

5.2.3 Beet Washing

The beets are cleaned to remove rocks, trash and soil prior to slicing. Beets are sluiced into the flume system with a mixture of fresh and recycled flume water. A feeder in the flume regulates the flow of beets into the downstream portion of the flume. A Dyer-type rock catcher removes rocks from the lighter beets using an upward flow of water to lift the beets and allow the rocks to settle downward in the rock chute. A chain conveyor removes the collected rocks. Weeds, leaves, and beet tails are removed in a Dalton-type trash separator. The trash is discharged from a rotating drum onto a belt conveyor for trash disposal. The beets return to the flume and enter the washer which has a dewatering section at the inlet. Fresh water is added as the beets pass onto a belt conveyor. Flume water and wash water pass over a trash screen and into a sump. The water can be recycled directly or discharged to a gravity clarifier for cleanup. Silt settles out in the clarifier and is pumped to one of two silt ponds. The clarifier overflow (about 80 percent) is recycled to the head end of the flume. The silt ponds allow further clarification to occur so additional water can be recycled. Sludge accumulates in the ponds and is dredged at the end of the beet processing season.

5.3.4 Beet Slicing

Washed beets are conveyed to a bucket elevator which lifts them to a horizontal transfer conveyor above the 50-ton capacity clean beet bin. The bin is mounted above three 1,000-ton-per-day capacity rotary slicers. Rotating knife blocks cut the beets into thin slices (cossettes). The knife blocks are changed out about every four hours for sharpening. Compressed air is used to clean the blocks during operation. The cossettes are fed onto a weigh belt conveyor (weightometer) which automatically weighs and totals the daily slice.

5.2.5 Diffusion

Hot water extraction of the juice from the cossettes is carried out in a continuous slope diffuser. The 3,200-ton-per-day capacity Silver D.d.S. diffuser is steam jacketed to maintain the juice and pulp at the desired temperature (160°F average). Cossettes enter the lower end and are conveyed upward by the scrolls. Hot water and pulp return water enter the top end and pass downward countercurrently contacting the cossettes. By diffusion, the juice phase passes from cellular material into the liquid. Exhausted cossettes (pulp) are discharged from the top end of the diffuser and drop onto a dewatering screen. The thin juice is discharged (on level control) from the low end of the diffuser into a tank. The thin juice amounts to about 114 percent based on the weight of the entering cossettes. The sugar content is 13.67 percent and represents a 97.8 percent sugar recovery.

5.2.6 Pulp Dewatering

The raw pulp is screened to remove free water and then conveyed to three horizontal twin-screw presses for dewatering to about 80 percent moisture content. Nearly 32 tons per hour of pressed pulp are generated. This material is conveyed to by-product drying. Screening water and press water are pumped to the diffusion water inlet. Hot process condensate water is also added to the return water stream ahead of a trim heater. Steam heating the diffusion water on occasion helps to control bacterial growth in the diffuser.

5.2.7 Thin Juice Concentration

Multiple-effect evaporation is used to raise the sucrose concentration in the juice to about 19.1 percent for optimum fermentation and alcohol recovery. A four-effect vertical tube evaporator system is operated with backward feed (to the fourth effect). Geothermal steam at 250°F in the first effect vaporizes water which is used as steam to the second, lower temperature effect. Concentrated juice is withdrawn from this effect and is used to preheat the thin juice feed. Vapor from the fourth effect (coldest) is condensed in an air-cooled condenser which also receives condensate from the previous two effects. A vacuum pump is used to maintain subatmospheric pressure. Recovered condensate is routed to the diffuser. The concentrated juice is sent to the fermentation section (400-A). Dilute hydrochloric acid is added in-line to drop the juice pH to 4.5 prior to fermentation.

The beet processing equipment is located in the upper left corner of the plot plan, Figure 5-1.

5.3 POTATO PROCESSING — SECTION 200

Potatoes are processed for five continuous months each year, March through July, following the four months of sugar beet processing. About 360,000 tons of potatoes are received by the plant for cleaning and processing during this period. On-site storage capacity is 36,500 tons. The design mash rate is 2,607 tons of potatoes (clean basis) per day. The daily mash contains 389 tons of starch which is converted to 432 tons of sugar. At the end of the batch fermentation, this sugar is converted to 202 tons per day of ethanol. The beer (containing 11 percent weight ethanol) is distilled to a 88 percent weight overhead product, then dehydrated to virtually a 200 proof ethanol product in a benzene-water-ethanol column.

The whole stillage from the beer still is centrifuged. The cake is dried thermally to 90 percent solids. Approximately 206 tons of this dried animal feed are produced per stream day.

5.3.1 Design Bases

Table 5-3 presents the assumed composition of the potatoes processed in the plant.

Table 5-3

AVERAGE POTATO COMPOSITION (CLEAN)

Water	77.5%
Starch	15.0%
Proteins and fats	2.1%
Fiber	5.4%
	100.0%

All foreign matter (assumed to be 1 percent weight on potatoes) is removed in cleaning and 0.1 percent of the soluble dry matter is assumed to be lost in dewatering.

Potatoes are processed 24 hours per day, seven days per week at a design stream factor of 90.4 percent (2,630 tons per stream day). Table 5-4 summarizes the principal design bases for each process step in Section 200. Figure 5-4 shows the process steps and material flows.

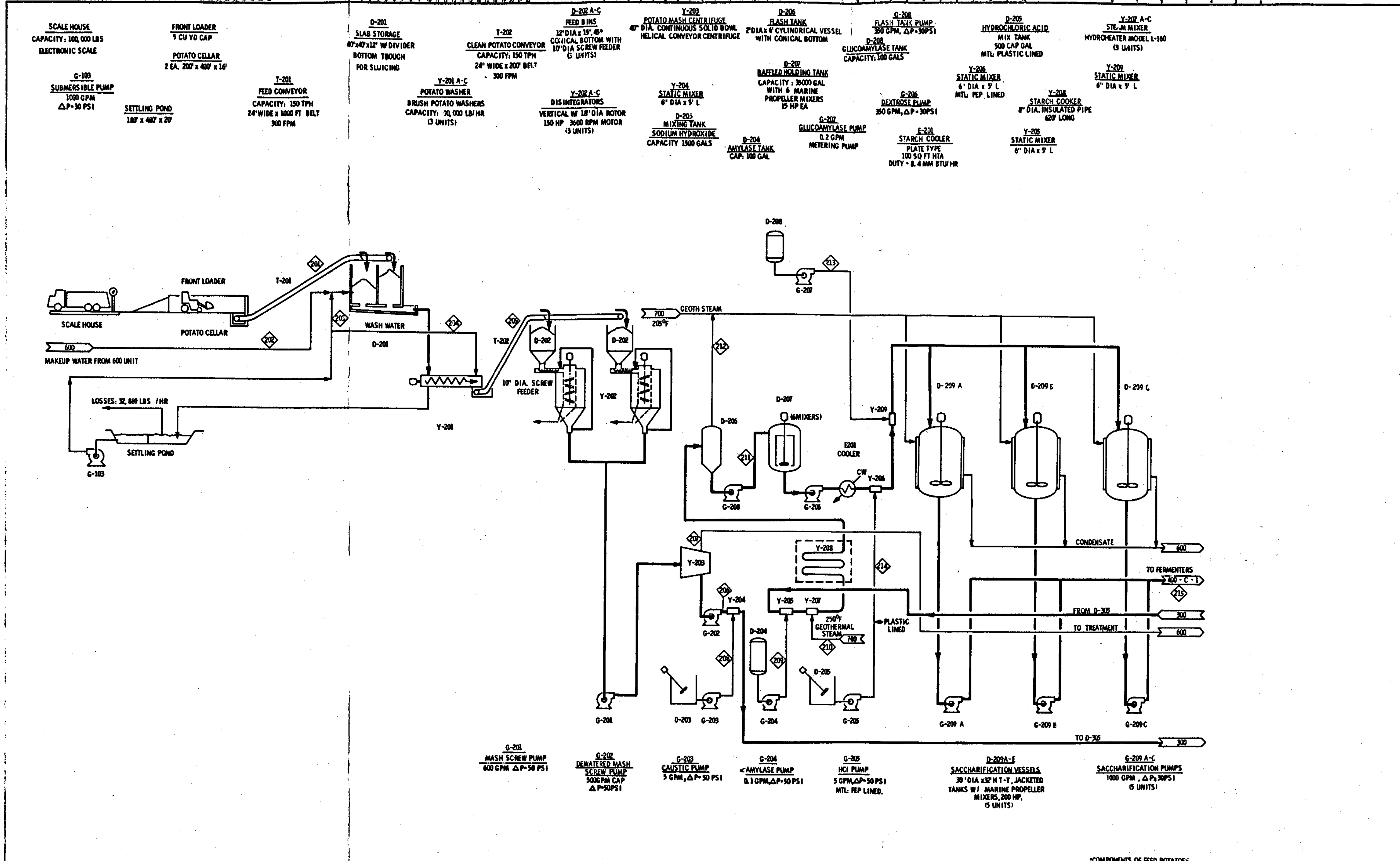
5.3.2 Potato Receiving and Storage

Potatoes are shipped to the ethanol facility by end dump tractor-trailers. The net load averages 20 tons. Trucks are weighed in (gross) and out (tare) to record the as-received tonnages. At the scale, trucks are diverted to the dump station where potatoes are dumped into the potato cellar which provides storage space for 14 days' potato requirement (36,500 tons). Potatoes are reclaimed by front-end loaders working at the toe of a pile. The loaders transfer the potatoes to the reclaim belt conveyor which discharges into the slab storage area which provides potato storage for eight hours of plant operation.

Table 5-4

PRINCIPAL DESIGN BASES — POTATO PROCESSING

Potato Receiving and Storage	
Receiving periods	daylight hours, 7 days per week
Carrier	20-ton net tractor-trailers (end dump)
Loads per day	142 (10% to storage)
Direct process	2607 tpd (clean)
Potato Washing	
Flume water	1920 gal/ton of potatoes flumed (design)
Wash water	100 gal/ton of potatoes (design)
Direct recycle	98 percent (design)
Lost to sludge	2 percent
Potato Mashing	
Number of disintegrators	3
Mashing rate	870 tpd per machine
Mash Dewatering	
Raw mash moisture	78% wt
Dewatered mash moisture	69% wt
Concentrate moisture	98% wt
Starch Liquefaction	
Crude starch slurry	32% wt dry solids (DS)
pH	6.5
Cooking steam temperature	250°F
Enzyme dosage	0.1% wt on DS
Cooking time and temperature	5 minutes at 221°F
Hold time and temperature	90 minutes at 203°F
Dextrose equivalent	10 - 14
Saccharification	
Enzyme dosage	0.15 gal/1000 lb DS
Holding time	40 hours
Temperature	140°F
pH	4.5
Starch conversion	95+%



*COMPONENTS OF FEED POTATOES

COMPONENTS	201 POTATO FEED LB/HR	%WT	202 FLUME WATER MAKE-UP LB/HR	%WT	203 FLUME WATER RECYCLE LB/HR	%WT	204 WASH WATER LB/HR	%WT	205 CLEAN POTATOES LB/HR	%WT	206 DEWATERED POTATO MASH LB/HR	%WT	207 CENTRATE LB/HR	%WT
POTATO	217,270	100.0							217,270	99.1				
WATER	168,384*		20,032	100	1,703,397	100.0	112,455	100.0	1,874	0.9	99,572	67.8	70,686	97.7
STARCH	32,590*										32,427	22.1	163	0.3
FIBERS	11,733*										11,674	7.9	59	0.1
PROTEINS & FAT	4,563*										3,194	2.2	1,369	1.9
GLUCOSE														
YEAST														
ETHANOL														
HCl														
NaOH														
CO_2														
α-AMYLASE														
GLUCOAMYLASE														
SOLUBLE SOLIDS														
TOTAL	217,270	100.0	20,032	100	1,703,397	100.0	112,455	100.0	219,144	100.0	146,867	100.0	72,277	100.0

COMPONENTS	208 2% NaOH SOLUTION LB/HR	%WT	209 α-AMYLASE LB/HR	%WT	210 COOKING STEAM LB/HR	%WT	211 COOKED POTATO MASH LB/HR	%WT	212 FLASHED STEAM LB/HR	%WT	213 GLUCOAMYLASE LB/HR	%WT	214 5% HCl SOLUTION LB/HR	%WT	215 FERMENTER FEED LB/HR	%WT
POTATO																
WATER	1470	98.0			18,326	100.0	119,179	71.6	189	100.0			513	95.0	116,089	69.4
STARCH							32,427	19.5								7.0
FIBERS							11,674	7.0							11,674	1.9
PROTEINS & FAT							3,194	1.9							3,194	21.6
GLUCOSE															36,030	
YEAST																
ETHANOL																
HCl													27	5.0		
NaOH	30	2.0														
CO_2																
α-AMYLASE			49	100.0												
GLUCOAMYLASE											73	100.0				
SOLUBLE SOLIDS							79	0.05							179	0.1
TOTAL	1500	100.0	49	100.0	18,326	100.0	166,553	100.0	189	100	73	100	540	100.0	167,166	100.0

Figure 5-4

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SCALE NONE

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
POTATO PROCESSING

JOB No. 13412 | DRAWING No. 200 | REV. 0

5.3.3 Potato Washing

The potatoes are conveyed via a flume to one of three potato washers. Flume water is recycled. Wash water is supplied to each washer at 75 gallons per minute. The wash water flow from the washer goes to a two-compartment silt settling pond. Suspended solids settle out in the first compartment and clarified water flows into the second compartment from which it is recycled as flume water makeup. Two silt ponds are provided. Sludge accumulates in the settling ponds and is dredged at the end of the potato processing season.

5.3.4 Potato Mashing and Dewatering

Washed potatoes are conveyed to one of three feed bins and then to three disintegrators where the potatoes are crushed, and residual foreign matter (tramp iron, etc.) is separated from the mash and discharged to waste. The mash flows from the disintegrators to screens where coarse potato pieces are removed and recycled to the disintegrators. The screened mash flows to a centrifuge where its moisture content is reduced to approximately 68 percent. The centrate containing 0.3 percent starch, is discharged to the wastewater treatment facility (Section 600).

5.3.5 Starch Liquefaction

A two percent solution of sodium hydroxide is added in-line to raise the pH of the dewatered mash from 5.6 to 6.5. An agitated vessel in Section 300 is used to provide a short holdup. Alpha amylase is next added to the mash to break down the starch bonds and about 18,330 pounds per hour of 250°F geothermal steam are injected into three parallel steam mixers to raise the temperature of the mash to 221°F for gelatinization and cooking of the starch. The starch is cooked for five minutes in a tubular cooker at 221°F and is then flash cooled to 203°F. The cooked mash next enters a six-stage baffled hold tank which provides 90 minutes detention time. Agitators are provided for adequate mixing of the hold tank contents to prevent settling of suspended matter. The hold tank effluent is cooled to 140°F and treated with a five percent hydrochloric acid solution to lower the pH from 6.5 to 4.5.

5.3.6 Saccharification

Glucoamylase is added to the liquified starch to break down the starch dextrins to produce a high yield of fermentable glucose. This takes place in five 170,000-gallon saccharification vessels, each with 40 hours retention time. A steam jacket around each saccharification vessel maintains the contents at 140°F. Each vessel is also equipped with an agitator to ensure adequate mixing of the reactants.

5.4 WHEAT PROCESSING — SECTION 300

Soft white winter wheat is processed in the alcohol facility three months per year, normally in August, September, and October. Wheat is purchased on the open market and delivered by truck to the plant during the processing period. The wheat is cleaned and ground whole. The whole ground wheat is processed much like potatoes to liberate the starch molecules and convert the starch to glucose prior to fermentation. About 371 tons per day of starch and 20 tons of sugars are converted to 433 tons of glucose which, in turn, are fermented to yield 203 tons of ethanol. About 227 tons per day of by-product solids are recovered from the fermenter mash solids.

5.4.1 Design Basis

Table 5-5 presents the assumed composition of the winter wheat processed in the plant. As delivered, wheat is assumed to contain up to 20 percent (on a clean wheat basis) inert foreign matter, including rocks, sand and field dust. Dry cleaning removes this foreign matter.

Wheat is processed 24 hours per day, seven days per week at a design stream factor of 90.4 percent. Table 5-6 indicates the principal design basis for each process step. Figure 5-5 is a process flow diagram of wheat processing Section 300.

Table 5-5

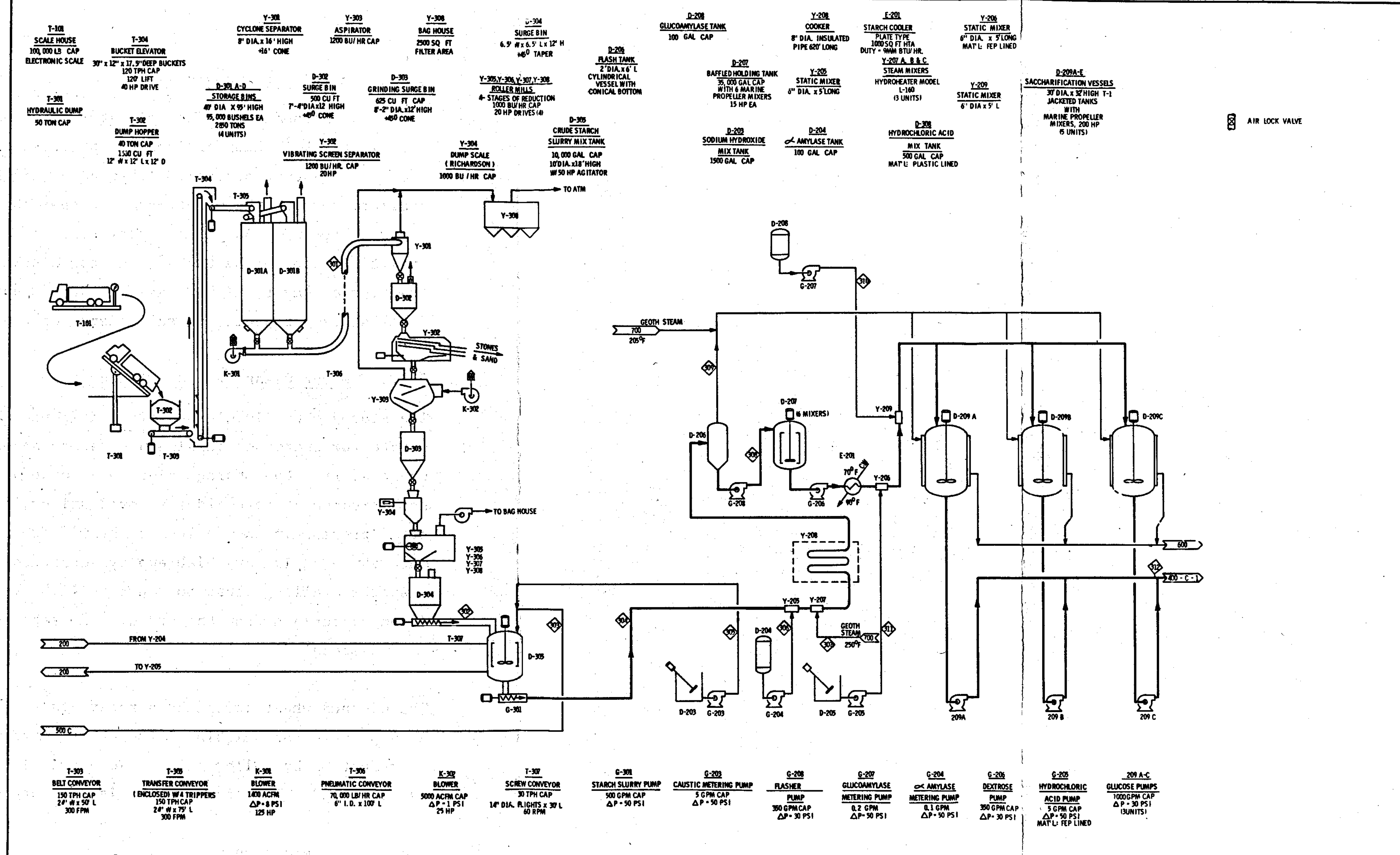
AVERAGE WHEAT COMPOSITION — CLEAN BASIS

Component	% Weight
Moisture	8.95
Starch	57.87
Sugars	3.15
Protein & Fat	11.57
Fibers	9.00
Soluble Solids	9.46
Total	100.00

Table 5-6

PRINCIPAL DESIGN BASES — WHEAT PROCESSING

Receiving & Storage	
Receiving periods	daylight hours, 7 days per week
Carrier	18-ton net tractor-trailers (end dump)
Loads per day	43
Storage capacity	360,000 bushels (14 days)
Reclaim rate	1070 bushels per hour (dirty)
Cleaning & Grinding	
Type of cleaning	screening and gravity separation
Grinding capacity	1000 bushels per hour
Stage of milling	4 (roller mills)
Size reduction	-20 mesh (99 percent)
Starch Liquefaction	
Crude starch slurry	30% wt dry solids (DS)
pH	6.5
Cooking steam temperature	250°F
Enzyme dosage	0.1% wt on DS
Cooking time & temperature	5 minutes at 221°F
Holding time & temperature	90 minutes at 203°F
Dextrose equivalent	10 - 14
Saccharification	
Enzyme dosage	0.15 gal/1000 lb DS
Holding time	40 hours
Temperature	140°F
pH	4.5
Starch conversion	95+%



NOTE: (1) FOREIGN MATTER = SAND, DIRT, STONES, STICKS

	301 FIELD RUN WHEAT		302 CLEAN GROUND WHEAT		303 SLURRY WATER MAKE UP		304 CRUDE STARCH SLURRY		305 2% NaOH		306 ∝-AMYLASE		307 COOKING STEAM		308 COOKED WHEAT MASH		309 FLASHED STEAM		310 GLUCOAMYLASE		311 5% HCl SOLUTION		312 FERMENTER FEED	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WHEAT	(53,487)	(80.0)	53,487	100.0																				
WATER	4,785	7.16	4,785	8.95	108,853	99.96	115,108	70.24	1470	98.0			11,072	100.0	123,526	71.67	2,654	99.93			513	95.0	120,599	69.73
STARCH	30,949	46.30	30,949	57.87			30,949	18.88							30,949	17.96								9
FIBERS	4,815	7.20	4,815	9.00			4,815	2.94							4,815	2.79							4,815	2.78
PROTEINS & FATS	6,190	9.26	6,190	11.57			6,190	3.77							6,190	3.59							6,190	3.58
SUGAR	1,687	2.52	1,687	3.15			1,687	1.03							1,687	0.98							36,074	20.86
ETHANOL					42	0.04	42	0.03							40	0.02	2	0.07					40	0.02
HCl																					27	5.0		
NaOH									30	2.0														
∝-AMYLASE											49	100.0												
GLUCOAMYLASE																			70	100.0				
FOREIGN MATTER	13,372 (1)	20.0																						
SOLUBLE SOLIDS	5,061	756	5,061	9.46			5,091	3.11							5,140	2.99							5,237	3.03
TOTAL	66,859	100.0	53,487	100.00	108,895	100.00	163,882	100.00	1500	100.00	49	100.0	11,072	100.0	172,347	100.00	2,656	100.00	70	100.0	540	100.0	172,955	100.00

Figure 5-5

0	1-20-80	ISSUED FOR REPORT	WM
NO.	DATE	REVISIONS	BY

SCALE NONE — DESIGNED RIASAN MASON — DRAWN W. MASON

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
WHEAT PROCESSING

JOB No. 13412 — DRAWING No. 300 — REV. 0

34x44 "E" SIZE

5.4.2 Receiving and Storage

Wheat is shipped from local elevators to the ethanol facility by end dump trailer trucks. Upon arrival at the gate, the trucks are weighed and proceed to a dump station. A hydraulic truck lift elevates the truck and trailer, dumping the wheat into a hopper that is equipped with dust control hooding. An under-hopper belt conveyor transfers the wheat to a bucket elevator. The bucket elevator discharges wheat onto an elevated transfer conveyor which feeds four 90,000-bushel capacity storage bins. Total storage capacity is sufficient for two weeks operation.

5.4.3 Wheat Cleaning and Grinding

The stored wheat is cleaned dry and ground whole to prepare it as a substrate for starch conversion and fermentation. The wheat is pneumatically conveyed from the storage bins to a surge bin ahead of the scalper. The shaker-screen type scalper removed sticks, stones, stalks and similar offal present in the uncleaned wheat. The screened wheat then passes through an aspirator which employs currents of air directed through the dispersed falling wheat to separate light (dust, fibers, chaff) and heavy (sand) materials from the grain. The separated debris is collected for land disposal.

The cleaned wheat is fed by a rotary valve into a surge bin and then into a dump scale for weighing. The wheat is ground to -20 mesh in four stages of reduction by roller mills. No physical separation of kernel components is attempted. The ground wheat is discharged to a surge bin.

5.4.4 Liquefaction

A rotary valve feeds the crude wheat flour into a 10,000-gallon mixing tank. Warm condensate is added to make up a slurry containing 30 percent dry solids. Two percent sodium hydroxide is added to the mixed tank contents to adjust the slurry pH to 6.5. Alpha amylase is added to the crude starch slurry in-line as the slurry is pumped to three parallel steam injectors (hydroheaters). About 11,070 pounds per hour of 250°F geothermal steam is injected to raise the slurry temperature to 221°F for gelatinization and cooking of the starch. The starch slurry is cooked for five minutes in a tubular coil and then flash-cooled to 203°F. The flash-cooled slurry enters a six-stage baffled hold tank which provides ninety minutes retention time. An agitator is provided in each baffled section to prevent settling of the suspended matter. The hold tank effluent is cooled in a plate-type exchanger to 140°F and five percent hydrochloric acid is added in-line to reduce the cooled slurry pH to 4.5. The liquefaction equipment is the same as that used for potato processing.

5.4.5 Saccharification

Glucoamylase is added to the liquefied starch slurry to break down starch dextrins to fermentable glucose. This conversion takes place in five 170,000 gallon vessels providing about 40 hours total retention time. Each vessel has a steam jacket to maintain the contents at 140°F. Each vessel is also equipped with an agitator to mix the contents during the hold period.

The saccharification equipment is the same as that used for potato processing. The glucose content of the saccharified slurry is about 20.8 percent.

5.5 FERMENTATION AND ALCOHOL RECOVERY — SECTION 400

The fermentation and alcohol recovery equipment is designed to process the sugar solution from any of the three feedstock processing sections. Fermentation is a batch process. Alcohol recovery is continuous process. The material and energy balances for the three feedstocks are all slightly different and hence three versions are presented.

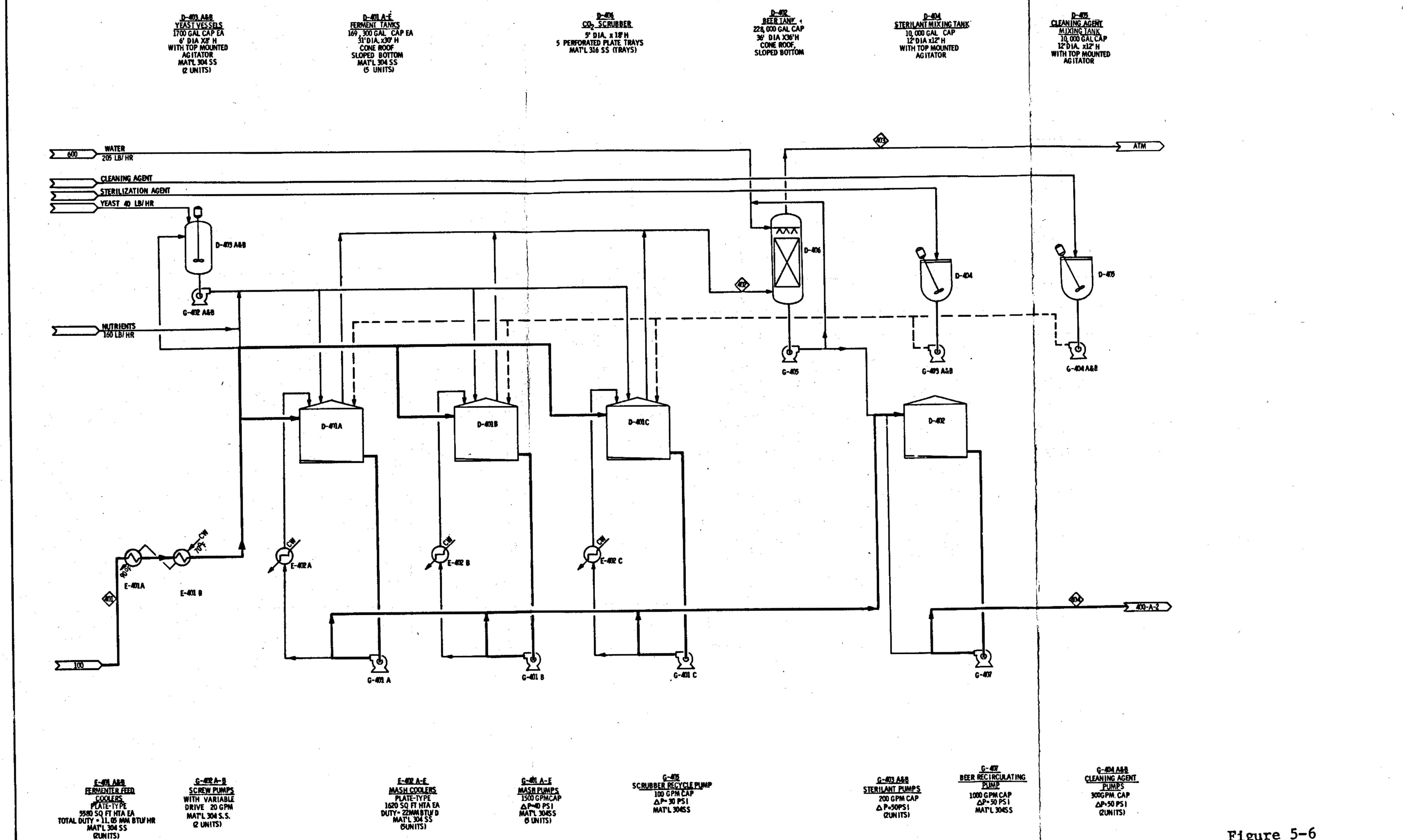
5.5.1 Fermentation

Figures 5-6, 5-7, and 5-8 show the material balances for fermentation of sugar solutions from beet processing, potato processing, and wheat processing, respectively. The sugar solution is cooled to 80°F prior to fermentation. Fermentation of the solution is carried out batch-wise in ten 170,000-gallon fermenters to yield a net of about 2,560 gallons per hour of ethanol. Table 5-7 summarizes the fermentation design parameters. The total cycle time per fermenter is 60 hours and eight batches are always in some stage of fermentation at any one time. One fermenter is being filled and one is being emptied and cleaned at any one time.

At the start of a cycle, sugar solution, yeast and nutrients are pumped into the fermentation tank. As the fermentation proceeds, heat released by the reaction increases the mash temperature. Carbon dioxide formed in the reaction also is released into the vapor space of the fermenter.

The mash is circulated through plate-type exchangers when the bulk temperature reaches about 90°F. Cooling water at 70°F removes the bulk of the heat of reaction and limits the mash temperature rise. Cooling is required only part of the fermentation time so one exchanger can be used to serve two fermenters. The mash can be circulated for mixing purposes alone by bypassing the exchanger. Evolved vapors, mainly CO_2, are water scrubbed in a 5-foot diameter, 5-tray column to recover ethanol. Blowdown from the scrubber is pumped to the beer well. Scrubber off-gas is vented to the atmosphere.

At the end of the 48-hour fermentation period, the fermented mash, containing about 10 percent ethanol, is pumped to the beer well. The empty fermenter is chemically cleaned by internal spraying machines, sterilized with an iodine solution, and rinsed with sterile water. The spent solutions are routed to wastewater treatment, and this tank is again ready for service.



STREAM	401 FERMENTER FEED		402 FERMENTER GAS		403 SCRUBBER OFF-GAS		404 BEER STILL FEED	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	139,696	77.86	335	1.91	205	1.18	139,187	85.25
SOLIDS - SOLUBLE	5,424	3.03					5,448	3.34
YEAST, PROTEIN & FIBER							859	0.53
ETHANOL			102	0.58	64	0.37	16,900	10.35
CARBON DIOXIDE	6	tr	17,111	97.31	17,110	98.25	107	0.06
FUSEL OIL			0.2	tr	tr		321	0.20
ALDEHYDE			35	0.20	34	0.20	447	0.27
SUCROSE	34,294	19.11						
TOTAL	179,420	100.00	17,583.2	100.00	17,413	100.00	163,269	100.00

Figure 5-6

0 1/24/80 ISSUED FOR REPORT W.M.

SCALE NONE DESIGNED RIASAN/W.M. DRAWN W. MASON

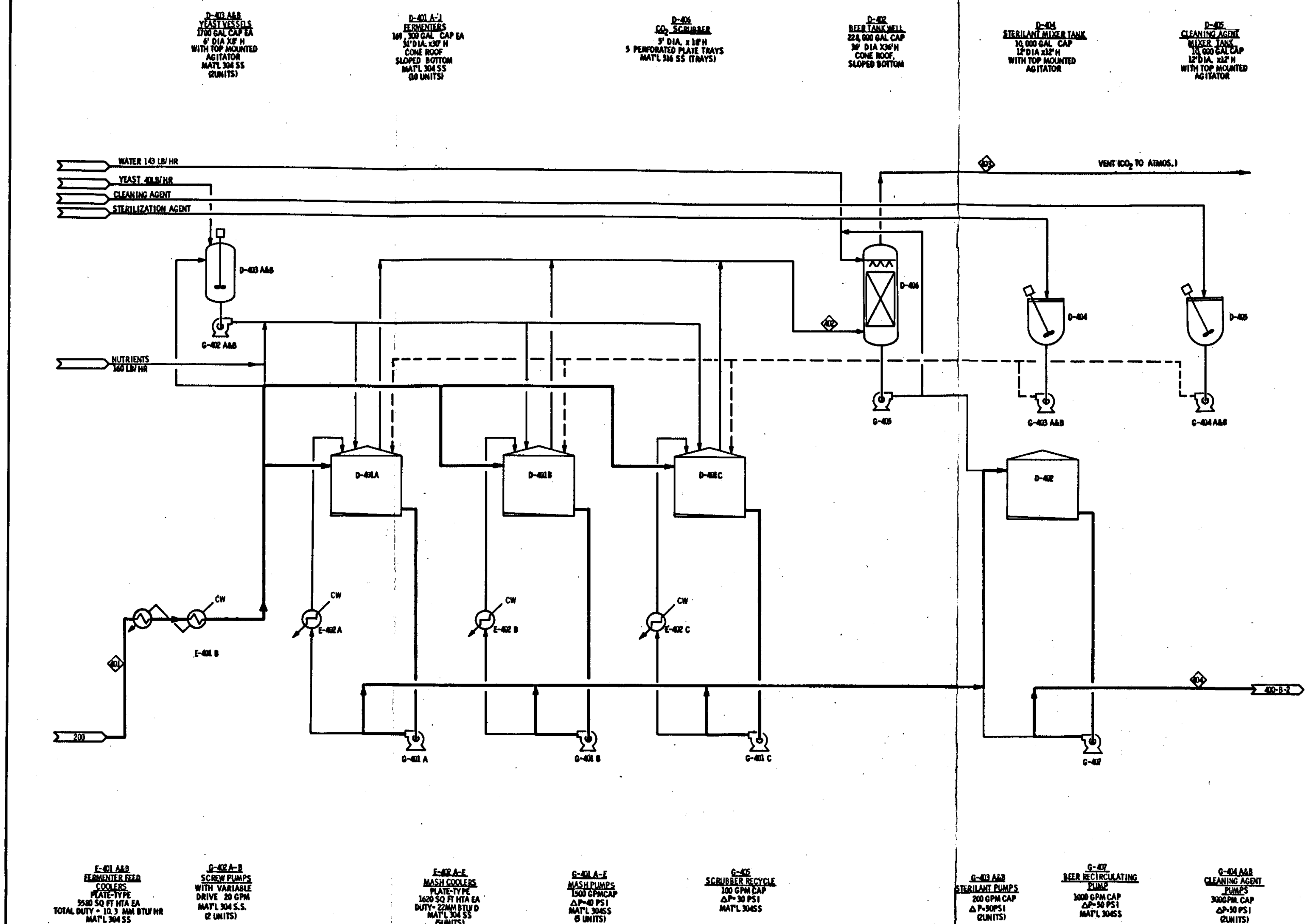
BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
SUGAR BEET FERMENTATION

JOB No.	DRAWING No.	REV.
13412	400-A-1	0

34x44 "E" SIZE



STREAM	401 FERMENTER FEED		402 FERMENTER GAS		403 SCRUBBER OFF-GAS		404 BEER STILL FEED	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	116,089	69.4	336	1.9	143	0.8	116,475	77.7
SOLIDS - SOLUBLE	179	0.1					179	0.1
YEAST/PROTEIN&FIBER	14,868	8.9					15,563	10.4
ETHANOL			96	0.5	49	0.3	16,874	11.2
CARBON DIOXIDE	tr	tr	17,150	97.4	17,149	98.7	115	0.1
FUSEL OIL							321	0.2
ALDEHYDE			33	0.2	32	0.2	449	0.3
GLUCOSE	36,030	21.6						
TOTAL	167,166	100.0	17,615	100.0	17,373	100.0	149,976	100.0

Figure 5-7

0	1-24-80	ISSUED FOR REPORT						
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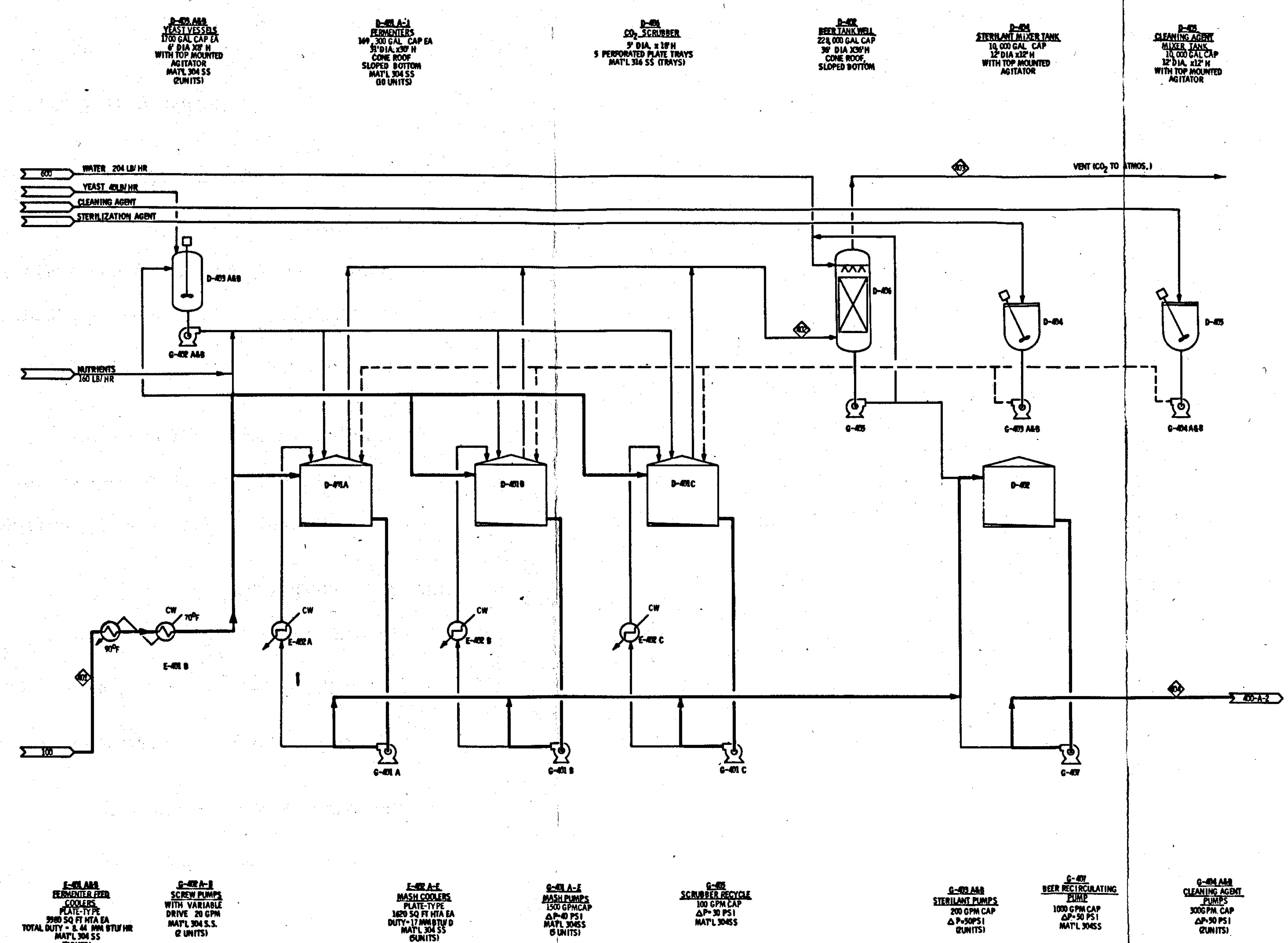
SCALE NONE — RIASAN/W.M. — W. MASON

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
POTATO FERMENTATION

JOB No.	DRAWING No.	REV.
13412	400-B-1	0



STREAM	401 FERMENTER FEED		402 FERMENTER GAS		403 SCRUBBER OFF-GAS		404 BEER STILL FEED	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	120,599	69.73	334	1.89	204	1.37	120,985	77.64
SOLIDS - SOLUBLE	5,237	3.03					5,237	3.36
YEAST,PROTEIN&FIBER	11,005	6.36					11,861	7.61
ETHANOL	40	0.02	117	0.66	70	0.40	16,911	10.85
CARBON DIOXIDE			17,208	97.20	17,207	98.20	82	0.05
FUSEL OIL			2.4	0.01	tr	tr	321	0.21
ALDEHYDE			41	0.24	40	0.23	441	0.28
GLUCOSE	36,074	20.86						
TOTAL	172,955	100.00	17,702.4	100.00	17,521	100.00	155,838	100.00

Figure 5-8

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SCALE NONE — RIASAN/W.M. — W. MASON

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FLOW DIAGRAM
20 MM GAL /YR NOMINAL ETHANOL FACILITY
WHEAT FERMENTATION

JOB No. 13412 — DRAWING No. 400-C-1 — REV. 0

Table 5-7

PRINCIPAL DESIGN BASES — FERMENTATION

Chemical Reactions & Conversions (Basis: 100 lbs glucose)

HYDROLYSIS:

Sucrose to glucose (100% conversion)

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2C_6H_{12}O_6$$

(95 lbs) (5 lbs) (100 lbs)

Starch to glucose (100% conversion)

$$(C_6H_{10}O_5)_n + nH_2O \longrightarrow nC_6H_{12}O_6$$

(90 lbs) (10 lbs) (100 lbs)

GLUCOSE CONVERSION:

To ethanol (91.818% conversion)

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2C_2H_5OH + 2CO_2$$

(91.818 lbs) (46.97 lbs) (44.848 lbs)

To yeast (3.636% conversion)

$$C_6H_{12}O_6 \xrightarrow{\text{innoculum}} \text{yeast} + 1.452\ CO_2 + 1.452\ H_2O$$

(3.636 lbs) (1.818 lbs) (1.290 lbs) (0.528 lb)

To other by-products (4.545% conversion)

$$2\tfrac{1}{2}C_6H_{12}O_6 \longrightarrow 3CH_3CHO + CH_3(CH_2)_3CH_2OH + 4CO_2 + 3H_2O$$

(4.545 lbs) (1.333 lbs) (0.89 lb) (1.777 lbs) (0.545 lb)

Table 5-7 (Continued)

Fermentation Conditions	
Feed sugar concentration	19 - 21 percent
Fermentation time	48 hours (batch)
Fermentation temperature	80 to 90°F
Fermentation pH	4.5
Heat of reaction	420 Btu/lb ethanol
Yeast makeup requirements	0.2385 lb/100 lbs ethanol
Nutrient requirements	0.954 lb/100 lbs ethanol
Number of fermenters	10
Fermenter fill time	6 hours
Fermenter empty & clean time	6 hours
Total cycle time	60 hours/fermenter
Maximum/design capacity	120 percent of design
Surge Capacity	
Fermenter product	8 hours
Off-gas Scrubbing	
Vapor superficial velocity	3 feet per second
L/G ratio	20 gals/1000 ACFM
Pressure drop	3-in WG
Gas inlet temperature	85°F average
Gas exit temperature	70°F average

The fermented mash (beer) charged to the beer well contains water, yeast and other insolubles, dissolved solids (organic and inorganic), fusel oil, and aldehydes in addition to the ethanol. The 228,000-gallon tank provides eight hours of surge capacity and the tank contents are circulated continuously to provide a uniform feed to the distillation section.

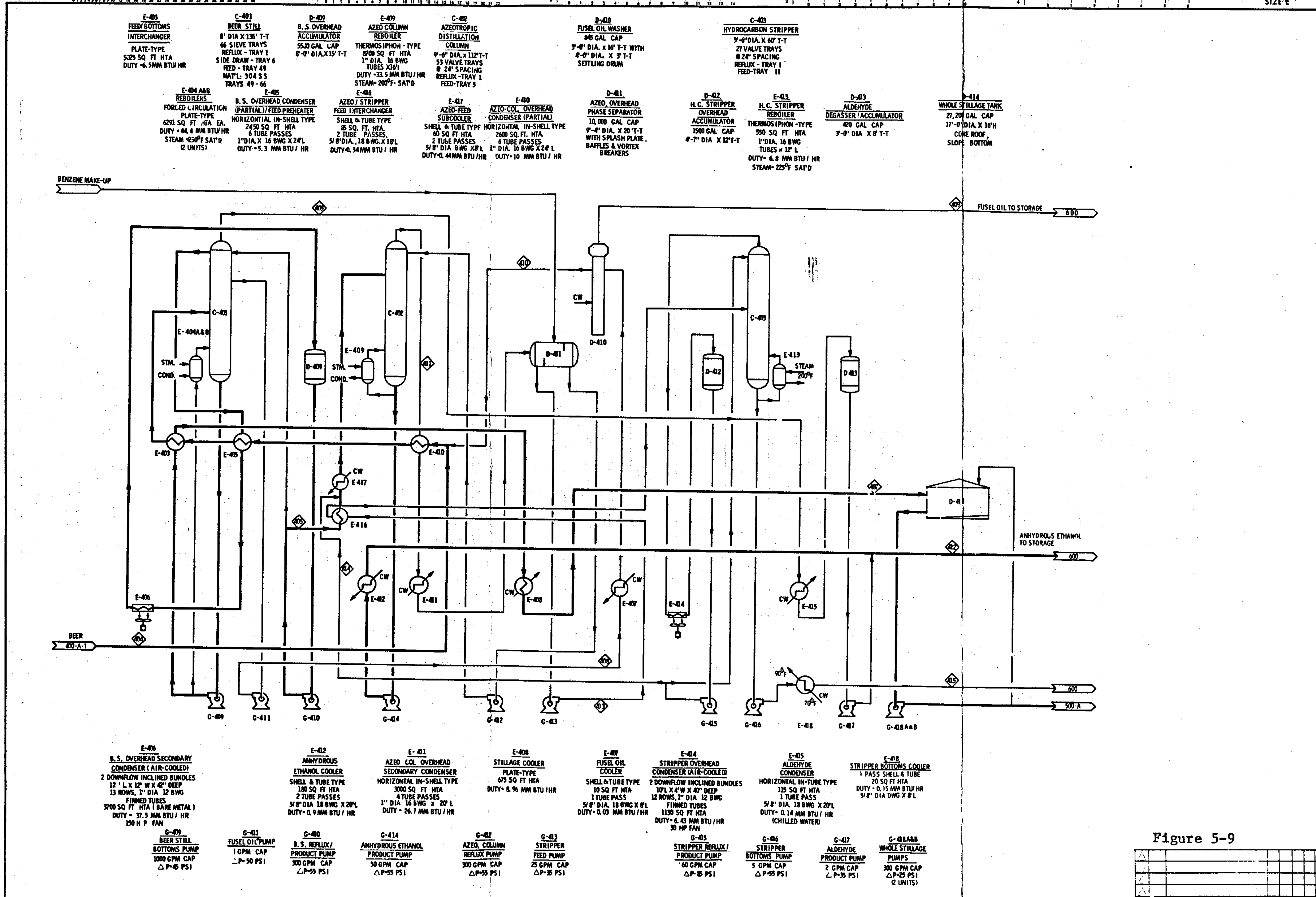
5.5.2 Alcohol Recovery

The alcohol recovery scheme is presented in Figures 5-9, 5-10, and 5-11. Distillation of the fermenter product is carried out in the same manner with the same equipment for all three feedstock cases. Table 5-8 lists the design bases for the three distillation columns.

Fermented beer from the beer well is preheated by exchange with the condensing vapors of the azeotropic column overhead and the beer still overhead streams, and also with the beer still bottoms. There is sufficient heat recovered to provide a bubble-point condition feed to the beer still.

The beer still is a 8-foot ID by 136-foot high column containing 66 sieve trays. It is operated at a pressure of 25 psia at the bottom of the column which corresponds to about the maximum temperature that can be achieved using the available 250^{o}F geothermal steam as the heating medium.

Geothermal steam to two forced-circulation plate-type reboilers provides the 44 million Btu per hour heat input required. Fusel oil concentrates in the upper part of the column and is removed as a side-draw, cooled, and water washed in a separate fusel oil washer. The alcohol and water phase recovered from the fusel oil is returned to the beer still feed. Washed fusel oil is pumped to storage. Aldehydes produced by side reactions in the fermentation are removed as an overhead stream and condensed. The aldehydes are reblended with the ethanol product. An 88 percent ethanol/ 12 percent water mixture is taken from tray 1 and condensed. Reflux is



COMPONENTS	404 BEER STILL FEED LB/HR	%WT	405 ALDEHYDE LB/HR	%WT	406 AZEOTROPIC COL. FEED LB/HR	%WT	407 WHOLE STILLAGE LB/HR	%WT	408 FUSEL OIL LB/HR	%WT	409 FUSEL OIL (WASHED) LB/HR	%WT
WATER	139,187	85.25			2,284	11.93	136,933	95.57	15	4.12	tr	
SOLIDS-SOLUBLE	5,448	3.34					5,448	3.80				
YEAST,PROTEIN&FIBER	859	0.53					859	0.60				
ETHANOL	16,900	10.35			16,860	88.07	40	0.03	28	7.69	tr	
CARBON DIOXIDE	107	0.06	107	19.3								
FUSEL OIL	321	0.20							321	88.19	321	100.00
ALDEHYDE	447	0.27	447	80.7								
BENZENE												
TOTAL	163,269	100.00	554	100.00	19,144	100.00	143,280	100.00	364	100.00	321	100.00

COMPONENTS	410 FUSEL OIL WASH WATER LB/HR	%WT	411 AZEOTROPIC COL. OVHD LB/HR	%WT	412 ANHYDROUS ETHANOL LB/HR	%WT	413 STRIPPER FEED LB/HR	%WT	414 STRIPPER OVHD LB/HR	%WT	415 STRIPPER BTMS LB/HR	%WT
WATER	45	61.6	3,643	2.82	tr		2,390	27.26	106	1.64	2,284	99.7
SOLIDS-SOLUBLE												
YEAST,PROTEIN&FIBER												
ETHANOL	28	38.4	29,459	22.80	16,853	100	5,672	64.70	5,665	87.48	7	0.3
CARBON DIOXIDE												
FUSEL OIL	tr	tr										
ALDEHYDE												
BENZENE			96,104	74.38	tr		705	8.04	705	10.88	tr	tr
TOTAL	73	100.0	129,206	100.00	16,853	100	8,767	100.00	6,476	100.00	2,291	100.00

Figure 5-9

NO.	DATE	REVISIONS	BY	CHKD
0	1-30-80	ISSUED FOR REPORT	WM	HWL

SCALE NONE   DESIGNED RIASAN   DRAWN W. MASON

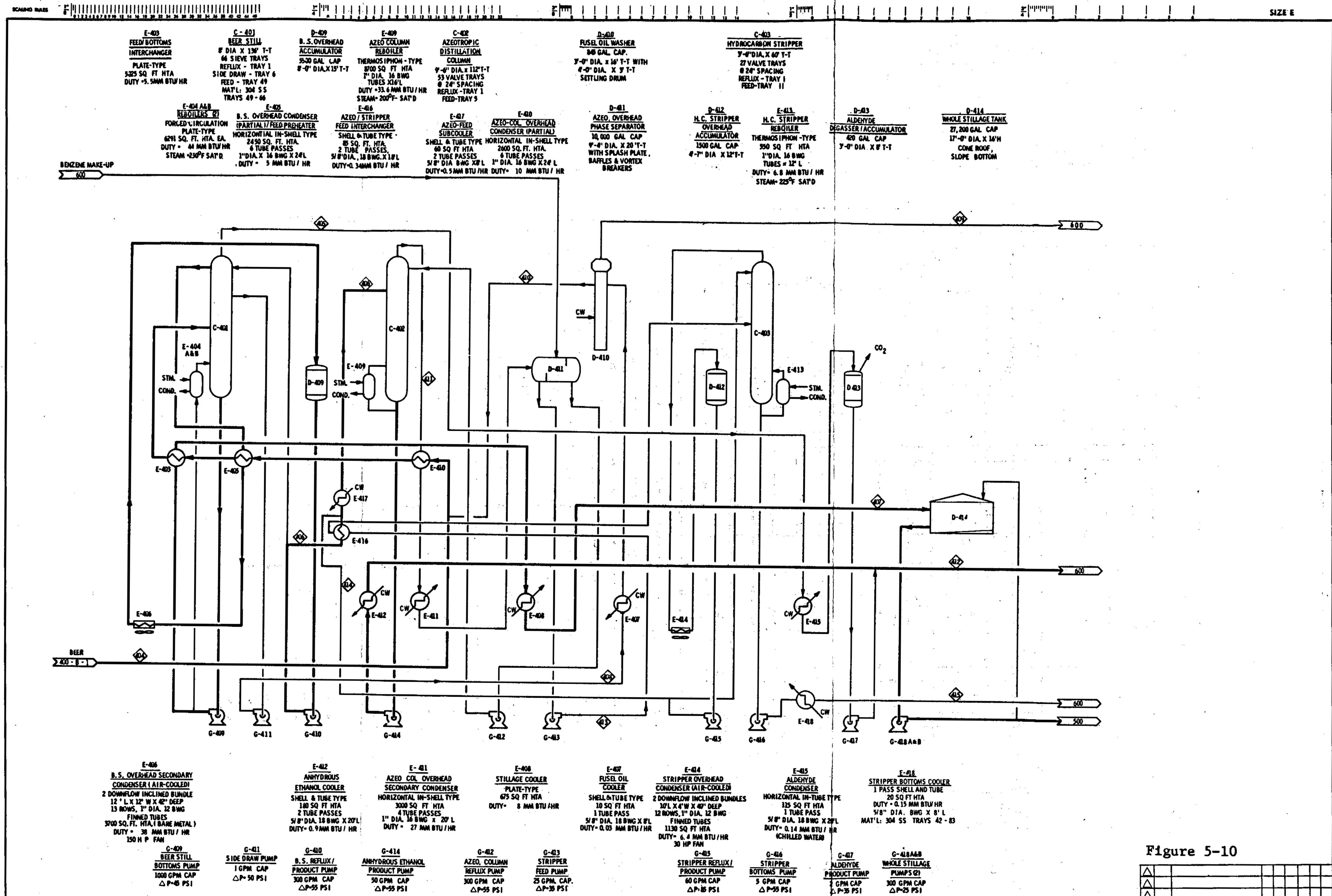
BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
SUGAR BEET ALCOHOL RECOVERY

JOB No.	DRAWING No.	REV.
13412	400-A-2	0

34 x 44 "E" SIZE



COMPONENTS	404 BEER STILL FEED LB/HR	%WT	405 ALDEHYDE LB/HR	%WT	406 AZEOTROPIC COL. FEED LB/HR	%WT	407 WHOLE STILLAGE LB/HR	%WT	408 FUSEL OIL LB/HR	%WT	409 FUSEL OIL (WASHED) LB/HR	%WT	410 FUSEL OIL WASH WATER LB/HR	%WT	411 AZEOTROPIC COL. OVHD LB/HR	%WT	412 ANHYDROUS ETHANOL LB/HR	%WT	413 STRIPPER FEED LB/HR	%WT	414 STRIPPER OVHD LB/HR	%WT	415 STRIPPER BTMS LB/HR	%WT
WATER	116,475	77.66	tr	tr	2,294	11.99	114,211	87.86	15	4.12	tr	tr	45	61.64	3,690	2.85			2,442	27.67	148	2.27	2,294	99.70
SOLIDS-SOLUBLE	179	0.12					179	1377 PPM																
YEAST,PROTEIN&FIBER	15,563	10.38					15,563	11.97																
ETHANOL	16,874	11.25	tr	tr	16,840	88.01	34	262 PPM	28	7.69	tr	tr	28	38.36	29,483	22.80	16,840	100.00	5,679	64.36	5,672	86.95	7	0.30
CARBON DIOXIDE	115	0.08	115	20.39																				
FUSEL OIL	321	0.21							321	88.19	321	100.00												
ALDEHYDE	449	0.30	449	79.61																				
BENZENE															96,166	74.35	tr	tr	703	7.97	703	10.78		
TOTAL	149,976	100.00	564	100.00	19,134	100.00	129,987	100.00	364	100.00	321	100.00	73	100.00	129,339	100.00	16,840	100.00	8,824	100.00	6,523	100.00	2,301	100.00

Figure 5-10

0	1-24-80	ISSUED FOR REPORT	WM					
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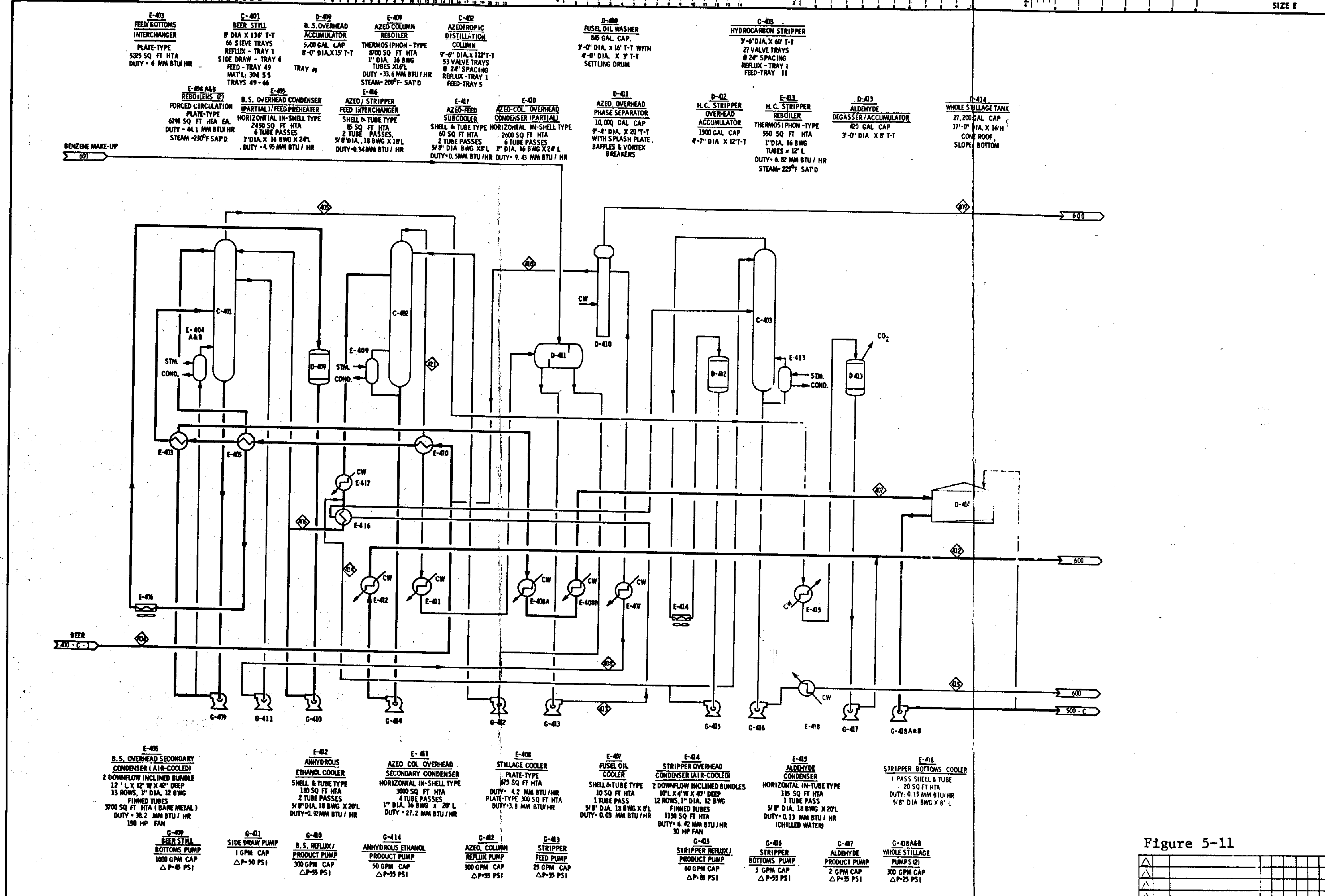
BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL./YR. NOMINAL ETHANOL FACILITY
POTATO ALCOHOL RECOVERY

JOB No.	DRAWING No.	REV.
13412	400-B-2	0



COMPONENTS	404 BEER STILL FEED LB/HR	404 %WT	405 ALDEHYDE LB/HR	405 %WT	406 AZEOTROPIC COL. FEED LB/HR	406 %WT	407 WHOLE STILLAGE LB/HR	407 %WT	408 FUSEL OIL LB/HR	408 %WT
WATER	120,985	77.64	tr	tr	2,283	11.92	118,733	87.39	15	4.12
SOLIDS-SOLUBLE	5,237	3.36					5,237	3.85		
YEAST,PROTEIN&FIBER	11,861	7.61					11,861	8.73		
ETHANOL	16,911	10.85	tr		16,872	88.08	40	0.03	28	7.69
CARBON DIOXIDE	82	0.05	82	15.68						
FUSEL OIL	321	0.21	tr						321	88.19
ALDEHYDE	441	0.28	441	84.32						
BENZENE										
TOTAL	155,838	100.00	523	100.00	19,155	100.00	135,871	100.00	364	100.00

COMPONENTS	409 FUSEL OIL (WASHED) LB/HR	409 %WT	410 FUSEL OIL WASH WATER LB/HR	410 %WT	411 AZEOTROPIC COL. OVHD LB/HR	411 %WT	412 ANHYDROUS ETHANOL LB/HR	412 %WT	413 STRIPPER FEED LB/HR	413 %WT	414 STRIPPER OVHD LB/HR	414 %WT	415 STRIPPER BTMS LB/HR	415 %WT
WATER	tr		45	61.6	3,638	2.82	tr		2,387	27.29	104	1.61	2,283	99.7
SOLIDS-SOLUBLE														
YEAST,PROTEIN&FIBER														
ETHANOL	tr		28	38.4	29,412	22.80	16,865	100.00	5,661	64.70	5,654	87.54	7	0.3
CARBON DIOXIDE														
FUSEL OIL	321	100.00	tr	tr										
ALDEHYDE														
BENZENE					95,956	74.38			701	8.01	701	10.85	tr	tr
TOTAL	321	100.00	73	100.00	129,006	100.00	16,865	100.00	8,749	100.00	6,459	100.00	2,290	100.00

Figure 5-11

ISSUED FOR REPORT

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
WHEAT ALCOHOL RECOVERY

13412 | 400-C-2 | 0

Table 5-8

PRINCIPAL DESIGN BASES — ALCOHOL RECOVERY

Beer Distillation	
Ethanol recovery	99.6% (minimum)
Reflux ratio	4.2
Bottoms temperature/pressure	240°F/25.2 psia
Pressure drop (total)	5 psia
Tray efficiency	60%
Heat source	250°F geothermal steam
Azeotropic Distillation	
Ethanol purity	100%
Bottoms temperature/pressure	178°F/19.7 psia
Pressure drop (total)	5 psi
Tray efficiency	75%
Heat source	205°F geothermal steam
Hydrocarbon Stripping	
Ethanol loss	0.13% of feed (maximum)
Reflux ratio	2.0
Bottoms temperature/pressure	215°F/15.7 psia
Pressure drop (total)	1 psi
Tray efficiency	75%
Heat source	225°F geothermal steam

returned to the top tray and the product portion of the overhead is cooled to the bubble-point condition for feed to the azeotropic column. The beer still bottoms stream, mainly water and solids, is cooled and sent to the whole stillage tank.

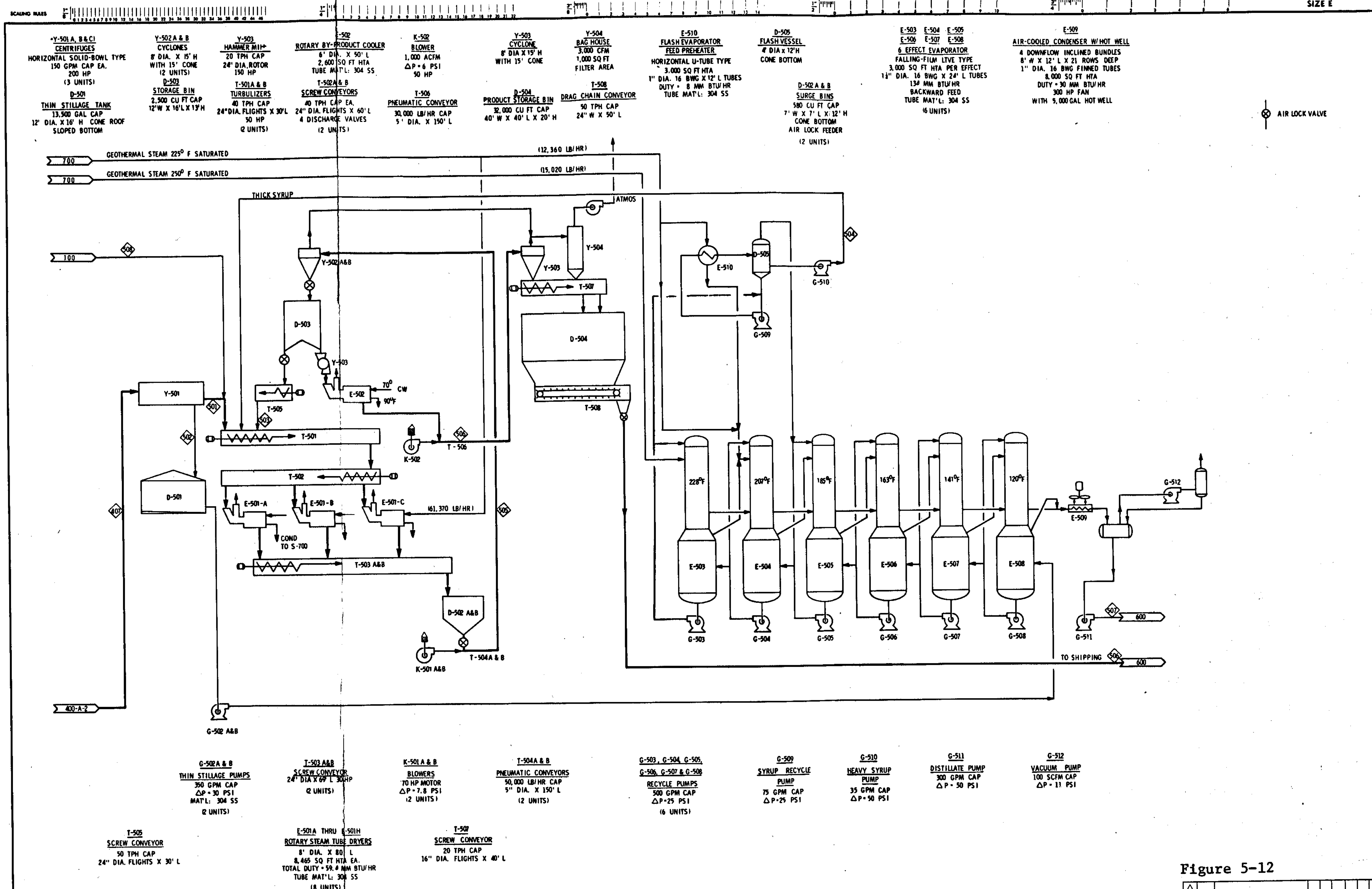
The azeotropic distillation column is 9.5-foot ID by 112-foot high and contains 53 valve trays. Benzene is used to form a ternary azeotrope with the ethanol-water mixture in the column. Water is removed in the overhead stream. The overhead is condensed, cooled, and collected in a phase separator. The benzene-rich layer is recycled to the top tray of the azeotropic column. The water-rich layer is fed to a hydrocarbon stripper. The azeotropic column bottoms is virtually 200 proof ethanol. This stream, which averages about 2,555 gallons per hour for the three feedstock cases, is cooled and pumped to product storage. Heat for the thermosiphon reboiler is supplied by condensing subatmospheric 205°F steam.

The hydrocarbon stripper is a 3.5-foot ID by 60-foot high column containing 27 valve trays. The water-rich feed is stripped of benzene in the column yielding an aqueous bottoms stream containing about 0.3 weight percent ethanol. The hydrocarbon-rich overhead stream is condensed. Part is returned as reflux and part is recycled to the azeotropic column feed. Geothermal steam at 225°F is used in the stripper reboiler.

The total geothermal energy requirement for Section 400 averages a little over 84-million-Btu-per-hour or 33,000-Btu-per-gallon ethanol product. Air coolers are used on high temperature vapor streams to minimize cooling water requirements.

5.6 BY-PRODUCT RECOVERY — SECTION 500

The by-product recovery section equipment is common to all three feedstocks, but the system is operated somewhat differently for each case. Figures 5-12, 5-13, and 5-14 illustrate the processing schemes for sugar beets, potatoes, and wheat, respectively. The system was designed to



COMPONENTS	407 WHOLE STILLAGE LB/HR	407 WHOLE STILLAGE WT	501 STILLAGE CAKE LB/HR	501 STILLAGE CAKE % WT	502 STILLAGE CENTRATE LB/HR	502 STILLAGE CENTRATE % WT	503 RECYCLE SOLIDS LB/HR	503 RECYCLE SOLIDS % WT
ETHANOL	40	0.03	1	0.04	39	0.03		
WATER	136,993	99.57	1,487	62.48	135,446	96.13	4,779	10.00
BENZENE								
SOLIDS-SOLUBLE	5,448	3.80	59	2.48	5,389	3.82	15,968	33.42
YEAST, PROTEIN, FIBER	859	0.60	833	35.00	26	0.02	27,039	56.58
TOTAL	143,280	100.00	2,380	100.00	140,900	100.00	47,786	100.00

COMPONENTS	504 RECYCLE SYRUP LB/HR	504 RECYCLE SYRUP % WT	505 BY PRODUCT TOTAL LB/HR	505 BY PRODUCT TOTAL % WT	506 BY PRODUCT NET LB/HR	506 BY PRODUCT NET % WT	507 WASTE WATER LB/HR	507 WASTE WATER % WT	508 PRESSED PULP LB/HR	508 PRESSED PULP % WT
ETHANOL							39	0.03	2	tr
WATER	5,415	50.00	6,873	10.00	2,095	10.00	130,031	99.97	50,183	80.00
BENZENE										
SOLIDS-SOLUBLE	5,389	49.76	22,968	33.42	7,000	33.42			1,552	2.47
YEAST, PROTEIN, FIBER	26	0.24	38,892	56.58	11,853	56.58			10,994	17.53
TOTAL	10,830	100.00	68,733	100.00	20,948	100.00	130,070	100.00	62,731	100.00

Figure 5-12

No.	DATE	REVISIONS	BY
	1/21/80	ISSUED FOR REPORT	

SCALE NONE — DESIGNED RIASAN/MASON — DRAWN R. MASON & S. ERLICH

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL /YR NOMINAL ETHANOL FACILITY
SUGAR BEET ALCOHOL BY-PRODUCT

JOB No.	DRAWING No.	REV.
13412	500-A	0

34 x 44 "E" SIZE

SCALING RULES

Y-501 A, B&C
CENTRIFUGES
HORIZONTAL SOLID-BOWL TYPE
150 GPM CAP EA.
200 HP
(3 UNITS)

D-501
THIN STILLAGE TANK
13,500 GAL CAP
12' DIA. X 16'H CONE ROOF
SLOPED BOTTOM

G-502 A&B
THIN STILLAGE PUMPS
350 GPM CAP
ΔP = 30 PSI
MAT'L: 304 SS
(2 UNITS)

Y-502 A&B
CYCLONES
8' DIA. X15'H
WITH 15' CONE
(2 UNITS)

D-503
STORAGE BIN
2500 CU FT CAP
12'WX16'LX13'H

T-505
SCREW CONVEYOR
50 TPH CAP
24' DIA FLIGHTS x 30' L

Y-503
HAMMER MILL
20 TPH CAP
24" DIA. ROTOR
150HP

T-501 A&B
TURBULIZERS
24' DIA. FLIGHTS X 30'L
40 TPH CAP
50HP
(2 UNITS)

E-501 (A-H)
ROTARY STEAM TUBE DRYERS
8' DIA X 80'L
8465 SQ FT HTA EA
TOTAL DUTY = 26.9 MM BTU/HR
TUBE MAT'L: 304 SS
(8 UNITS, 4 OPERATING)

E-502
ROTARY BY-PRODUCT COOLER
6'DIA X 50'L
2600 SQ FT HTA
TUBE MAT'L: 304 SS

T-502 A&B
SCREW CONVEYORS
40 TPH CAP EA
24' DIA FLIGHTS x 60' L
4 DISCH. VALVES
(2 UNITS)

D-502 A&B
SURGE BINS
580 CU FT CAP
7'WX7' LX10'H
CONE BOTTOM
AIR LOCK FEEDER
(2 UNITS)

K-502
BLOWER
1000 ACFM CAP
ΔP = 6 PSI
50 HP

T-506
PNEUMATIC CONVEYOR
30,000 LB/HR CAP
5" DIA x 150' L

K-501 A&B
BLOWERS
1000 ACFM CAP.
ΔP = 7.8PSI
70 HP

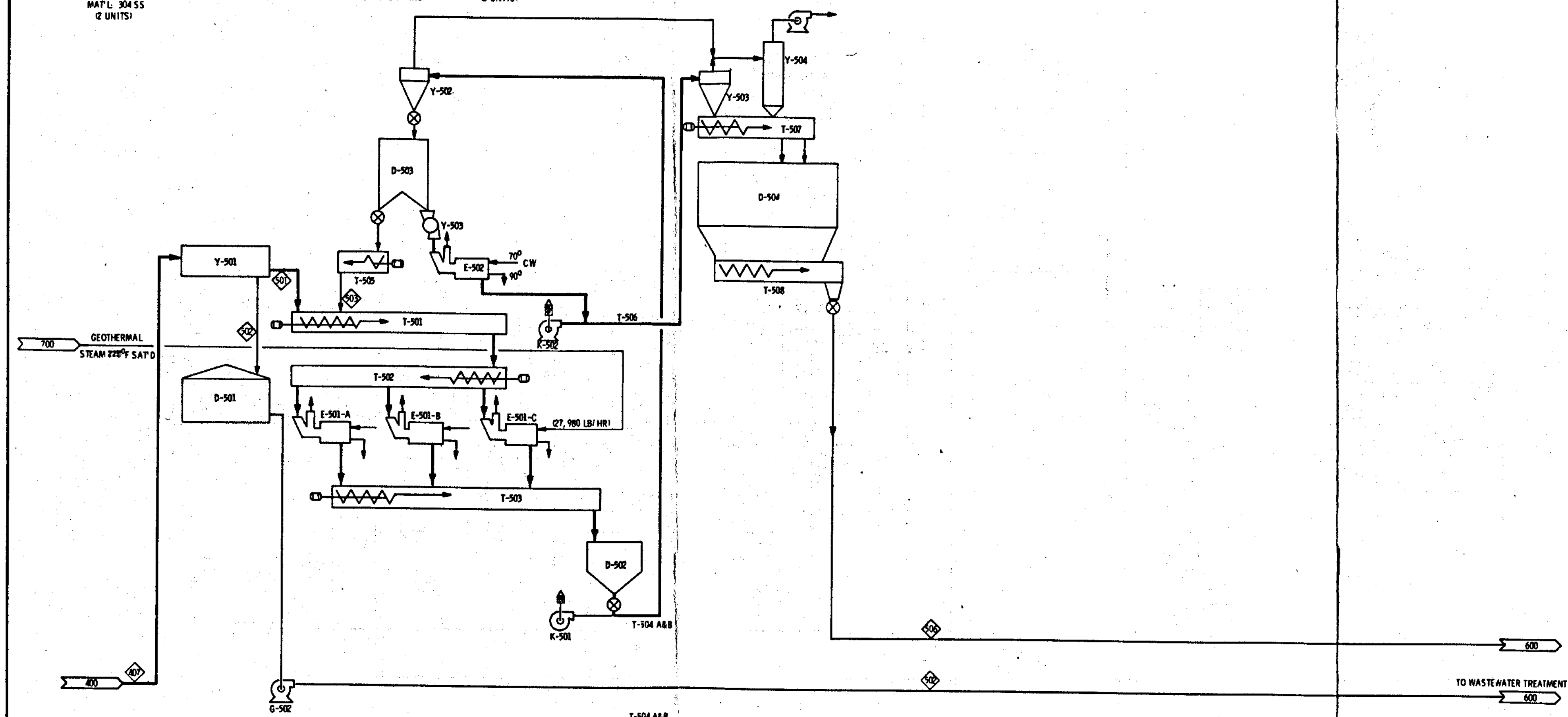
Y-503
CYCLONE
8'DIAX15'H
WITH 15' CONE

T-507
SCREW CONVEYOR
20 TPH CAP
16' DIA FLIGHTS x 40' L

D-504
PRODUCT STORAGE BIN
32,000 CU FT CAP
40'WX40'LX20'H

T-508
DRAG CHAIN CONVEYOR
50 TPH CAP
24'W X 50'L

Y-504
BAG HOUSE
3000 CFM
1000 SQ FT
FILTER AREA



T-504 A&B
PNEUMATIC CONVEYORS
50,000 LB/HR CAP EA
5" DIA x 150' L
(2 UNITS)

	407 WHOLE STILLAGE		501 STILLAGE CAKE		502 STILLAGE CENTRATE		503 RECYCLE SOLIDS		506 BY-PRODUCT-NET	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
ETHANOL	34	264 PPM	9	0.02	25	0.03			tr	
WATER	114,211	87.86	28,560	64.88	85,651	99.63	978	10.00	1,717	10.00
SOLIDS, SOLUBLE	179	1377 PPM	45	0.10	134	0.16				
YEAST, PROTEIN, FIBER	15,563	11.97	15,407	35.00	156	0.18	8,806	90.00	15,452	90.00
TOTAL	129,987	100.00	44,021	100.00	85,966	100.00	9,784	100.00	17,169	100.00

Figure 5-13

No.	DATE	REVISIONS	BY	CHKD
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SCALE NONE DESIGNED RIASAN/MASON DRAWN W MASON

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
POTATO ALCOHOL BY-PRODUCT

JOB No. 13412 DRAWING No. 500-B REV. 0

34 x 44 "E" SIZE

Y-501 A, B & C CENTRIFUGES
HORIZONTAL SOLID-BOWL-TYPE
150 GPM CAP EA.
200 HP
(3 UNITS)

D-501 THIN STILLAGE TANK
13,500 GAL CAP
12' DIA. X 16' H CONE ROOF
SLOPED BOTTOM

Y-502A & B CYLONES
8' DIA. X 15' H
WITH 15' CONE
(2 UNITS)

D-503 STORAGE BIN
2,500 CU FT CAP
12' W X 16' L X 13' H

Y-503 HAMMER MILL
20 TPH CAP
24" DIA. ROTOR
150 HP

T-501A & B TURBULIZERS
0 TPH CAP
24" DIA. FLIGHTS X 30' L
50 HP
(2 UNITS)

E-502 ROTARY BY-PRODUCT COOLER
6' DIA. X 50' 2600 SQ FT HTA
TUBE MAT'L: 304SS

T-502A & B SCREW CONVEYORS
40 TPH CAP EA.
24" DIA. FLIGHTS X 60' L
4 DISCHARGE VALVES
(2 UNITS, 1 OPERATING)

K-502 BLOWER
1000 ACFM
ΔP = 6 PSI
50 HP

T-506 PNEUMATIC CONVEYOR
30,000 LB/HR CAP
5" DIA. x 150' L

Y-503 CYCLONE
8' DIA X 15' H
WITH 15' CONE

Y-504 BAG HOUSE
3000CFM
1000 SQ FT
FILTER AREA

D-504 PRODUCT STORAGE BIN
32,000 CU FT CAP
40' W 40' W X 40' L X 20' H

E-510 FLASH EVAPORATOR FEED PREHEATER
HORIZONTAL U-TUBE TYPE
3000 SQ FT HTA
- 1" DIA. 16 BWG x 12' TUBES
6.5 MM BTU / HR
TUBE MAT'L: 304 SS

D-505 FLASH VESSEL
4' DIA x 12' H
CONE BOTTOM

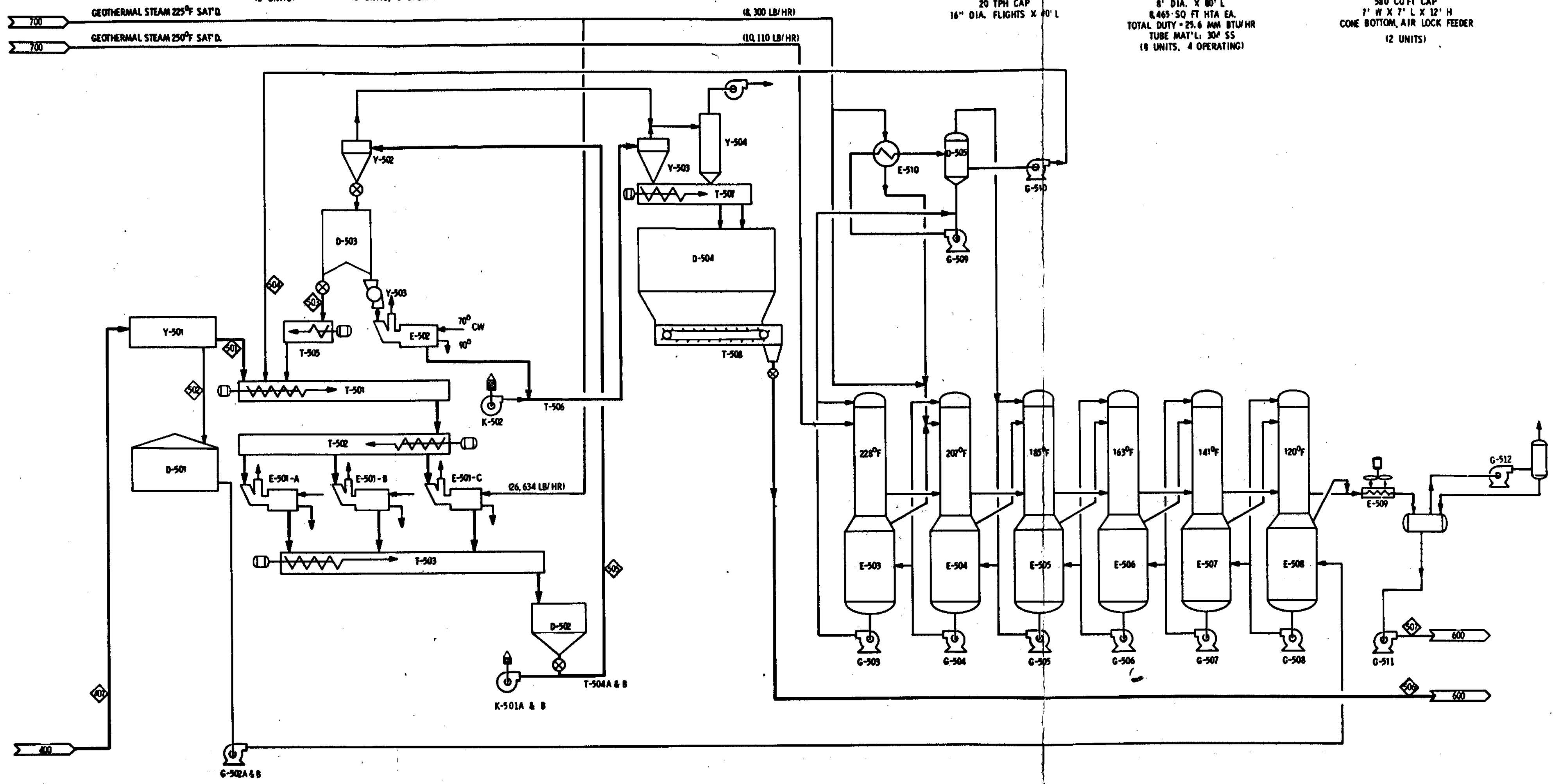
T-507 SCREW CONVEYOR
20 TPH CAP
16" DIA. FLIGHTS X 40' L

E-503 THRU E-508 6 - EFFECT EVAPORATOR
FALLING FILM LTVE TYPE
3,000 SQ FT HTA PER EFFECT
1½" DIA. 16 BWG X 24' L
96 MM BTU/HR
BACKWARD FEED
TUBE MAT'L: 304 SS
(6 UNITS)

E-501 A THRU E-501 H ROTARY STEAM TUBE DRYERS
8' DIA. X 80' L
8,465 SQ FT HTA EA.
TOTAL DUTY = 25.6 MM BTU/HR
TUBE MAT'L: 304 SS
(8 UNITS, 4 OPERATING)

E-509 AIR-COOLED CONDENSER W/ HOT WELL
4 DOWNFLOWS INCLINED BUNDLES
8' W X 12' L X 21 ROWS DEEP
1" DIA. 16 BWG FINNED TUBES
8,000 SQ FT HTA
DUTY = 22 MM BTU/HR
W/5,000 GAL HOT WELL

D-502A & B SURGE BINS
580 CU FT CAP
7' W X 7' L X 12' H
CONE BOTTOM, AIR LOCK FEEDER
(2 UNITS)



G-502A & B THIN STILLAGE PUMPS
350 GPM CAP
ΔP = 30 PSI
MAT'L: 304 SS
(2 UNITS)

K-501A & B BLOWERS
1,000 ACFM CAP
ΔP = 7.8 PSI
(2 UNITS)

G-503 THRU G-508 RECYCLE PUMPS
500 GPM CAP
ΔP = 25 PSI
(6 UNITS)

G-509 SYRUP RECYCLE PUMP
75 GPM CAP
ΔP = 25 PSI

G-510 HEAVY SYRUP PUMP
35 GPM CAP
ΔP = 50 PSI

G-511 DISTILLATE PUMP
300 GPM CAP
ΔP = 50 PSI

G-512 VACUUM PUMP
100 SCFM CAP
ΔP = 11 PSI

T-505 SCREW CONVEYOR
50 TPH CAP
24" DIA. FLIGHTS X 30' L

T-504A & B PNEUMATIC CONVEYORS
50,000 LB/HR CAP EA.
5" DIA. X 150' L
(2 UNITS)

T-508 DRAG CHAIN CONVEYOR
50 TPH CAP
24" W X 50' L

	407 WHOLE STILLAGE		501 STILLAGE CAKE		502 STILLAGE CENTRATE		503 RECYCLE SOLIDS		504 RECYCLE SYRUP		505 BY PRODUCT TOTAL		506 BY PRODUCT -NET		507 WASTE WATER	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
ETHANOL	40	0.03	7	0.02	33	0.03	tr		tr						33	0.04
WATER	118,733	87.39	20,875	62.23	97,858	95.63	2,782	10.00	4,437	50.00	4682	10.00	1,900	10.00	93,421	99.96
BENZENE																
SOLIDS-SOLUBLE	5,237	3.85	921	2.75	4,316	4.22	5,738	23.44	4,316	48.64	10,975	23.44	5,237	23.44		
YEAST, PROTEIN, FIBER	11,861	8.73	11,740	35.00	121	0.21	19,297	66.56	121	1.36	31,158	66.55	11,861	66.56		
TOTAL	135,871	100.00	33,543	100.00	102,328	100.00	27,817	100.00	8,874	100.00	46,815	100.00	18,998	100.00	93,454	100.00

Figure 5-14

ISSUED FOR REPORT

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL /YR NOMINAL ETHANOL FACILITY
WHEAT ALCOHOL BY-PRODUCT

13412 | 500-C | 0

handle the beet pulp and stillage from beet processing as a worst case. Not all the equipment is needed for potato or wheat processing and differences in operation are noted in the description.

Whole stillage from the 27,000-gallon stillage tank contains insoluble solids (yeast, protein, and fiber) and soluble solids (organic and inorganic), much of which originates from the feedstock material. The stillage is centrifuged, producing a thin stillage stream (centrate) and a cake stream containing about 35 percent weight solids. Three horizontal solid-bowl centrifuges are provided. Thin stillage from beet and from wheat processing is evaporated to heavy syrup for blending with the stillage centrifuge cake. The soluble solids in thin stillage from potato processing are not economically worth recovery.

The by-product solids drying system is designed to produce a 10 percent moisture material that is to be sold as an animal feed supplement. The by-product composition as well as the production rate will be different for each feedstock. When beets are processed, pressed beet pulp is added to the centrifuged cake and heavy syrup is added prior to drying. By-product from potato processing is derived only from the centrifuged stillage solids while the wheat processing by-product contains centrifuged stillage solids and syrup recovered from the thin stillage.

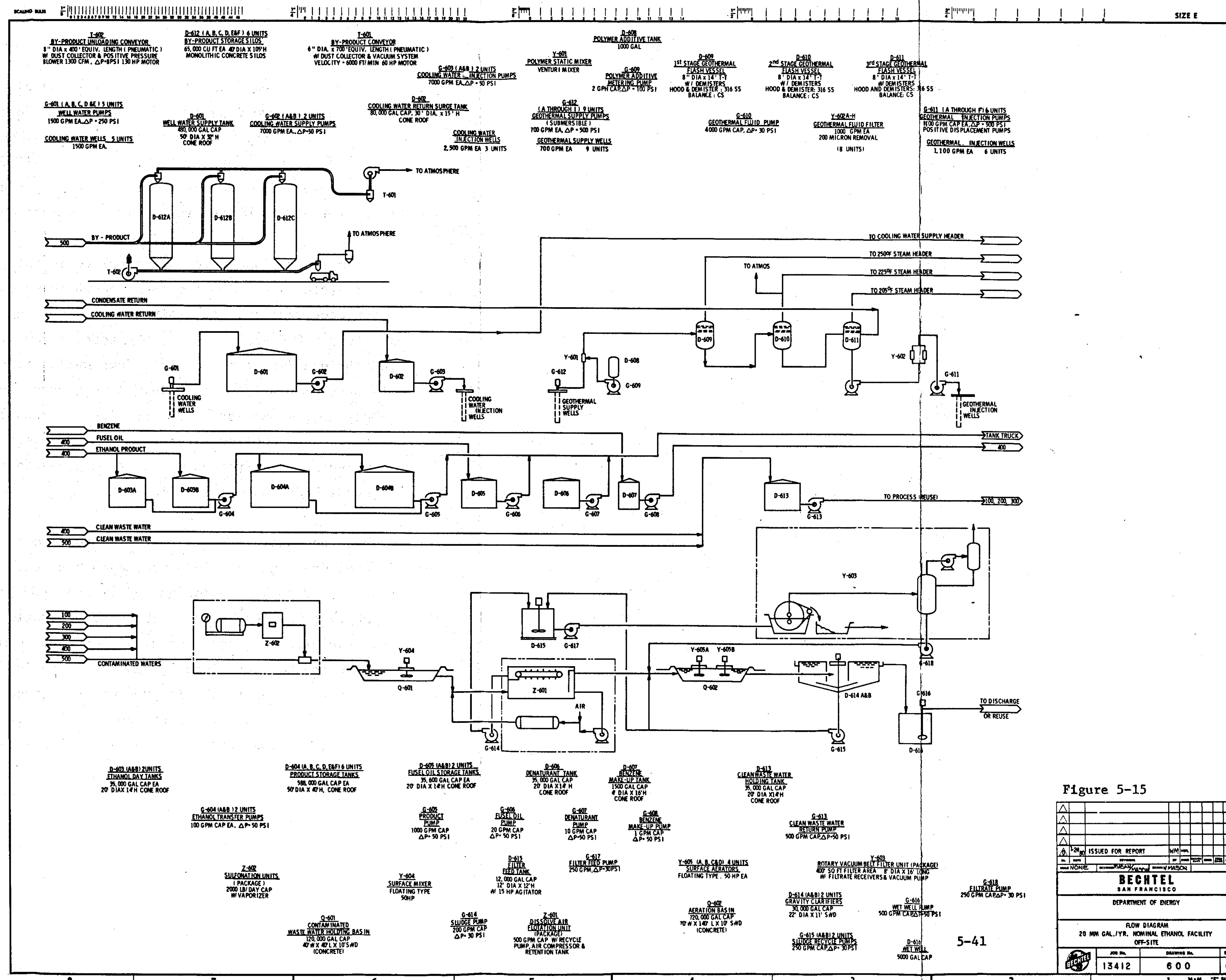
A six-effect evaporator system is used to concentrate the thin stillage from beets and wheat to a medium syrup. Falling film-type long tube vertical evaporator units are used. The system is operated with backward feed (to the sixth effect) and 250°F geothermal steam supplied to the first effect. Vapor from the first effect is supplemented with 225°F geothermal steam to provide the heat for evaporation in the second effect. Each effect has a recycle pump to provide uniform distribution of the liquor at the top of the tube bundle. The medium syrup concentrate from the first effect is sent to a flash evaporator for further concentration. Geothermal steam at 225°F is used to preheat the flash evaporator feed. Flash vapor is routed to the third evaporator effect and the heavy syrup (50 percent solids) is pumped to the solids drying system. Vapor from the first effect is condensed in an air-cooled condenser. A rotary vacuum pump maintains the condensate system at the desired condensing pressure. The combined condensate is pumped to Section 600. The syrup concentration system has an overall economy of about five.

Eight rotary steam-tube dryers in two parallel trains are used to dry wet solids from beet processing. A design dryer feed moisture of 50 percent is attained by recycling dried solids to blend with wet feed consisting of pressed pulp, stillage cake and syrup. Blending occurs in two parallel turbulizers and the blended solids are fed by screw conveyors into the 8-foot ID by 80-foot long dryer drums. Geothermal steam at 225°F is used as the heating medium in the dryer tubes. Evaporated water (vapor) is vented from the solids feed end. Discharged material is collected by screw conveyors and transferred to surge bins. Pneumatic conveyors lift the material to an elevated storage bin. About 70 percent of the dry material is recycled. The balance is ground in a hammer mill, cooled to 100°F in a rotary drum cooler, and conveyed pneumatically to a 32,000-cubic-foot capacity product storage bin. The dry by-product is transferred from the bin by pneumatic conveyor to the six storage silos in Section 600. Net production is about 21,000 pounds per hour.

When potatoes or wheat are being processed, only one of the two dryer trains (four dryers) is in operation. Significantly less solids recycle is required and the dryer feed moisture is reduced to 40 percent. Net by-product yields in these two cases are about 17,000 and 19,000 pounds per hour, respectively.

5.7 OFFSITES — SECTION 600

Section 600 contains product and by-product storage facilities, cooling water supply injection facilities and wastewater handling facilities. Figure 5-15 illustrates these systems which are common to all three feed-stocks. The geothermal system was described previously in Section 4.



SIZE E
BY - PRODUCT
CONDENSATE RETURN
COOLING WATER RETURN
TO ATMOSPHERE
TO COOLING WATER SUPPLY HEADER
TO 250°F STEAM HEADER
TO 225°F STEAM HEADER
TO 205°F STEAM HEADER
TO ATMOS
BENZENE
FUSEL OIL
ETHANOL PRODUCT
TANK TRUCK
TO PROCESS (REUSE)
CLEAN WASTE WATER
CONTAMINATED WATERS
TO DISCHARGE OR REUSE
AIR
ISSUED FOR REPORT
NONE
BECHTEL
SAN FRANCISCO
DEPARTMENT OF ENERGY
FLOW DIAGRAM
20 MM GAL./YR. NOMINAL ETHANOL FACILITY
OFF-SITE
13412
600
0

Figure 5-15

Dried solids from Section 500 are pneumatically conveyed to six storage silos each with a capacity of 65,000 cubic feet. Fifteen days of storage is provided at the maximum production rate (beet case) of 10.5 tons per hour. Wheat and potato by-products have higher bulk densities, so more than 15 days of production can be stored. The by-product is shipped offsite in tractor-trailers which are loaded pneumatically at a loadout station.

Process and cooling water are supplied to the processing units from a well water system. Air coolers are used where practical to reduce the cooling water requirements. At design conditions, the maximum cooling water demand is about 6,000 gpm. Five of the total six wells can provide this demand. The 16-inch diameter, 300-foot deep wells are rated at 1,500 gpm each and are spaced on a 1/4-mile grid. A well water surge tank provides an 80-minute supply to the suction of the cooling water supply pumps (one 100 percent spare). Warm cooling water from the process exchangers is returned to a small surge tank from which it is returned to the same groundwater aquifer through three injection wells.

Hydrocarbon storage facilities are isolated in a tank farm. Two 35,000-gallon ethanol dry tanks provide intermediate storage for ethanol from Section 400. Six product tanks provide an additional 3 1/2 million gallons of storage capacity equivalent to two months of production. Ethanol product is shipped from the plant in tank trucks. Denaturant is metered in during tank truck loading at the truck loading station. Two fusel oil tanks also provide two months storage of fusel oil production. It can be blended with the product alcohol or shipped offsite by separate tank trucks. A 1,500-gallon benzene tank provides the storage for a year's benzene makeup requirements.

Process wastewaters are segregated into two types: (1) clean condensates and, (2) contaminated wastes. Clean wastes are collected in a surge tank and pumped back to processing sections for reuse. These wastes contain only small amounts of ethanol as a contaminant and used for flume, wash water and diffusion water makeup in beet processing and for starch slurry makeup in wheat processing. Only the hydrocarbon stripper bottoms is available as clean wastewater in the potato processing case. It normally would be used as part of the potato wash water.

Contaminated wastes include blowdown water from the silt ponds (beets and potatoes), potato mash centrate, fermenter cleaning wastes, stillage centrate (potatoes) and general wash down water. The peak waste flow is about 500 gpm (during potato processing). Waste treatment consists of equalization, dissolved air flotation (DAF) and activated sludge treatment. The mixed equalization basin provides four hours of detention. Most of the suspended matter is removed in a DAF unit. DAF effluent is biologically treated to remove soluble organics and the biological solids are removed in two parallel gravity clarifiers. Clarifier overflow is pumped either to discharge or to reuse in front end processing. The sludge streams are combined and vacuum filtered for on-site disposal in a landfill. A sulfonation unit is provided to detoxify the sterilization chemical used in fermenter cleaning.

5.8 GEOTHERMAL ENERGY REQUIREMENTS

Geothermal energy requirements (steam) for the production of ethanol from beets, from potatoes, and from wheat are summarized below. Beet conversion requires about 50 percent more geothermal energy than either of the other two feedstocks. The beet byproduct recovery section (Section 500-A) is a particularly large energy consumer. The higher (gross) heating value of ethanol is about 84,750 Btu's per gallon. The geothermal energy input represents a fairly large part of the thermal energy value of the product ethanol.

Table 5-9

GEOTHERMAL ENERGY REQUIREMENTS

	Beets MM Btu/hr	Potatoes MM Btu/hr	Wheat MM Btu/hr
Section 100	37.4	-	-
Section 200	-	17.4	-
Section 300	-	-	10.5
Section 400	84.7	84.4	84.5
Section 500	85.4	29.1	43.2
Total	207.5	130.9	138.2
Btu consumed per gallon ethanol produced	81,180	51,250	54,030

Section 6

ECONOMIC ANALYSIS OF GEOTHERMAL ALCOHOL SCHEME

Capital and operating cost estimates were prepared for the conceptual geothermal-alcohol facility. These costs were used in an economic analysis to determine alcohol selling prices under a range of economic conditions.

6.1 CAPITAL COST ESTIMATE

The capital cost estimate for the multiple feedstock ethanol production facility was prepared from the conceptual design information. In order to provide a comparison, the three feedstock cases were also costed as separate plants, each with its own handling, fermentation, and processing facilities sized individually to produce 20 million gallons per year of anhydrous ethanol. The cost of the geothermal production facility, including production wells, reinjection wells and energy extraction facilities, are estimated separately. Table 6-1 summarizes the estimates:

Table 6-1

CONSTRUCTION CAPITAL COST ESTIMATE SUMMARY

	$MM
Overall ethanol plant	64.0
Ethanol plant using sugar beets only	51.6
Ethanol plant using potatoes only	43.1
Ethanol plant using wheat only	40.4
Geothermal facility	21.0

6.1.1 Estimate Basis

The estimates are based on the conceptual design and engineering information prepared for the study in the form of engineering flow diagrams, outline specifications, and equipment lists. Estimating methods consistent with the conceptual nature of the design information were employed and rely on informal vendor contact as well as extrapolation from Bechtel historical information.

The cost estimate is composed of field costs, engineering services and contingency. The largest category, field costs, comprises the direct cost of permanent plant equipment and the indirect cost of temporary construction materials, supervision, etc., that are to be distributed across the entire facility. The estimate anticipates an engineer-constructor direct-hire operation employing field construction labor forces.

6.1.1.1 Pricing Levels

The estimates have been prepared at first quarter, 1980, price and wage levels. No allowance has been made for future escalation.

6.1.1.2 Field Construction Costs

The direct field construction costs of permanent plant equipment, materials, subcontracts, and construction labor have been included in the estimate on the basis of the following discussion.

Equipment. Budgetary quotations based on conceptual designs and specifications were obtained verbally or in writing for approximately 70 percent of the equipment items. Some of the major items are:

- Beet Washer
- Continuous Slope Diffuser
- Pulp Presses
- Trash Screen and Sump

- Rock Catcher
- Beet Slicer
- Potato Mash Pump
- Rotary Steam-Tube Dryer
- Potato Mash Centrifuge
- Centrifugal Separator
- Distillation Columns and Trays
- Cooling Water Wells
- Vacuum Filter
- Gravity Clarifier
- Geothermal Wells and Pumps

Bulk Material. The cost of bulk materials including piping, instrumentation, electrical, civil and structural were estimated as a percentage of the mechanical equipment based on similar plants, historical information and recent studies.

Construction Labor. The construction labor costs for the installation of the plant equipment are based on labor contracts and fringe benefits for the south-central Idaho area.

A composite rate of $17.00 per hour was used and is based on a craft mix appropriate to the type of construction, together with a 2.5 percent allowance for casual overtime. Sufficient manual labor to complete the project within the construction schedule is assumed to be available in the project vicinity.

Subcontracts. Subcontracts for equipment and materials commonly installed by subcontractors were estimated and priced in accordance with Bechtel experience.

Indirect Field Costs. The indirect field costs represent those activities that cannot be ascribed the direct portions of the faciltiy and thus are accounted for separately. They were estimated based on plants of a similar nature resulting in an assessment of 65 percent of direct labor costs.

The items covered by indirect field costs are:

- Temporary Construction Facilities. Temporary buildings, working areas, roads, parking areas, utility system, and general purpose scaffolding.
- Miscellaneous Construction Services. General job clean-up, maintenance of construction equipment and tools, material handling and surveying.
- Construction Equipment and Supplies. Construction equipment, small tools, consumable supplies, and purchased utilities.
- Field Office. Field labor of craft supervision, engineering, procurement, scheduling, personnel administration, warehousing, first aid, and the costs of operating the field office.
- Preliminary Check-Out and Acceptance Testing. Testing of materials and equipment to ensure that components and systems are operable.
- Project Insurance. Public liability, property damage, and builder's risk insurances.

6.1.1.3 Engineering Services

The engineering services include engineering costs, other home office costs and fee. Engineering includes preliminary engineering, optimization studies, specifications, detail engineering, vendor-drawing review, site investigation, and support to vendors. Other home office costs comprise procurement, estimating and scheduling services, quality assurance, acceptance testing, and construction and project management. Fee is included as a function of the total project cost.

The sum of these three categories falls into historically consistent percentages in the range of 10 to 20 percent, depending on the complexity of the project. For this study, a figure of 15 percent of field construction costs has been used as typical for a plant that, while new in concept, does not depart radically from basic engineering principles.

6.1.1.4 Contingency

Included in the estimate is a contingency that exists within the conceptual design in quantity, pricing or productivity and that is under the control of the constructor and within the defined scope of the project. Implicitly, the allowance will be expended during the design and construction of the project and cannot be considered as a source of funds for overruns or additions to the project scope.

Experience shows, however, that it is quite difficult to assess the degree to which future processes are understood in the hardware sense. Thus, if the conceptual arrangement of the plant contains major uncertainties, or the design duty of plant components proves to be more severe than anticipated, or if additional major subsystems are utlimately found to be necessary, then the scope of the project is deemed to have been inadequately defined and this then would not be covered by the contingency allowance. A nominal figure of 20 percent has been used for this study.

6.1.2 Qualifications

The following are the major items for which design data was not available when the estimate was prepared and required the use of historical data and previous studies:

- Site specific items which affect civil/structural costs
- Piping, instrumentation and electrical systems

6.1.3 Exclusions

The following items are excluded from the scope of the study and from the estimate:

- All facilities beyond the hypothetical site boundary
- Any special construction such as widening and strengthening existing roads
- Ecological and environmental considerations other than those incorporated in the present conceptual design
- State and local taxes
- Future escalation
- Site investigation and land acquisition
- Client engineering and similar client costs
- Allowance for funds during construction
- Process royalties and licenses
- Training of plant operators
- Initial charges, stocks of operating supplies and spares
- Plant startup and operations

6.1.4 Conceptual Estimate

The previous discussion of estimate bases and qualifications form the basis of the cost summaries contained in Table 6-2.

6.2 OPERATING COST ANALYSIS

Operating and maintenance (O&M) costs were estimated for both the geothermal extraction system and the alcohol facility. Initial feedstock costs (delivered) selected by Bechtel and approved by DOE were:

- Sugar beets @ $25 per ton = $1.03 per gallon of alcohol produced
- Potatoes @ $1.50 cwt = $1.23 per gallon of alcohol produced
- Wheat @ $4.20 per bushel = $1.41 per gallon of alcohol produced

Table 6-2

CAPITAL COST SUMMARY

(Base Case)

FACILITY		$1000s
100	Sugar Beet Preparation	10,740
200	Potato Preparation	6,520
300	Wheat Preparation	1,500
400	Product Recovery	4,410
500	By-Product Processing	10,010
600	Off-site, Excluding Geothermal Facility	4,130
	Yard Facility and Utilities	3,700
	TOTAL DIRECT COST	41,010
	Indirect Cost	5,500
	TOTAL FIELD COST	46,510
	Engineering Services	6,990
	Contingency	10,500
	TOTAL CONSTRUCTED COST	64,000
GEOTHERMAL FACILITY		21,000

(All price & wage levels at 1st Quarter, 1980.)

Based on a 4/5/3 month processing sequence, the average feedstock cost is equivalent to $1.21 per gallon of alcohol produced.

In February 1980 DOE recommended the following less optimistic feedstock costs:

- Beets @ $31/ton = $1.28/gallon
- Potatoes @ $3/cwt = $2.45/gallon
- Wheat @ $4/bu = $1.34 gallon

It should be noted that feedstock costs, more than any other factor, very significantly affect the production cost of alcohol. Using the DOE costs above, one calculates that feedstock costs represent $1.79 per gallon of alcohol produced on the same 4/5/3 processing sequence basis.

Clearly, one would not choose to convert potatoes at $3 per cwt into alcohol if there were lower cost feedstocks available.

Direct operating and maintenance costs for the four-month beet/five-month potato/three-month wheat operation are summarized in Table 6-3.

Table 6-3

ESTIMATED ANNUAL DIRECT O&M COSTS

Item	$1000s	¢/gal alcohol
Chemicals	2886	13.7
Electric power (25 mills/kWh)	1102	5.2
Manpower (including administrative)	5264	25.0
Operating supplies & maintenance materials	1700	8.1
Local taxes and insurance	1700	8.1
Lease payments	60	0.3
	12,712	60.4

Direct operating costs for the geothermal facility are quite low and consist mainly of electric power costs ($350,000), scale depressant costs ($105,000) and operating and maintenance labor and materials costs.

The total plant staff was estimated at 160 full-time personnel consisting of:

- 87 operators and shift foremen
- 31 maintenance personnel
- 25 day laborers, guards, and clerks
- 17 technical, medical, and administrative personnel

At first quarter 1980 wage and price levels, manpower costs represent 25¢ per gallon of ethanol produced. Chemicals are the next highest direct cost element. Enzyme costs are over 80 percent of the total chemical costs. Both the denaturant cost and its volumetric addition to product alcohol were excluded. Two percent of the total constructed cost was allowed for operating supplies and maintenance materials and also for local taxes and insurance. A small annual cost is also incurred for private and federal lease payments. Lease arrangements are discussed in Section 8. It was assumed that about 400 acres of private land and about 640 acres of federal land would be leased. The bulk of the lease payments would go to private landowners.

6.3 ECONOMIC EVALUATION

Capital cost elements were combined with annual O&M cost elements under a number of assumed economic conditions to analyze the economics of the geothermal-alcohol operation. Economic parameters were:

- Escalation
- Return on equity
- Debt to equity

- Interest rate on debt
- Feedstock costs
- By-product value
- Tax credits
- Alternate energy costs
- Two and one feedstock plant operations

A discounted cash flow (DCF) program was used to calculate alcohol selling prices for different values of the above economic parameters. Common to all cases were:

• Plant operating life	20 years
• Plant construction period	1980 - 1981
• Depreciation schedule	9.5 years, double declining balance for new equipment; 40 years, straight line for new buildings
• Debt repayment period	20 years

To the $85 million total constructed cost of the geothermal-alcohol facility were added:

Land costs	$100,000	(60 acres @ ~$1650/acre)
Other owner costs	$1,280,000	(2 percent of $64 million)
Startup costs	$2,560,000	(4 percent of $64 million)

to arrive at a total capital investment of $88.94 million (excluding only allowance for funds during construction and working capital). The land cost is assumed to be the only non-depreciable investment other than working capital — which is expensed.

Base case economic conditions selected for the parametric sensitivity study are:

- 0 percent escalation
- 15 percent return on equity
- 60 percent debt/40 percent equity
- 12 percent interest on debt
- $31 per ton beet cost
- $3 per cwt potato cost
- $4 per bushel wheat cost
- $100 per ton by-product value
- 20 percent investment tax credit
- 46 percent federal income tax
- 6.5 percent state income tax

Straight escalation was considered first and then a differential escalation scheme was used throughout the rest of the sensitivity runs. Zero escalation keeps all costs and revenues at first quarter, 1980 dollar values. As noted in Section 6.2, direct costs for feedstocks and the other O&M items totalled $2.39 per gallon of alcohol. The calculated selling price of $2.76 per gallon includes a by-product credit of about $0.35 per gallon. The margin of $0.72 per gallon is required to cover debt, interest, and income tax payments plus the 15 percent return on equity over the life of the project. On the basis of the initial feedstock costs listed in Section 6.2, the calculated selling price is about $2.28 per gallon.

Table 6-4 summarizes the results of the parametric studies. Alcohol selling prices for 1980 (base dollar), 1982 (first year of operation), 1992 (eleventh year of operation), and 2001 (twentieth year of operation) indicate the impact of geometric escalation. Most of the cases include a differential escalation in which feedstock costs and by-product credits are escalated at 4 percent per year and all other costs and revenues are escalated at 8 percent per year.

Table 6-4

ALCOHOL PRICE SENSITIVITY TO ECONOMIC PARAMETERS

Parameter	Value	Economic Basis	Alcohol Selling Price, $/gal. 1Q, 1980	1982	1992	2001	Tax Credits $1,000
Escalation	0	Base Case 1	2.76	2.76	2.76	2.76	—
	8%/year	—	2.68	3.12	6.74	13.48	—
	12%/year	—	2.31	3.33	10.35	28.69	—
	8%/4% differential	Base Case 2	2.14	2.50	5.39	10.77	—
Return on equity	15%	Base Case 2	2.14	2.50	5.39	10.77	—
	20%	—	2.32	2.70	5.84	11.67	—
	25%	—	2.49	2.90	6.26	12.52	7,247
Debt to equity	0/100	—	2.31	2.69	5.80	11.59	9,341
	60/40	Base Case 2	2.14	2.50	5.39	10.77	—
	80/20	—	2.06	2.40	6.19	10.57	—
Interest on debt	10%	—	2.11	2.46	5.32	10.63	—
	12%	Base Case 2	2.14	2.50	5.39	10.77	—
	14%	—	2.17	2.53	5.47	10.93	—
Feedstock costs	90%	—	2.01	2.34	5.05	10.10	—
	100%	Base Case 2	2.14	2.50	5.39	10.77	—
	110%	—	2.27	2.65	5.72	11.43	—

Table 6-4 (Continued)

Parameter	Value	Economic Basis	Alcohol Selling Price, $/gal. 1Q, 1980	1982	1992	2001	Tax Credits $1,000
By-product value	$100/ton	Base Case 2	2.14	2.50	5.39	10.77	—
	$110/ton	—	2.12	2.47	5.32	10.64	—
	$120/ton	—	2.09	2.09	5.26	10.51	—
Wheat & Potato facility, $60.8 million capital	7/5 mo. operation	Base Case 2	2.02	2.36	5.10	10.20	—
Wheat only facility, $56.2 million capital	$3.50/bushel	—	1.50	1.75	3.79	7.57	—
	$4.00/bushel	Base Case 2	1.63	1.90	4.10	8.19	—
	$4.50/bushel	—	1.75	2.04	4.40	8.80	—

Without escalation considered in the economics, alcohol would have to sell for $2.76 per gallon (current day) for the project to realize a reasonable return on investment. One cannot imagine a venture based on these economic conditions, principally because the base feedstock price for potatoes is unattractive. As escalation (geometric) is allowed to be included, the current day selling price drops because the 15 percent return on equity includes income in inflated dollars over 20 years. A differential escalation rate was then selected which basically assumed that all costs and revenues will escalate at 8 percent per year, except the feedstock costs and the animal feed by-product which will escalate at only 4 percent per year. This differential escalation results in a current price of $2.14 per gallon of alcohol — still unattractive.

The various economic parameters considered in the sensitivity study are important to potential investors in evaluating benefits versus risks and the combination of parameters that would make an investment attractive. Return on equity or return on investment is a measure of the profitability of a project. Increasing the desired return, of course, increases the selling price of alcohol. If the resulting selling price is above the market value (as is the case indicated in Table 6-4), for a particular desired or minimum acceptable return, the project is unsound. Various financing plans may be considered. A high equity position may be attractive for a large company. A high debt position may be the only realistic possibility for a local venture group. A geothermal loan guarantee may be available to help obtain debt financing at a relatively low interest rate. The debt portion cannot exceed 75 percent of the aggregate cost of the project. The interest rate on long-term debt does not have a major impact on the selling price of alcohol, however.

The (20 percent) investment tax credits are largely unused because the project has no taxable income during the first several years of operation when depreciation write-offs are high. Under new tax laws, the 10 percent energy tax credit is excluded from the seven-year limitation. The discounted cash flow program used does not include the new energy tax credit provision and, hence, about $9 million are not properly credited in all of the cases. Inclusion of the credit would reduce the 1980 selling price by about 3¢/gallon.

As indicated in the operating cost section, feedstock cost is a significant economic parameter. Under the assumed base case economic conditions, a 10 percent variation results in a 6 percent change in the alcohol selling price. The impact is more pronounced when costs of individual feedstocks are looked at in one- or two-feedstock operation cases. If the sugar beet portion of the plant were eliminated and the two-feedstock plant then operated seven months on wheat and five months on potatoes, the 1980 alcohol selling price would only drop $0.12 to $2.02 per gallon. If a wheat-only alcohol facility was constructed and operated with wheat costing $4 per bushel, the 1980 alcohol selling price would be only $1.63 per gallon. Even with wheat at $4.50 per bushel, the alcohol price of $1.75 is still attractive.

This economic analysis indicates that the average feedstock costs would have to be significantly lower than assumed here for a three-feedstock alcohol facility to be economically feasible. In particular, one could not afford to pay more than about $1.50 per cwt for potatoes. An alcohol facility processing only wheat year-round, however, looks quite attractive for two reasons: (1) the capital investment for both the alcohol facility and the geothermal facility would be lower ($56 versus $85 million) and, (2) wheat is a relatively cheap feedstock in cost per gallon of ethanol produced. A facility processing wheat for eight months and sugar beets for four months would also produce alcohol somewhat cheaper than the three-feedstock facility.

For a smaller-scale facility, the capital investment and the operating costs per unit of alcohol production would be higher. Under the same financial conditions, a wheat-only facility would probably yield the lowest cost alcohol. Using a 0.6 scale factor, the capital cost for a 10-million-gallon-per-year wheat-only facility (including geothermal) would be about $36 million. Under the base case financial conditions, it is estimated that the current day alcohol selling price would be about $1.80 per gallon versus $1.63 per gallon for a 20-million-gallon-per-year wheat-only facility. For a five-million-gallon-per-year capacity plant, the alcohol selling price would be a little over $2.00 per gallon.

Both the federal government and the State of Idaho are encouraging the use of gasohol through tax incentive programs. The federal government allows a 4¢ per gallon excise tax exemption for gasohol which is equivalent to a 40¢ per gallon subsidy for the alcohol portion of the 90:10 blend. A crude oil entitlement credit of about 5¢ per gallon of alcohol is also being allowed. The State of Idaho also allows a 4¢ per gallon gasoline tax exemption for gasohol and a small income tax credit for alcohol producers in the state. The income tax credit is 0.8 percent in the first year of production and drops by 0.2 percent in each of next four years. These credits (equivalent to about 85 cents per gallon of alcohol) allow wholesalers and retailers to buy expensive alcohol, blend it with unleaded regular gasoline, and sell a premium fuel at a price not much above unleaded regular. While $1.80 per gallon of alcohol would be a good selling price, alcohol even at $2.00 per gallon may still be attractive to wholesalers and retailers under the current tax incentive programs.

The cost of geothermal energy was also estimated under the base case economic conditions as about $3 per million Btu's of heat input to the process. Figure 6-1 shows the effect of steam costs on the price of alcohol. The geothermal energy system (capital and operating costs) adds about 18¢ to the 1980 alcohol selling price. On a cost basis, this is a relative bargain compared with the purchased cost of steam generated from gas or oil fuels. Fuel costs alone would exceed $3 per million Btu's.

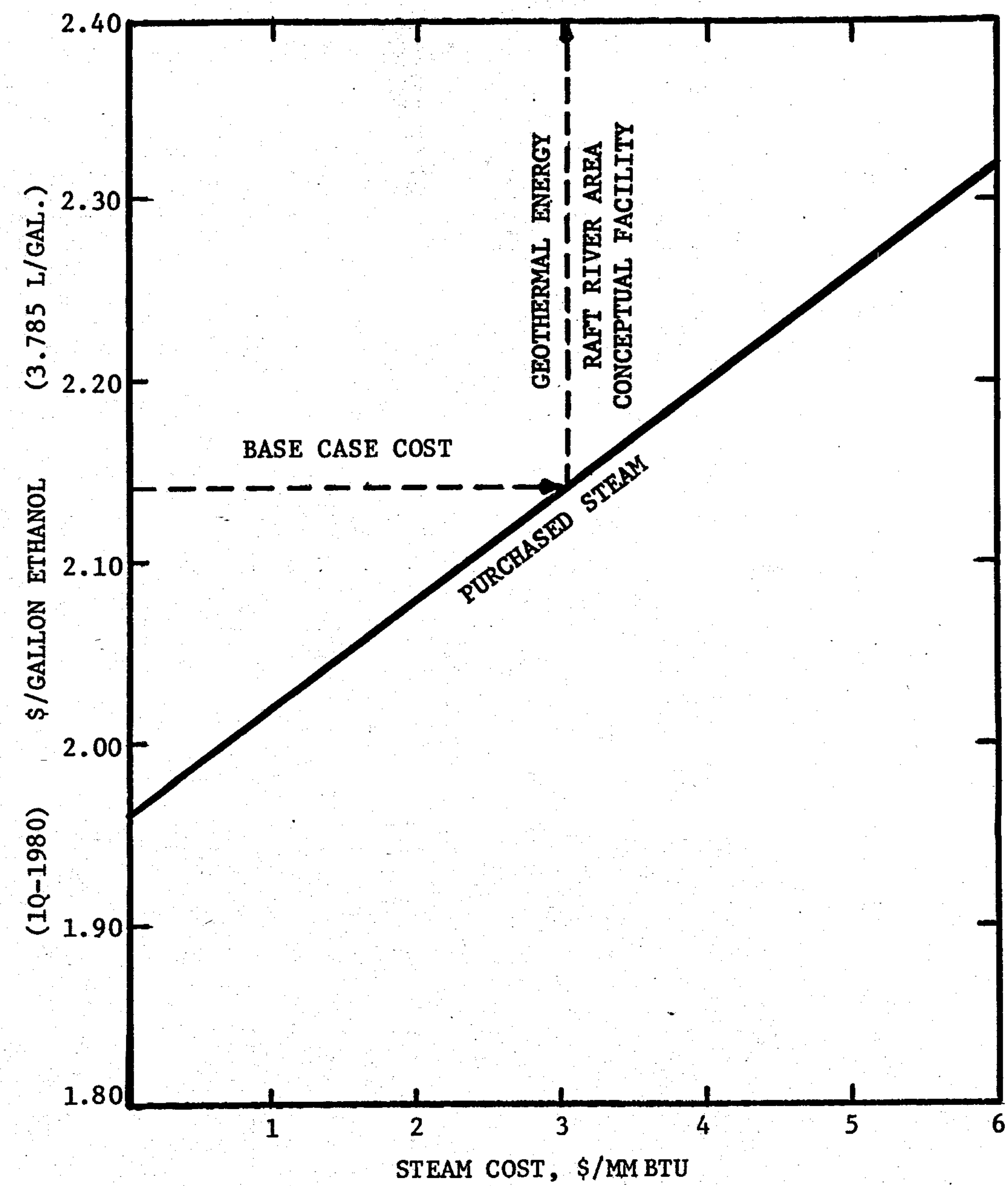


Figure 6-1. Alcohol price/steam cost sensitivity.

Section 7

PRELIMINARY IMPLEMENTATION PLAN FOR DEMONSTRATION FACILITY

A geothermal-alcohol facility of the type conceptualized here could be operational by early to mid-1982. However, many steps need to be taken to bring this concept to fruition. Among them are identification of potential participants and development of an infrastructure capable of handling geothermal, agricultural, governmental, financial, marketing and transportation aspects of the project.

Interest in participating in this type of project has been widespread in Idaho. Benefits will also be derived from the project, e.g., direct employment during construction and operation, some stabilization of crop production and perhaps agricultural prices, and the extension of available motor fuel supplies in the region.

7.1 DEFINE PROGRAM GOALS

The implementation program should have as its primary goal the establishment of a geothermal-alcohol demonstration project of a commercial scale in the Raft River KGRA. To be successful, the project must be economically feasible and present an acceptable risk to potential investors. The project must also have the support of local communities, agricultural associations, and local and state government.

Table 7-1 lists major implementation plan activities which need to be carried out to achieve the goal of a successful demonstration project. At this point, a specific timetable for accomplishing each activity cannot be given, but approximate activity durations are listed. Many activities

Table 7-1

IMPLEMENTATION PLAN ELEMENTS

Duration	Activity	Organizations Involved
2 months	Information transfer	Study contractor, DOE - public
2 - 6 months	Formation of project venture group	Refiners, wholesalers, farmers, ranchers, grain & feed dealers, KGRA landowners
3 - 6 months	Assessment of feestock availability and potential supply contracts	Venture group — growers associations, farmers, commodities and agricultural specialists, current purchasers
3 - 6 months	Marketing arrangements for fuel-grade alcohol	Venture group — refiners, products wholesalers and retailers
3 - 6 months	Marketing of by-product as animal feed supplement	Venture group — animal feed suppliers, feedlot operators, cattle ranchers
6 - 12 months	Development of feedstock receiving station network and contract hauling requirements	Venture group — growers associations, storage facility operators, trucking firms
4 - 6 months	Development of exploratory geothermal data	Venture group — geothermal resource experts, drilling companies, and KGRA landowners
6 - 9 months	Procurement of land, leases, and water rights	Venture group — BLM (federal lease bids), private landowners, real estate agents, State of Idaho
2 - 4 months	Demonstration of technical aspects	Venture group — DOE, EG&G Idaho (RRGP), pilot equipment suppliers
12 - 16 months	Development of permitting requirements, application preparation and approval	Venture group — BLM, USGS, EPA, DOE, State of Idaho, local government agencies

Table 7-1 (Continued)

Duration	Activity	Organizations Involved
12 - 16 months	Development of environmental baseline data and ER preparation	Venture group — DOE, USGS, environmental services firms, local agencies
6 - 12 months	Identification of financial lenders and approval of loan applications	Venture group — principals, private and public lending institutions
4 - 6 months	Preparation of definitive scope and cost estimate	Venture group — Title II engineering firm
2 - 4 months	Engineering/procurement/construction (EPC) bid requests, evaluations, award	Venture group — Title III EPC firms on bidder's list
6 - 12 months	Application for and approval of geothermal loan guarantee (if desired)	Venture group — DOE
3 months	Public hearings on environmental aspects	Venture group — lead agency and public
12 - 16 months	Execute EPC activities to construction completion	Venture group — Title III engineering firm, subcontractors

will need to start early and run concurrently in order to avoid potential costly delays. The composition of the venture group will also affect the timing and efficacy of carrying out these activities. The availability of equity capital and human resources (project management, technical, environmental, and financial specialists) within the venture group will enable effective planning and execution of the project.

Potential participants in such a project include:

- Oil companies (petroleum refiners and products distributors)
- Gasoline wholesalers and retailers
- Farmers and cattle ranchers
- Grain and animal feed dealers and feedlot operators
- Landowners in the Raft River KGRA
- Other interested businessmen (real estate, commodity brokers, and others)
- Current processors of agricultural products
- Potential users of low temperature geothermal energy

Specific individuals expressing interest in gasohol are not identified in this report. A list of interested parties is available through Senator Frank Church's field representative in Boise.

One of the first tasks for the venture group will be to define the scope of the demonstration project. As indicated in Section 6, constructed capital costs for a 20-million-gallon-per-year geothermal-alcohol facility would range from about $56 million to $85 million, depending on the feedstocks processed. The economic analysis indicated that wheat and sugar beets are economical feedstocks while field run potatoes are generally not. A smaller capacity plant designed for processing one (wheat) or two feedstocks may be the best choice for a demonstration project because of the institutional constraints identified later in this section. This discussion is oriented toward a larger-scale project, but the same activities would be required for a smaller-scale project. Feedstock availability and marketing activities listed in Table 7-1 are necessary for this project scope definition. It is possible that a cattle feedlot operation could be developed jointly with the geothermal-alcohol project. Applications for low temperature geothermal energy utilization could be considered at this stage because the alcohol facility, when operational, will have large quantities of 200+°F geothermal fluid available. Gary Crook's greenhouse operation in the KGRA is a commercial demonstration of low temperature geothermal utilization.

Geothermal resource verification will require geophysical investigations including geochemical surveys, heat flow measurements, and core drilling on private lands. Access for these investigations will have to be negotiated with landowners. At the same time, negotiation on lease/purchase arrangements can begin. Nomination of units to BLM for competitive lease bidding or noncompetitive lease applications should be filed. Exploratory work on BLM leased land will be required. Well drilling and construction of the alcohol facility will require consumptive groundwater use. Groundwater rights (and permits) will have to be acquired before these activities can commence.

Collection of environmental baseline data, environmental report (ER) preparation and permit applications preparation are long-term activities which likely will require the services of environmental specialists working with the venture group. Environmental restrictions in the geothermal leases will also have to be met during development of the geothermal resources. When a draft environmental impact assessment or environmental impact statement has been issued by the lead agency, the applicant (venture group) will be involved in public hearings.

Two other major activities involve financing the project and constructing the project. Before debt financing arrangements can be concluded, a definitive project scope and cost estimate must be prepared. Title II engineering and cost estimation will usually be sufficient to obtain financing for the balance of the debt capital required. Economic analyses should be reviewed at various stages to ensure that the project still remains economically attractive. If a geothermal loan guarantee is to be sought, a detailed project scope and milestone schedule, a detailed budget breakdown, and projected cash flows over the life of the project must be submitted as part of the supporting information supplementing the guarantee application.

Final engineering, procurement, and construction (Title III) activities will take on the order of 12 to 16 months from project award. The bulk of the capital expenditure will occur during this phase. After construction completion, pre-startup testing, startup and successful performance testing, the venture group accepts the project and begins commercial operation.

Successful implementation of a geothermal-alcohol project will require many successful steps along the way. This brief discussion only highlights major activities and the type of organizations which need to be involved in these activities. The project will be complex because of the unique combination of geothermal resource development and utilization with ethanol production from renewable resources in a non-industrial environment. Site-related requirements including environmental consequences are examined in Section 8.

7.2 INFORMATION TRANSFER

Information transfer is a means of stimulating interest in a private geothermal resource development whether by fostering implementation of a geothermal-alcohol project or by helping to develop concepts for other applications of geothermal energy.

An information transfer program recommended during the course of this study included:

- An open project review presentation in Idaho Falls (completed in February 1980)
- Presentation of papers at the AIChE 79th National Meeting in Portland, Oregon and at the IECEC conference in Seattle, Washington (completed August 18 and 19, 1980)
- Public forum presentation of the study results in one or more Idaho communities (subsequently cancelled by DOE)

At DOE's request, a presentation of the study results was made at the Geothermal Resources Council meeting in Boise on June 18th.

7.3 TECHNICAL DEMONSTRATION

The objective of using conventional technology throughout the design of the geothermal facility and the alcohol production facility was to minimize the need for technical demonstration. Two technical areas do need to be confirmed through demonstration testing: (1) long-term scaling and fouling control in the geothermal flash system and, (2) fouling and foaming control in sugar beet juice concentration. Both could be tested simultaneously in the Raft River Geothermal Project facilities under DOE sponsorship (with funding provided by the venture group). Skid-mounted flash vessel units and multiple-effect evaporator units could be rented rather than fabricated. Three months or less of testing would be adequate to demonstrate the technical feasibility of both operations.

Section 8

SITE INSTITUTION REQUIREMENT FOR DEMONSTRATION PROJECT

The Raft River geothermal resource area is in a relatively undeveloped portion of the state. Commercialization of geothermal resources will impose stresses on the Raft River area as well as provide benefits for the area. A geothermal-alcohol project such as conceptualized here, would induce expansion of the local population and a demand for community services, as well as increase local traffic by movement of people and materials in and out of the area. Institutional requirements are discussed in the following subsections on the basis of a 20-million-gallon-per-year geothermal-alcohol facility. Major constraints in the implementation of this size demonstration project are identified.

8.1 FEEDSTOCK AVAILABILITY

The study has focused on three agricultural products grown in significant amounts in the south-central region of Idaho. The annual production of each is sufficient to support a 20-million-gallon-per-year ethanol production facility. However, the total crop production cannot be considered available as feedstock for the alcohol facility. In fact, on a three-crop basis, the conceptual facility is about the largest that the area could conceivably support without severely distorting existing market relationships.

Figure 8-1 is a general cropland map showing the geographic relationships of the geothermal area with the potential feedstock production areas. The potential cropland area indicated in Figure 8-1 is not all under cultivation. In 1975, according to the U.S. Department of Commerce, a little over 2 million acres in Cassia, Jerome, Twin Falls, Minidoka and Power counties were in farms.[10] The cropland acreage in these five counties was about 1.3 million acres, of which more than 500,000 acres were planted in wheat, potatoes, and sugar beets.[2, 10]

Approx scale: 1 inch = 15.3 miles

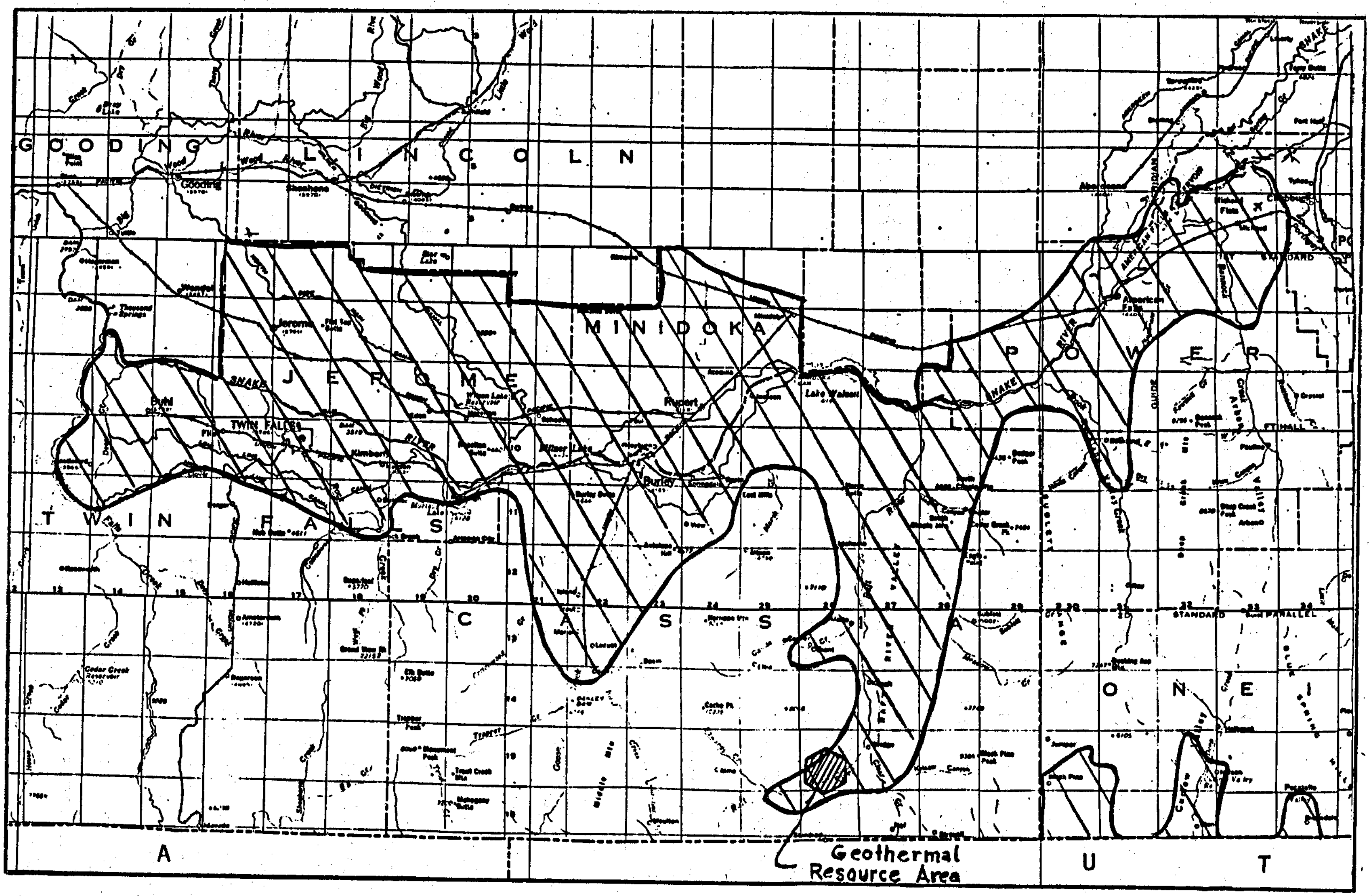


Figure 8-1. Cropland map of region around Raft River Valley.

Most of the cropland lies on either side of the Snake River, which is north of the KGRA. Collection and transportation facilities in this belt are presumably in place, having been developed and maintained by existing producer-consumer relationships. There is significant storage capacity in the area for both potatoes (about 25 percent of production) and wheat (about 400,000 to 450,000 tons). Wheat can be grown on nearly all of the cropland acreage. Potatoes and sugar beets are limited to areas where irrigation water is relatively abundant. Since groundwater resources are a critical problem, especially in the Raft River Valley, it is unlikely that significant expansion of acreage for these crops can be achieved.

Currently, Amalgamated Sugar Company contracts for the bulk of the sugar beets grown in the region. Beets are delivered by farmers to their receiving stations for transshipment to the Paul (Mini-Cassia), Idaho beet sugar factory. Operation of the geothermal-alcohol facility for up to four months on sugar beets would require contracting with growers for nearly 300,000 tons of beets, or roughly 15,000 planted acres. Direct competition with Amalgamated for some portion of this acreage is very likely. A receiving station network (roadside) and a transportation system also need to be developed. Contract hauling might be preferable to an owner operated truck fleet. Off-site storage of most of the beets with daily hauling to the plant ought to be considered as a means of minimizing the hauling fleet required. Sugar beets must be processed in the winter months just after harvesting. Five months is about the maximum storage life without significant degradation.

At potato production costs of up to $3 per cwt, the alcohol facility cannot economically operate on field run potatoes. Based on five months of operation, the plant would consume about 27 percent of the total potato crop grown in the region. It is unlikely that this percentage could be procured except in years, such as in 1979, when production exceeds the demand. The procurement approach each year should be to buy culls and perhaps potato wastes supplemented by only enough field run potatoes to provide a reasonable length process run. Size, taste, texture, and appearance of potatoes are unimportant in the fermentation process so there is some procurement advantage over potato processors.

Wheat currently is the most attractive feedstock material from both a cost and an availability standpoint. It is easy to grow, is not water intensive, and can be stored for relatively long periods. Soft white winter wheat is compatible with whole kernel processing and field run wheat can be processed without wet cleaning. Storage capacity in the region exceeds 14 million bushels and offers the opportunity for year-round procurement. Transportation costs for hauling wheat to the plant will be considerably lower on a cents per gallon ethanol basis than for potatoes or sugar beets.

A wheat-only ethanol production facility is the most economically attractive case for a demonstration project. The risk, which is inherent in all single-feedstock alcohol facilities, is that wheat prices could rise enough in the future to make the operation unprofitable. Other high starch grains could theoretically be processed, however.

Primary transportation access to a proposed geothermal-alcohol facility located in the KGRA is limited to Highway 81 running approximately north-south through the Raft River Valley. Interstate Highway 80N runs in a north-northwest direction through the northeast corner of Cassia County about 15 miles away from the existing geothermal project. Another hard surfaced secondary road runs west from Malta between the Cotterel and the Jim Sage mountains. There is no rail service in the Raft River. Nearly all feedstock and product materials would have to be transported on Highway 81. A minimum of 120 truckloads per day of beets or potatoes would have to be delivered to a 20 MM gpy capacity plant. The mean hauling distance from roadside stations would be in the range of 50 to 60 miles.

Assuming a two-hour round trip, some 25 to 30 trucks would be in transit on the access road in any hour during a 10 to 12 hour daily hauling period. Shipping of alcohol and dry by-product would also add two to three trucks per hour to the vehicle traffic. The carrying capacity of this highway would not be exceeded, however, traffic congestion is likely. For most of the year, the vehicle activity on this highway will be similar to that on haul roads near receiving stations at harvest time. The transformation of the rather infrequently travelled road into a major haul road will be an unavoidable consequence of a demonstration project of this size.

The transportation logistics problem points again toward a demonstration project of a smaller size with wheat being the predominant feedstock material.

8.2 ENVIRONMENTAL EFFECTS

A geothermal-alcohol facility constructed and operated in a primarily rural area will have both positive and negative effects on the environment. A full assessment is beyond the scope of this study and cannot be made without adequate baseline data. Significant likely impacts are discussed after a brief summary of the existing environment obtained primarily from References 11 and 12.

8.2.1 Environmental Setting

The Raft River KGRA is located in the southwestern portion of the Raft River Valley which is about 38 miles long by 12 to 15 miles wide. The north-south trending valley is bounded on the east, west, and south by fault-block mountain ranges. The valley is drained by the perennial Raft River which flows northward into the Snake River. It is the only perennial stream in the valley. The floor of the valley averages about 4,600 feet in elevation while the surrounding hill ranges attain elevations above 9,000 feet. The valley floor is relatively flat and slopes gently toward the north.[11, 12]

The valley is classified as a cold desert steppe with evaporation exceeding precipitation. Climate in the valley is semi-arid with an annual average temperature of about 46°F (8°C) and extremes of -27°F (-33°C) and 104°F (40°C). Temperature inversions occur about 40 percent of the time during the summer and about 50 percent of the time during the winter. Severe dust storms occur on occasion, as do moderate thunderstorms.[(11)] Precipitation averages about 10 inches per year.

The KGRA is located within the cold desert formation. The dominant plant species are shrubs such as greasewood, sagebrush, and saltbrush. Small portions of the area are used for agricultural purposes, primarily for the production of small grains and alfalfa hay along with some grass pastureland.[(11)] Cropland is more predominant in the northern portion of the Raft River Valley.

Predominant mammals are herbiverous rodents. Some larger mammals are also present. Six sensitive animal species are known to inhabit the KGRA. Of these, the ferruginous hawk is the most important because of its extreme sensitivity to human disturbance. Active nesting areas are protected by the BLM. No threatened or endangered specie is known to inhabit the KGRA.[(11)]

The Raft River Valley is very sparsely populated. Malta is the largest community near the KGRA. Its population is about 200. Albion, located somewhat further away to the northwest, has a slightly larger population.[(11)]

Community services in the area are quite limited as would be expected in a predominantly rural area with little commercial and manufacturing activity to attract people.

The Raft River area is considered to be archaeologically significant. A survey in the KGRA located seven sites and 13 finds. Six of the sites were within a 2.5 km stretch of the Raft River and subsurface resources probably exist in the immediate locale.[(11)]

The Raft River Basin was closed in 1963 to further appropriation of groundwater because of declining water levels in the lower end of the valley. About two-thirds of the total yield of the basin moves as groundwater in shallow alluvial and sedimentary formations. Groundwater quality varies with depth and location. Irrigation wells in the vicinity of the geothermal area show the influence of upward leakage from the geothermal resource by higher temperature, fluorides, and dissolved solids than wells away from the area.[11, 12]

The KGRA is the most studied geothermal area in Idaho and thermal waters are thought to originate in deep fault systems and circulate upward through extensive fracture systems. A total of seven deep production and injection wells have been drilled. Water up to 300°F has been successfully produced.[11, 12] The moderate-temperature resource is believed to be extensive enough to support major commercial development for direct utilization of these resources.

8.2.2 Anticipated Environmental Effects

Major activities will occur during both the construction and operation phases of the project. An influx of skilled labor will be required for construction. The peak labor force would be on the order of 200 to 250. Some camp-type facilities would probably be located near the construction site. Other workers might drive or be bussed in from more populated areas in the north. Some unskilled or semi-skilled local residents could be recruited and trained for construction and/or operation jobs to help the local economy and to reduce the influx of temporary workers, which also initially lessens the strain on local community services.

Expansion of the local population will begin during construction with the influx of some temporary workers. Expansion of retail trade establishments may begin during the construction period. Public services such as education and health care will need to be expanded to meet the demands imposed by the additional population. The project may need to financially assist the local communities in providing services through tax advances.

Major construction activities will include clearing and grading the plant site, constructing a road to Highway 81, shipping of construction materials to the plant site, installing foundations and superstructure and buildings, erecting the equipment, installing piping, electrical and instrumentation equipment, and pre-startup testing. Temporary facilities for power, water and sewage will be installed, used, and removed.

Geothermal facility development will involve exploratory drilling on several sites, production and injection well drilling, installation of the fluid gathering and fluid disposal piping networks, and pre-production testing.

These construction-related activities will consume resources (land, materials, manpower, water, power and fuel) and alter the immediate environment on and near the construction sites. Temporary adverse impacts will include disturbance of wildlife by construction noise and removal of habitat, modification of drainage patterns, increase in fugitive dust emissions, local traffic congestion, and increase in vehicle pollutant emissions. Long-term impacts from construction will be primarily the loss of plant species on cleared areas and the permanent displacement of the animal life inhabiting these areas. Presumed archaeologically significant areas would be identified and avoided in the siting stage of the project.

Environmental benefits from construction will primarily be economic in nature. Direct employment opportunities will be provided in the Raft River Valley. Some construction materials and services will be procured locally. Some of the income derived from the project will be spent locally, adding money to the economy of the area. Taxes will accrue to local and state government which can help to finance needed community services.

The transition from construction to operation will involve short-term adverse economic effects as non-local construction workers leave the area and construction project expenditures drop off. At this time, employment opportunities for operating personnel will be developing.

Operation of the geothermal-alcohol facility will have some different and some more long-term impacts on the environment. Operational activities will appear more routine and stable compared with construction activities. Some 160 full-time personnel will be employed at a 20-million-gallon-per-year facility. Transportation of raw materials into and products out of the facility will be the major visible activity.

The plant itself will have a visual impact. Figure 6-2, presented previously, is an illustration of the plant as it would appear in the valley-mountain context near the KGRA. Its appearance will contrast sharply with the rural surroundings and may not be aesthetically pleasing to some local residents or the the casual observer.

Onsite plant activities will normally have little effect on the surrounding environment. Pollutant emission levels are expected to be low. There will be no stationary combustion sources. Process air emissions will consist primarily of fugitive dust, carbon dioxide, water vapor, small quantities of hydrocarbons (aldehyde, ethanol and fusel oil), and combustion products from mobile equipment. Normally, there will be no aqueous process effluents (except for treated sanitary sewage). Geothermal resource use will be largely non-consumptive. Some geothermal steam will be consumed in cooking wheat and potatoes and some will be vented from the flash system for control purposes. Injection will be below the shallow aquifers which have been developed for potable and for irrigation uses. Cooling water will be used in a non-consumptive system. Fresh water will only be required for potable uses. Normally, the plant will be a net producer of water (by virtue of the water present in the feed materials). Most of the excess water will accumulate in the silt ponds in the form of wet sludge. Some will evaporate.

Significant amounts of solid wastes will result from processing the feed materials. The bulk will be composed of rocks, trash and silt shipped in with the beets, potatoes and wheat. It is intended that these materials be confined and disposed of on-site (by burial) as the materials are relatively inert.

Some disturbance of nearby wildlife will occur because of the noise and activity associated with on-site operations.

The principal adverse impacts will result from the increased traffic density in the vicinity of the plant and along Highway 81 throughout the Raft River Valley. In a more industrialized environmental setting, the increase in highway traffic would go relatively unnoticed. In this rural setting, the increase will appear dramatic at first, and then with time the traffic density will likely be perceived as a routine, though unpleasant, state of affairs. Effects, in addition to localized congestion and resulting annoyance to residents, will include increased noise levels along the roadway, increased combustion product emissions, a potential for increased fugitive dust emissions, and a higher potential incidence of traffic accidents.

The socioeconomic benefits of a geothermal-alcohol project would be substantial. A 10 to 20-year steady demand for agricultural crops will be a good incentive toward stabilizing production of these particular crops in the region. This steady demand would be a factor in helping to stabilize farm prices by (1) reducing the farmers' risk of loss if a crop is overproduced — the plant could absorb some of the overproduction by operating longer on that particular crop, and (2) switching away from a crop in short supply so that its price is not driven excessively high. Stabilization has good and bad aspects for both producers and consumers. The aim of the project would be to procure agricultural crops at fair prices consistent with the economic objective of producing ethanol at competitive prices.

By-product dry solids would be marketed as an animal feed supplement. A fair size (more than 20,000 head) cattle feedlot operation could be developed in conjunction with a 20 MM gpy geothermal-alcohol facility. The by-product solids, though rich in protein, fat, and fiber, are not complete feed materials. A combined feedlot-alcohol production project may be economically attractive, especially if wet by-product feeding can be practiced. Environmental problems associated with feedlot operations would have to be overcome. Consumptive use of groundwater and disposal of manure are two areas of concern. Theoretically, the manure could be converted to low or medium Btu fuel gas, with the residue refed to the cattle. Groundwater rights would have to be acquired unless an existing landowner with developed water were to be involved in the feedlot operation.

Other direct economic benefits of the operating project include permanent employment of the plant staff, income derived by the staff (about $5 million annually), expenditure of part of that income in the local economy for goods and services, taxes deriving to state and local governments, and income to suppliers of equipment, materials, power, and motor fuel purchased for plant operation.

Indirect benefits would include development of retail and wholesale services in the area to serve the increased population, increased housing construction (initially, at least), and improvement of community services (although at a cost to local and state agencies).

The alcohol production itself will have a significant beneficial impact. Twenty million gallons per year of alcohol would equivalently displace the gasoline consumption of about 30,000 automobiles. This savings in petroleum-derived motor fuel is environmentally important in that a renewable resource would be displacing an expensive, non-renewable resource — hopefully without a significant economic penalty.

Overall, a geothermal-alcohol project would be beneficial to the Raft River area if the project were implemented in a way that would mitigate the increased traffic and increased population impacts on the local communities. Implementation of a smaller-size project would be one way of reducing the adverse impacts. Economic benefits would also be reduced.

8.3 RESOURCE LEASEHOLD ARRANGEMENT

Private land acquisition is the simplest approach for a demonstration project and was the approach initially envisioned for this conceptual study. Frank Glover's quarter section (R. 26E T.158 Section 25) was initially considered as a site for the conceptual plant and the geothermal wells. Based on subsequent discussions with EG&G-Idaho and DOE personnel on the location and extent of geothermal resources in the KGRA, a revised layout concept was adopted that would encompass both private and BLM lands.[1] The revised concept provides more confidence that enough producing wells will be available to provide the required geothermal fluid flow over the life of the project. With a well layout such as indicated in Figure 4-1 previously, the venture group would have to acquire leases (with geothermal rights) on some private lands and some BLM lands. DOE has also applied for withdrawal of 1,980 hectares (about 4,900 acres) of the federally owned portion of the KGRA for research and development. Some of the BLM lands and some of the private lands are already leased to various parties. Figure 8-2 illustrates the extent of private and federal holdings in the area of interest in the KGRA. Each number section is one mile square (640 acres).

For unleased private lands of interest, three basic arrangements are likely:

1) Direct purchase of the land (with geothermal rights if needed) at market value

2) Leasing the land with mineral rights for a yearly consideration with or without additional monetary incentives to the owner based on successful geothermal fluid production and financial success of the project

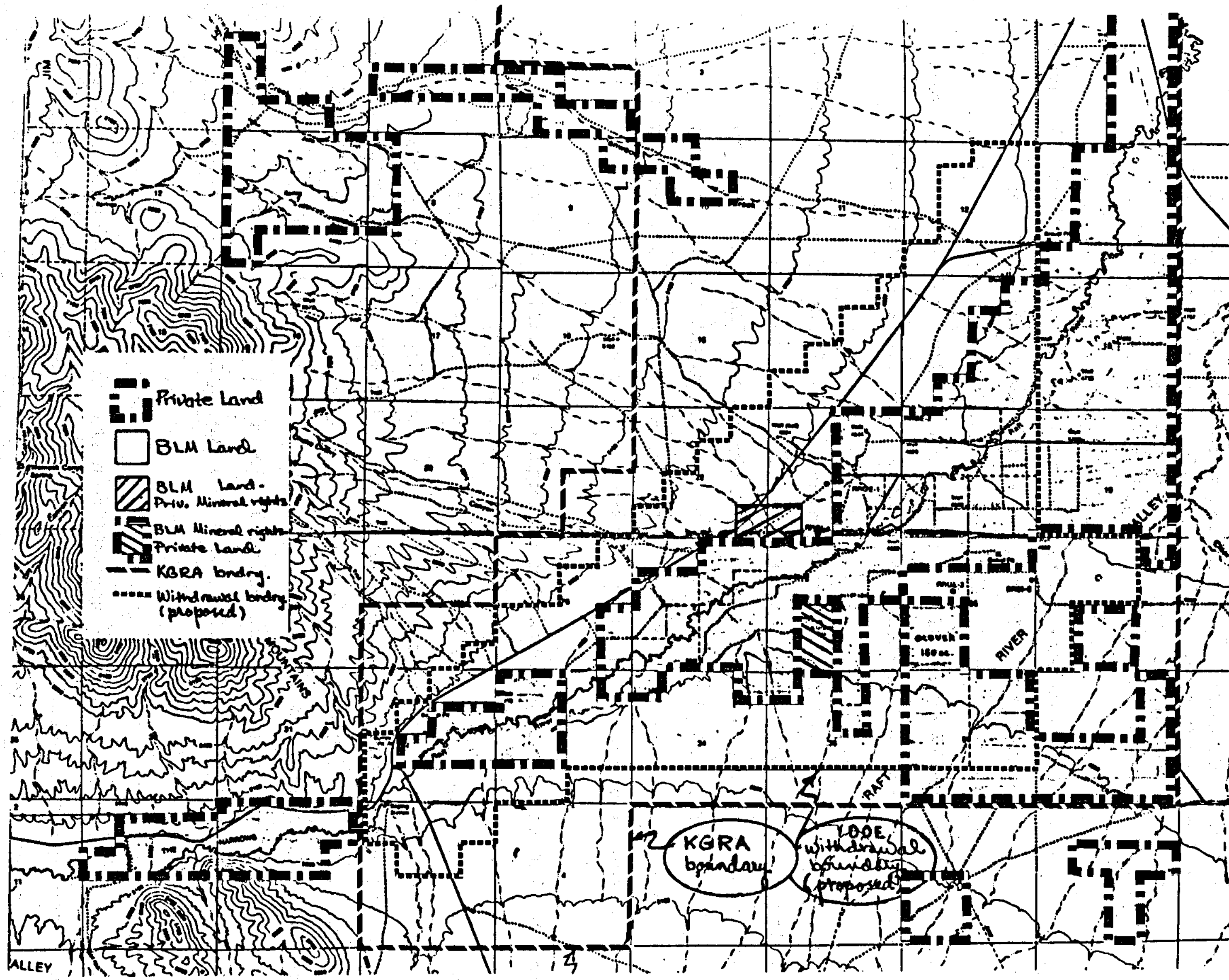


Figure 8-2. Ownership map in the vicinity of the Raft River KGRA.

3) Participation of the land owner in the project through financial remuneration in exchange for all rights to the land (and its minerals) for the life of the project. A land owner may or may not be interested in providing equity capital.

Private land leased to others presents a more difficult problem. A lease may or may not be acquirable through transfer or assignment, and the lessor may not be interested in relinquishing the lease for consideration. If a current lease could be acquired, negotiation with the owner for a suitable purchase/lease arrangement would then have to be successful.

In this study, purchase/lease arrangements were discussed only with Messrs. Gary Crook and Frank Glover. Both would consider lease arrangements or outright sale of all or some parts of their properties. A 1977 ERDA report [13] indicated that private land owners would likely ask yearly lease payments in excess of the fair market value of raw acreage in the area. Purchase price would also be above market value.

Lease of BLM lands may be obtained through a competitive bidding procedure. Leasing is authorized by the Geothermal Steam Act of 1970, with the BLM administering the regulations for this law and the USGS administering another set of regulations for exploration, development, and production operations under federal lease. Generally, the BLM would offer units for geothermal leasing through sealed bids to the highest bidder of the highest cash bonus. Nomination of units for federal lease may be made to the BLM by interested parties. A successful bidder on a unit must comply with the general requirements of the lease and any special stipulations which may be issued.

A venture group interested in a smaller-scale geothermal-alcohol project would have greater flexibility in locating the project and acquiring, through purchase or lease, rights to a sufficient geothermal resource supply. Consideration in the initial stage should be given to the additional resources that may be needed over the life of the project for replacement wells and for facility expansion plans.

8.4 PROCEDURAL CONSIDERATIONS

Part of the implementation plan activities will involve preparing permit applications and preparing an environmental report (ER). A number of federal and state regulations potentially will apply to a demonstration project and several major permits will be required. Table 8-1 briefly summarizes major legislation and principal applicant activities or permits which may be required.

The venture group proposing a geothermal-alcohol demonstration project would likely be required to prepare an environmental report on the proposal activity. The applicants should consult with the lead agency (probably DOE if a geothermal loan guarantee is involved) early in the planning process to obtain guidance on the appropriate scope and level of detail of environmental information to be submitted. A year's environmental baseline data may be required before the facility is permitted to operate. Data supplied by the applicant provides the essential background material needed by the lead agency in preparing an environmental impact assessment (EIA) or an environmental impact statement (EIS). ERDA has prepared a general guideline for preparation of an environmental report for geothermal development projects which can be of use to potential private developers.[14]

The geothermal lease(s) will contain general and specific requirements with which the lessee must comply. The actions to be taken by the lessee may require submission of plans and specifications to the lease supervisor for approval, monitoring of activities and operations, and documenting compliance by submission of records and reports. The lessee is also required to comply with applicable federal, state, and local environmental

Table 8-1

ENVIRONMENTAL REGULATIONS AND PERMITS
POTENTIALLY APPLICABLE TO A
GEOTHERMAL-ALCOHOL PROJECT

Activity or Permit Required	Legislation and Administering Agency
• ER (applicant), EIA, and perhaps EIS (prepared by lead agency)	National Environmental Policy Act of 1969 (PL 91-190,42 USC 4321 et seq.)
• Lease requirements and stipulations, GROs	Geothermal Steam Act of 1970 (PL 91-581, 84 Stat. 1566), BLM and USGS
• Prevention of significant deterioration	Clean Air Act Amendments of 1970 (PL 91-604, 42USC 1857 et seq.), EPA
• Comply with waste discharge standards	Federal Water Pollution Control Act Amendments of 1972 (P1 92-500, 86 Stat. 816), EPA
• Comply with EPA noise criteria	Noise Control Act of 1972 (P1 92-574, 86 Stat. 1234), EPA
• Avoid protected species	The Endangered Species Act of 1973 (PL 93-205, 87 Stat. 884), EPA
• Approval of plans and specifications for loan guarantee	The Geothermal Energy, Research, Development and Demonstration Act of 1974 (PL 93-410, 88 Stat. 1086, Title II of the Act), DOE
• Geothermal permit, water right permit	Idaho Geothermal Resources Act of 1972 (Idaho Code Sections 42-4001 to 42-4015, amended 1974; Sections 47-1601 to 47-1611, 1972. The Idaho Department of Water Resources
• Applies to resources leased by state (probably not applicable)	Rules and Regulations Governing the Issuance of Geothermal Resource Leases, 1974. The Board of Land Commissioners
• Permit to drill, modify, or convert geothermal well	Drilling of Geothermal Resources: Rules and Regulations and Minimum Well Construction Standards, 1975. The Department of Water Resources

Table 8-1 (Continued)

Activity or Permit Required	Legislation and Administering Agency
• Permit to construct	Rules and Regulations for the Control of Air Pollution in Idaho, 1973. Idaho Department of Health and Welfare
• Waste water discharge permit	Rules and Regulations for the Establishment of Standards of Water Quality and for Wastewater Treatment Requirements for the Waters of the State of Idaho, 1973. Idaho Board of Environmental and Community Services
• Approval of plans and specifications for solid waste disposal	Solid Waste Management Regulations and Standards, 1973. Idaho Board of Environmental and Community Services
• Permit to construct, modify, or maintain waste disposal and injection wells	Construction and Use of Waste Disposal and Injection Wells (Proposed Rule), January 23, 1979. Idaho Department of Water Resources and Department of Health and Welfare
• Distilled spirits plant permit	The Internal Revenue Code of 1954, (26USC 5171), Bureau of Alcohol, Tobacco and Firearms, Department of the Treasury

standards (incorporated in legislation listed above), and with the USGS geothermal resources operation (GRO) orders.[11]

A number of local building-type permits will be required during construction of the facility. Normally these types of permits are handled by the construction contractor and his subcontractors.

The project will also have to obtain a Distilled Spirits Plant Permit from the Bureau of Alcohol, Tobacco and Firearms (ATF), Department of the Treasury. ATF is in the process of drafting legislation for consideration in Congress that will simplify the regulations involving the production of fuel-grade alcohol.

The permitting process can be somewhat lengthy. Collection of adequate information for preparation of permit applications and timely submission of applications will help to avoid costly delays in a project. Applicants for geothermal loan guarantees must submit, as part of the supporting information, a listing of all permits or authorizations required by federal, state, and local government agencies and a copy of each application for approval when issued or a statement of planned filing dates and expected dates of approval.[15]

Specific permits will be required from the Idaho Department of Water Resources for the development of geothermal resources, whether on private, state, or federal land:

- Drilling permit - permit required to drill for geothermal resources at depths greater than 1,000 feet (also permit required to modify or deepen an existing well or to convert an existing well into an injection well). A notice of intent is required to construct a hole for the gathering of geotechnical data (written approval is required) — applies to exploratory drilling, drilling of production wells and injection wells

- Waste disposal and injection well permit - permit is required to construct, modify or maintain a waste disposal or injection well — applies to cooling water supply or and reinjection wells

- Geothermal resource permit - permit is required for geothermal development in a designated GRA if the operation of well 900 m or more deep does not affect any source of developed underground water

- Water right permit - permit required to appropriate water including geothermal water which involves consumptive use and water for construction and operation involving consumptive use — water right permits obtained for the geothermal production wells would provide protection from third party interferences

The Idaho Board of Environmental and Community Services would require a permit for any wastewater discharge (including sanitary sewage) from the alcohol facility and would require approval of the plan for disposal of the plant's solid waste. The Idaho Department of Health and Welfare has the authority for the control of air pollution in Idaho. It will require control of fugitive emissions during construction and operation and may require a permit to construct for the alcohol facility if the fermenter vent gas is considered a significant new stationary source.

This discussion of institutional requirements and constraints has focused on the implementation of a 20-million-gallon-per-year geothermal-alcohol demonstration project in the Raft River KGRA. The technology and economics favor a wheat-only or wheat and sugar beet based geothermal-alcohol facility of this size. The institutional constraints — transportation access, manpower and community resources, and water use — point toward a smaller-scale facility as being more appropriate for immediate implementation. A smaller facility, i.e., 5 to 10 million-gallon-per-year alcohol capacity, will have a less profound impact on the Raft River Valley and would be easier to implement. There would be economic penalties for the smaller scale which would lessen, but perhaps not erase, the economic attractiveness of geothermal-alcohol production.

Appendix A

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