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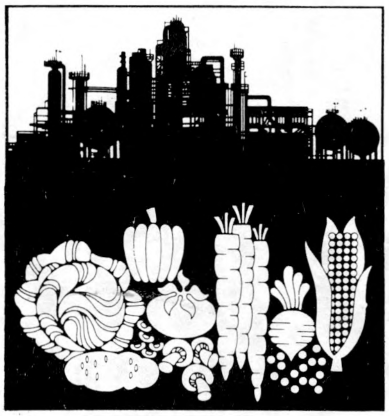

ALCOHOL FUELS GRANT PROGRAM

Integration and Testing of a Cogenerating Concentrating Solar Collector with Advanced Distillation Equipment

March, 1983

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INTEGRATION AND TESTING OF A COGENERATING CONCENTRATING SOLAR COLLECTOR WITH ADVANCED ALCOHOL-DISTILLATION EQUIPMENT

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Power Kinetics, Inc.

March 1983

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Summary

An advanced concept of vapor recompression of alcohol in a distillation column has been demonstrated. Its potential as a primary method separating alcohol from water lies in its operational simplicity, potential for automation, and low operating cost. Though it does use electrical power to drive the compressor, the benefits of using the heat of condensation to drive the reboiler warrant its use. Further development of a small alcohol burner to initiate startup and provide some reflux heat would eliminate any boiler with required water treatment, feed system, blowdown, and other operation/ maintenance aspects. Full heat recovery on the beer feed/ stillage/ alcohol subsystems and the reflux/ vapor- compression intake greatly enhance performance.

I. Project Evolution

The original project design, contemplated during 1979, has undergone several iterations of changes in its evolution into hardware. Work on the project began during the fall of 1981 at the onset of funding. Discussions with alcohol still operators, manufacturers, and chemical plant designers indicated that safety concerns eliminated use of a vacuum-type still by inexperienced operators. Vacuum leaks will draw in oxygen with the air which forms a potentially explosive mixture within the distillation column and ancillary apparatus.

Analysis of a conventional (atmospheric) distillation column shows that there can be substantial energy savings if a vapor recompression technique is used instead of a conventional condenser. Using this technique, alcohol vapor at the top of the rectifying column is adiabatically compressed so that its temperature is increased above that needed to boil the liquid in the reboiler at the bottom of the still. By doing so, the alcohol then at a higher pressure, will condense at this higher temperature, adding its heat of vaporization to the reboiler and not merely dissipate it in condenser cooling water.

Another step in the evolution of the system occurred during optimization of the originally proposed sieve plates in the column. Mass flow quantification, stability, and flexibility along with availability of dumped packings made their use expedient. Because of the way that the dumped packings work, an easy way to segregate the beer flow in the stripper section of the distillation column as the alcohol is removed was not found. Some unsuccessful effort was expended in developing a way to concentrate the suspended/dissolved solids in the beer to make their recovery and use as a protein supplement for animals.

The current cost of energy in the market place, along with the state of the economy, the system complexity and required investment for the PKI 80 m^2 solar collector, preclude mass marketing of a solar collector, electrical power generator and alcohol distillation package as proposed. For this reason connection of the still to the solar collector in any major way was not done. Controls, electrical power and fluid loops were kept completely separate to allow independent operation and quantification. Electrical power generated by the solar system was dumped into a load bank and line power was used to run the alcohol plant. Quantified steam from the exhaust of the steam engine was used to run the distillation column. This steam could have been generated by burning biomass of any other method. The solar collector does support the distillation column, which could be replaced by guy cables for an independent system.

Another change from the system proposed initially which used a steam boiler at the receiver of the solar collector, has been addition of a Syltherm loop to transport the energy from the receiver to the boiler. This use of a heat transfer medium eliminates the need for freeze protection of this portion of the system, allows higher performance of the steam engine, reduces the amount of 800 psi high pressure piping, and adds only minimal additional costs to the system.

The above changes to the original proposed work allowed the project to encompass the growing technology of fuel alcohol production as the researchers gained appropriate experience.

II. Description of the PKI Collector

Design Elements

The PKI collector has three primary subsystems: the Square Dish Concentrator, the Receiver/Fluid Loop, and the Microprocessor. These subsystems are described below:

The Square Dish Concentrator

The Square Dish provides the point-focusing function of the PKI system. It consists of 864 flat, one-foot-square, second-surface, silvered glass mirrors. The mirrors are affixed to rows of identical curved supports positioned in a faceted Fresnel design.

Each mirror assembly within the dish rotates through its center of gravity to provide elevation tracking. Two drag links each serve to interconnect half of the mirror assemblies. Each drag link is moved by a lead screw worm gear drive, which is mechanically connected to the elevation drive motor.

The dish is supported by a lightweight spaceframe structure composed of steel tubing members and steel plate joints. This design distributes all wind and gravity loads to the base supports.

The base of the structure is a circular track, inverted to eliminate problems of dirt and ice build-up. The track rides on wheels mounted on concrete piers and is motor-driven by a simple, reliable sprocket/roller chain assembly. The rotation of the entire collector on its base provides azimuthal tracking.

The Receiver/Fluid Loop

A well-insulated steel receiver is mounted on a boom at the focal point area of the square dish concentrator. A variety of receivers appropriate for specific applications have been tested, including monotube and parallel tube configurations.

The Microprocessor

A microprocessor-based package provides automatic two-axis tracking and operational control. Shadowbands mounted on the dish are the basis for active tracking during sunny periods. A software program provides azimuthal tracking during cloudy periods so that collection can begin immediately upon reappearance of the sun.

This feature permits the system to begin collection of energy after an extended cloudy period within 10 minutes of detection of a threshold insolation level. An added advantage is the reduction in parasitic losses, since a large motor is not required in order to "catch up" to the sun position.

The control package also includes a real time clock, digital display, and an integral digital voltmeter.

Automation and Safety Features

One key feature of the PKI collector is its ability to operate in an unattended mode. This is a reflection of the safety features built into the system, the microprocessor control and overall system reliability. The collector is protected against significant damage from any system malfunction or dangerous environmental conditions.

Automatic shut-down conditions include boiler overheating, low feedwater pressure, high winds, user-initiated manual stow, controller failure, AC power loss, low focus, and activation of the low limit switch on the elevation drive.

Although all control functions are automatic and do not require a human operator, periodic inspection is naturally required for maintenance and to resolve shutdowns.

Reliability and Ease of Installation

Reliability has been enhanced through recent design modifications that have either reduced the number of parts or provided for additional standardization. Other refinements have been made to enhance ease of installation and maintenance.

Platforms have been incorporated into the space frame supporting structure to allow safe and easy installation of mirror assemblies and the elevation drive package. The drag link assemblies are located behind the face of the collector, allowing ready access from the working platforms. An electric winch is incorporated into the design to permit easy raising and lowering of the boom for servicing the receiver.

(A review of the PKI technology is given in Applied Concepts Corporation's "Verification Testing of the PKI Collector at Sandia National Laboratories, Albuquerque, New Mexico and JPL's "The Solar Thermal Report" Vol 3, Number 2, February/March 1982. Both reports are provided as Appendixes F and G.

III. Syltherm Loop/Steam Engine

Syltherm, a silicon based oil which is usable up to 800°F, is the heat transfer fluid used to bring the energy reflected to the receiver of the solar collector, to the shed behind the concentrator. In a system which has undergone much more development, the location of choice for the engine/generator would be behind the receiver, 40 feet up the boom, to minimize heat losses and use of materials. In this demonstration project, it has been necessary to be able to closely monitor the engine, adjust valves, the oiler, and dynamometer setup, requiring these units to be operator accessible.

A monotube boiler, which is a coiled basket-like form of tubing, would have been the only way to construct a boiler at the receiver capable of taking the 800 psi used for the steam engine. Because it is very difficult to remove water from this type of receiver, which is necessary to prevent damage from freezing, a non-freezing medium was chosen to transport the heat to inside the heated building. Other aspects of the system which also made this choice expedient were boiler control restrictions and the ability then to utilize superheated steam in the engine. If steam is generated at the receiver, some forty feet from where the engine is located, heat losses would minimize the ability to deliver steam with any superheat to the engine. Superheated steam, requires very little energy to raise it temperature hundreds of degrees. The higher the temperature delivered to the engine, the better the Carnot efficiency. Because the Syltherm oil remains a liquid with a moderate heat capacity, it arrives at the heat exchanger only a few degrees cooler than it left the receiver. Superheated steam can expand in an engine (or outside, for that matter,) without beginning to condense, allowing the maximum amount of mechanical energy to be developed.

The Syltherm fluid loop, (see Figure 1), uses a turbine pump to force the fluid up through the receiver monotube coils and back down to inside the shed. There it first superheats steam in a counterflow heat exchanger, then boils water with the rest of its energy before being returned to the pump by way of a deaerator/expansion tank. Static pressure on this fluid loop is between 20 and 30 pounds per square inch.

The high pressure steam loop uses two pumps, one for circulating the high pressure water through the Syltherm/water heat exchanger, the other to maintain the water at the proper level in the boiler. Dry saturated steam is taken from the top of the boiler and run through the superheater before going through a steam separator to the engine. Valves associated with the engine are used both for control, (to insure proper soft startup) and to protect the system in the event of overspeed.

The steam engine, designed in the 1930's by the Doble brothers, uses two double acting cylinders, one high pressure the other low, making it compound. The high pressure cylinder, with a displacement of 1.8 cubic inches on the top side, expands the input steam and exhausts it to the low pressure side with a displacement of 7.4 cubic inches, topside (Volumetric Ratio 1:4). Balanced spool valves effect the transfer of the steam to the proper ends of the pistons. The steam engine is direct coupled to a DC generator set up as a dynamometer and able to measure torque and RPM as well as electrical power delivered. Electrical power is dissipated in resistance banks outide the building. Depending on parameters set on the load, and availability of sun, the system runs between 1100 and 2000 RPM, delivering between 8 and 16 HP. Exhaust steam can be wasted, condensed in an external condenser or shunted into the reboiler of the distillation column.

"K" type thermocouples are used throughout these loops to indicate temperatures (see Figure 1).

IV. Distillation Apparatus

The alcohol separation portion of this project has received most of the design attention. The distillation column is the major item of this system, with heat exchangers, pumps, a compressor, controls and lots of piping with fittings comprising the rest (see Figure 2).

Beer, or a 10% alcohol/water solution, is pumped from a holding tank through a filter and flowmeter and on through three heat exchangers in series. The first cools primarily non-condensible gases from the system to condense any alcohol which may have been carried through the gas separator. The next heat exchanger cools product alcohol, bringing its temperature to as low as practical to prevent excess vapor pressure losses in its storage vessel. The third heat exchanger cools the spent stillage on its way to its holding tank, recovering most of its heat. For 100 gallons of 10% beer, 90 gallons of stillage (primarily water) are delivered for reuse or irrigation, with 10 gallons of alcohol delivered to the product tank. The then superheated beer is injected at a port one quarter up the length of the distillation column. Because the stillage from the reboiler is at 212°F it heats the beer, then under about 150 psi pressure, above its boiling point at atmospheric pressure. The alcohol in this beer flashes to vapor along with some water and begins the reflux in the column.

The column is built in two sections, the lower built out of stainless steel being 15 inches in diameter and the upper made out of aluminum, 11 inches in diameter. Both are about 10 feet long. The lower column has two separators built into it to prevent the dumped packing from filling the bottom one foot, the reboiler section, or the 8 inch beer injection section at the middle of this lower column. At the beer injection port there are two valves in parallel, one under operator(or automatic) control to maintain a minimum level in the reboiler, the other a temperature operated valve which opens at a set temperature.

The speed of the beer feed pump is variable so that the injection pressure can be used to smooth out unwanted hysteresis. The still is started by filling the reboiler with beer and bringing it to a boil either by injecting steam in the heating coil or by electrically heating it. The rising vapors heat the distillation column from the bottom up and as the temperature probe at the beer injection port reaches the set temperature, it allows beer to begin spraying in at this point. To aid the purging of air from the column, the variable speed compressor is started slowly at this point. The compressor is connected to the upper end of the 20 foot column by an 1-1/4" tube. The compressor draws the gases up the column and down into the building where they are pumped through the reboiler and into a gas separator. Here any liquids are split into two flows, one returns back up the column to be injected at the top, the other is cooled by the beer flow and dumped into the product vessel.

The compressor, in compressing the gases from atmospheric to between 100 and 150 psi, increases their temperature. Once the distillation column has reached its operating temperature, with the top of the column between 175° and 185°, the compressor increases the alcohol vapors drawn from the top to about 220°, enough to boil the water in the reboiler in the bottom as the alcohol vapor condenses. Once all the air has been purged from the system, dissolved gases such as carbon dioxide must still be continuously purged from the system. Two adjustable pressure relief valves, one on each side of the gas separator, control this aspect of the system. The first maintains a pressure head on the compressor to insure the proper compression ratio for adequate heating. The second maintains enough pressure on the system to insure adequate transport of the reflux alcohol back to the top of the column and the product alcohol to its holding tank. Because the reflux alcohol comes from the reboiler at 212°F, it would be too hot to introduce into the top of the column without cooling. To alleviate this, it is run inside the downcomer tube carring the vapor to the compressor preheating it while cooling to the proper injection temperature.

The column is packed with Glitch 5/8" Metal Ballast Rings made of T-304SS. Their weight is 37 lbs/ft^3, with a surface area of 109 ft^2/ft^3 and free space of 93%. Seventeen cubic feet are in the distillation column. With the packed column including the steel and aluminum comprising the column, it requires about 30,000 Btu's to bring it to operating temperature starting at

60°F, or less than 10 minutes of output of the collector on a sunny day. This amount of heat is essentially not recoverable in that at shutdown, the heat is lost to ambient as the system slowly cools.

V. Test Performance

A 10.9% beer solution was made by mixing together denatured alcohol with water. Steam from a wood fired boiler was used to bring the distillation column and associated piping and heat exchangers to operating temperatures and also to supplement the vapor compression heat input to the reboiler. A three horsepower DC variable speed motor/drive was used to run the vapor compressor. Heat input was quantified by measuring the water condensed in the steam input loop in the reboiler. A steam separator and bucket trap was included just before the input to the loop to insure only steam entered this coil.

Initial heating of the distillation column was done by filling the reboiler with beer to the proper level, then bringing it to a boil by running steam through the steam coil. At boiling, the compressor was started so that the vapor could displace the air in the column. Once the entire column was brought to a high enough temperature (200°F at the beer injection port) the beer flow was started. From this time on the compressor was run at full speed. It took many runs to adjust beer feed rate, reflux injection and alcohol withdrawal rates. Once the system was roughly adjusted, a new run would take ten minutes for the system to reach equilibrium. It turned out that the steam coil was undersized which resulted in reducing system capacity. Since the outlet of the stillage from the reboiler section of the column is gravity fed back to the tank by way of the heat exchanger, a column pressure at or above atmospheric is required. Attempts to run the still at rated throughputs (20-30 gpm alcohol out) resulted in reducing the pressure in the column below atmospheric which prevented outflow of the stillage.

To bring the still and the 19.8 gallons of feed in the reboiler to operating temperature, 56,300 Btu were required, at an ambient temperature of 45°F. In addition, heat was required to raise the crankcase and oil temperature of the compressor above the condensation temperature of the alcohol, amointing to 1.3 Kwhr. Once this temperature was achieved, the heater was turned off since the heat transfer from the alcohol vapor and the compressor were adequate to maintain the 200°F temperature. The 3 HP motor driven compressor required 2.7 Kw of electrical power input. In addition, the beer feed pump required 0.26 Kw. Steady state maximum throughput at the reduced capacity required by the inadeqate steam coil was 7.2 gallons of 192 proof (via hydrometer) alcohol per hour, tabulated as follows:

Output(gph)	Reflux(gph)	Steam(Btu)	Electrical(Btu)
7.2	7.4	68,300	10,100

Total Btu required for the 7.2 gallons per hour were 78,400 for a rate of 10,900 Btu per gallon. Since capacity reduction of the compressor was accomplished by throttling the output, performance reduction also occurred. Heat losses per gallon were also high since the still can handle four times the throughput with the addition of a stillage pump and by increasing the surface area of the steam reboiler coil. These heat losses when prorated over 20-30 gallons of output would reduce the heat required per gallon ethanol delivered.

In conclusion, the prototype system functioned remarkably well at this proof-of-concept stage of development. Avenues for system modification and refinement which will result in a significant improvement in performance are clear. (See Section VII)

VI. Economic Analysis

An economic analysis of a packaged system, a solar collector, steam engine, and alcohol still, shows no short-term feasibility. This is largely due to high interest rates which offer more to an investor (farmer) than than an investment in hardware which can be avoided in producing alcohol. The solar collector and steam engine can be purchased for $59,500-$72,000 installed when produced in moderate quantities. An economic analysis of these two components (see Table I and Table II) using a price of displaced fuel oil at $1 per gallon indicates that a $72,000 to $59,500 capital cost would not be paid back for eleven or twelve years. The present value of future fuel savings from the system over twenty years is $55,733, less than the installed value of the system produced in small quantities.

A similar analysis of the alcohol still indicates shorter term viability.

Attachment I, a photocopy of a Canadian journal lists several figures for this analysis as follows:

1. One acre of farm produces three bushels of screenings.

2. Ethanol is selling for 55¢/litre.

3. Screenings from 56 (170,000 bushels/1000 head divided by 3 bushels/acre) acres produce enough mash to feed one head of cattle after processing.

4. 1.1 gallon of ethanol is derived from one bushel of screenings.

5. .00676 tons dry livestock feed are produced from one bushel of screening (170,000 bushels/1150 tons) used to make alcohol.

6. Screenings are unused today by the farmer.

Currently in Saskatchewan, screenings (small particles normally mixed in with grain) from a 4500 acre farm are not only unused but additional charges are incurred for shipping and storage of the screenings. The screenings would produce $24,000 in alcohol revenues for the farmer calculated as follows:

4,500	acres
x 3	bushels per acre
13,500	bushels of screenings
x 1.1	gallon ethanol per bushel of screening
14,850	gallons of ethanol per 4500 acre farm
$2.00	per gallon ethanol (lower grade than 55¢/litre)
$29,700	per farm
90%	efficiency (10% waste assumed)
$26,730	gross revenue from alcohol sales from screenings

In addition, the byproducts of the alcohol operation could feed 80 head of cattle from the partially dehydrated mash, for a value of $12,328 at $135 per ton. This value however would off-set the cost of labor to distribute the seed and process the wash for the alcohol operation.

The costs for establishing the above production are as calculated:

$ 6,000	seed cleaning equipment
30,000	alcohol still as per Power Kinetics, Inc. design
20,000	miscellaneous beer equipment
$56,000	

Without counting labor the payback could be less than three farming years (see Table III and Table IV).

Labor costs for operating the still are estimated as follows:

14,850 gal. of ethanol / 25 gal. / hour = 594 hours of production or approximately 33 daysto process the screenings from a 4500 acre farm.

4 hrs. labor / 18 hrs. of production (1 day)
x 33 days days production (18 hour day) = 132 labor hours
at $10 per hour = $1,320.

The labor hours connected to the still operation have little impact on the farming operation since such hours could be scheduled off season from other farming operations.

The example of the 4500 acre farm using screenings was used since it is the shortest term market for such a product. Where cooperatives are formed, the alcohol still used under this grant can handle 10-12 times the capacity of the screenings from a 4500 acre farm. We will not judge what costs would be added to scale up the independent operation discussed in this paper. Using grain could also convert produce into energy without giving up the good value of the grain altogether. It is not our expertise to calculate the food value of the by-products from the distillation system. With whole grain, the estimated value of the by-product is roughly 30% of the original grain.

In view of the current price of energy today, the solar collector portion of the Power Kinetics system under this grant is unjustified. The solar collector provides the same output as alcohol or fuel oil and would have to be priced to compete head on with these traditional alternatives, net of energy tax credits and other incentives. Today the Power Kinetics solar collector cannot be sold at such a competitive price with alcohol priced at $1.00 per gallon from the alcohol plant under study.

This economic analysis did not consider methods of distribution in assessing costs of installed equipment. Specific methods of distribution have identifiable costs which must be added to those estimates of costs given.

TABLE I

ECONOMICS - POWER KINETICS SOLAR COLLECTOR MARCH 25, 1983

ASSUMING THAT 1 YEAR'S SOLAR ENERGY FROM COLLECTOR IS
EQUAL TO ENERGY FROM USE OF 2400 GALLONS OF FUEL OIL

PER GALLON COST OF FUEL DISPLACED	1.00	MONEY @ 12%	1.12
FUEL ESCALLATION	.15 *		

YEAR	$ AMOUNT FUEL DISPLACED	PAYBACK	MULTIPLIER (PRESENT VALUE OF FUTURE $)	PRESENT VALUE OF FUTURE $	CUMULATIVE PRESENT VALUE OF FUTURE $
1	2400	2400.00	.8928571429	2142.86	2142.86
2	2760	5160.00	.7971938776	2200.26	4343.11
3	3174	8334.00	.7117802478	2259.19	6602.30
4	3650	11984.10	.6355180784	2319.70	8922.01
5	4198	16181.72	.5674268557	2381.84	11303.85
6	4827	21008.97	.5066311212	2445.64	13749.49
7	5551	26560.32	.4523492154	2511.15	16260.63
8	6384	32944.37	.4038832280	2578.41	18839.04
9	7342	40286.02	.3606100250	2647.47	21486.52
10	8443	48728.92	.3219732366	2718.39	24204.91
11	9709	58438.26	.2874761041	2791.20	26996.11
12	11166	69604.00	.2566750930	2865.97	29862.08
13	12841	82444.60	.2291741901	2942.73	32804.81
14	14767	97211.29	.2046198126	3021.56	35826.37
15	16982	114192.99	.1826962613	3102.49	38928.86
16	19529	133721.93	.1631216618	3185.59	42114.45
17	22458	156180.22	.1456443409	3270.92	45385.38
18	25827	182007.26	.1300395901	3358.54	48743.91
19	29701	211708.35	.1161067769	3448.50	52192.41
20	34156	245864.60	.1036667651	3540.87	55733.28
TOTALS	245865	245864.60		55733.28	55733.28

* FUEL PRICES BY YEAR:

YEAR	FUEL COST	YEAR	FUEL COST
1982	1	1991	3.52
1983	1.15	1992	4.05
1984	1.32	1993	4.65
1985	1.52	1994	5.35
1986	1.75	1995	6.15
1987	2.01	1996	7.08
1988	2.31	1997	8.14
1989	2.66	1998	9.36
1990	3.06	1999	10.76

TABLE II

POWER KINETICS, INC.
ECONOMIC ANALYSIS
OF SOLAR COLLECTOR
AND STEAM ENGINE

PRICE OF EQUIPMENT TO BE PAID BACK:

	SOLAR COLLECOR ECONOMICS	
ITEM OF COST	PRODUCTION @ 50 UNTTS PER YEAR	PRODUCTION @ 100 UNITS PER YEAR
70 (M) 2 SOLAR COLLECTOR	55000	45000
SEED CLEANING EQUIPMENT		
STILL PACKAGE		
STEAM ENGINE	7000	4500
MISC. BEER EQUIPMENT		
INSTALLATION	10000	10000
TOTAL	72000	59500

ENERGY DISPLACEMENT:

TABLE III

ECONOMICS - ALCOHOL STILL USING GRAIN SCREENINGS

3/25/1983

PER GALLON COST OF ALCOHOL 2.00

MONEY @ 12% 1.12

ALCOHOL FUEL ESCALLATION .15 *

YEAR	$ AMOUNT OF FUEL PRODUCED	PAYBACK	MULTIPLIER (PRESENT VALUE OF FUTURE $)	PRESENT VALUE OF FUTURE $	CUMULATIVE PRESENT VALUE OF FUTURE $
1	26730	26730.00	.8928571429	23866.07	23866.07
2	30740	57469.50	.7971938776	24505.34	48371.41
3	35350	92819.93	.7117802478	25161.73	73533.15
4	40653	133472.91	.6355180784	25835.71	99368.86
5	46751	180223.85	.5674268557	26527.74	125896.59
6	53764	233987.43	.5066311212	27238.30	153134.90
7	61828	295815.54	.4523492154	27967.90	181102.79
8	71102	366917.87	.4038832280	28717.04	209819.83
9	81768	448685.56	.3606100250	29486.25	239306.08
10	94033	542718.39	.3219732366	30276.06	269582.13
11	108138	650856.15	.2874761041	31087.02	300669.16
12	124358	775214.57	.2566750930	31919.71	332588.87
13	143012	918226.75	.2291741901	32774.70	365363.57
14	164464	1082690.77	.2046198126	33652.60	399016.16
15	189134	1271824.38	.1826962613	34554.00	433570.17
16	217504	1489328.04	.1631216618	35479.56	469049.72
17	250129	1739457.25	.1456443409	36429.90	505479.63
18	287649	2027105.83	.1300395901	37405.70	542885.33
19	330796	2357901.71	.1161067769	38407.64	581292.98
20	380415	2738316.96	.1036667651	39436.42	620729.39
TOTALS	2738317	2738316.96		620729.39	620729.39

* FUEL PRICES BY YEAR:

YEAR	FUEL COST	YEAR	FUEL COST
1982	2	1991	7.04
1983	2.30	1992	8.09
1984	2.65	1993	9.30
1985	3.04	1994	10.70
1986	3.50	1995	12.31
1987	4.02	1996	14.15
1988	4.63	1997	16.27
1989	5.32	1998	18.72
1990	6.12	1999	21.52

TABLE IV

POWER KINETICS, INC.
ECONOMIC ANALYSIS
OF ALCOHOL STILL
USING GRAIN SCREENINGS

PRICE OF EQUIPMENT TO BE PAID BACK:

ITEM OF COST	PKI ALCOHOL STILL PRODUCTION @ 50 UNITS PER YEAR	 PRODUCTION @ 100 UNITS PER YEAR
70 (M) 2 SOLAR COLLECTOR		
SEED CLEANING EQUIPMENT	6000	6000
STILL PACKAGE	35000	30000
STEAM ENGINE		
MISC. BEER EQUIPMENT	25000	20000
INSTALLATION	2500	2500
TOTAL	68500	58500

North America's first

Grain screenings feedstock for Prairie ethanol plant

By JOHN MEISSNER
KERROBERT, SASK.

NORTH AMERICA'S first fuel ethanol plant to operate entirely on grain screenings will open here this fall in a venture that is hoped will lead a new prairie fuel alcohol movement.

The 700,000-litre-a-year plant will be owned and operated by Northwest Food and Fuel (NWFF), a Saskatoon-based company made up of 25 area wheat farmers and seven other individuals.

A recent $199,200 grant from the Enterprise Development Corporation of the federal Department of Industry, Trade and Commerce has provided the extra funding needed for the plant, to be built 200 km west of Saskatoon. Construction is expected to be complete by late October.

Twenty-three-cent-a-litre anhydrous ethanol will be produced from the $250,000 still, says David Malcolm, engineer and president of NWFF, using 170,000 bushels a year of undried screenings. As well, 200,000 gallons of a liquid, protein-rich byproduct will be centrifuged out of the moist feedstock, to be used as a fertilizer. Also 1,150 tons of dry livestock feed will be produced, presently selling for $135 a ton.

The commercial prospects for the operation look excellent, as Malcolm says NWFF is already negotiating two contracts to sell ethanol at 55 cents a litre.

Seed cleaning

At present, very few Canadian farmers have chosen to invest the $3-6,000 necessary to purchase seed cleaning equipments. For most, a weight dockage is even recorded against them at either the local elevators or the export terminals at Vancouver and Thunder Bay.

The use of a feedstock that is not only free, but saves the expense of carting it away, therefore looks very attractive.

Up until now, as much as 70 per cent of these screenings have been sold by grain trading companies at $80 a metric ton for use as cattle feed in the United Kingdom, with no return, only the dockage, for Canadian farmers.

Coincidently, this market may soon dry up as both France and Denmark are insisting the European Economic Community double its duty on screenings and systematically raise tariffs to protect the Community's feedstock industry.

"Such a move would inhibit the export of screenings, encourage local, efficient use of a Canadian product, and cut down on transportation costs," says Malcolm.

He adds, "Farmers are getting an average of three bushels of screenings per acre and this adds up to the continuous use of 1,000 hopper cars just to ship the screenings. Besides taxing the grain transportation system's capacity, farmers have to pay to ship their screenings only to give them away."

At a time when the Federal government is going to revise Western Canadian shipping rates, the cost of transporting grain is a sensitive issue with Prairie farmers.

Prototype

Ralph Sweet, a farmer from Forgan who works 4,500 acres with his two sons is one of the founders of NWFF. He sees the Kerrobert plant as a prototype for prairie communities. Along with 25 other farmer-shareholders Sweet advocates farm scale production of ethanol as a means of survival in the face of rising costs for farm imputs and lower grain prices.

If Ralph Sweet and David Malcolm's plant produces as expected, their dream of every prairie community having its own ethanol plant will be hard to resist.

Malcolm explains, "Our company started out with a group of friends which developed into a small network of 32 shareholders. We're out to make a couple of points. First, farmers can utilize all of the protein in their crop and make money on the alcohol by-product. Second, the protein produced is good enough for human consumption. And finally, farmers can sell a finished product rather than a raw material which gets finished in some other country." The Kerrobert plant will be built to standards which allow for human consumption of the protein.

Northwest Food and Fuel has raised over $66,000. from its shareholders and will be submitting a prospectus to the Saskatchewan Securities Commission in order to raise another $400,000. The total project is expected to cost around $650,000.

Background studies

Before Industry, Trade and Commerce approved the decision they asked for background studies on the availability of screenings as a front end supply, the demand for livestock feed, and studies on the conversion rates of screenings to alcohol.

The department then helped to fund an initial study by Kembur Engineering Consultants Ltd. of Thunder Bay with a $10,000 interim grant. Kembur's report established a conversion rate of 1.1 gallons of ethanol per bushel of screenings.

The plant will require 170,000 bushels of screenings per year, but 210,000 bushels are currently available in the area, indicating an adequate supply on an ongoing basis.

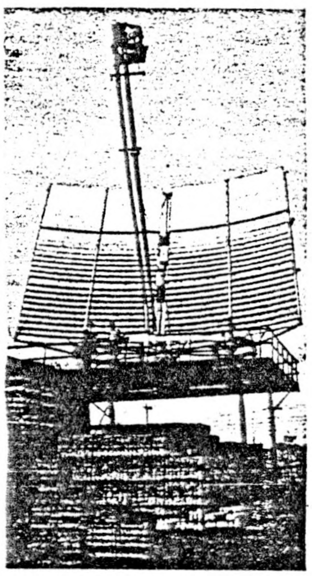
It is hoped the Kerrobert operation will produce enough partially dehydrated (60 per cent moisture) mash to feed 1,000 to 1,200 head of cattle. The feed, assessed by the Saskatchewan Department of Agriculture, is regarded as palatable and nutrious. When Kembur Engineering surveyed the market around Kerrobert, they received assurances from one area cattle feeder he would buy all the feedstock produced.

Another byproduct of the ethanol plant that could be eventually exploited is carbon dioxide which could be pumped into adjacent greenhouses to enhance plant growth.

With gasoline prices planned for as high as $3.75 per gallon in 1986 under the National Energy Plan, NWFF thinks its ethanol plant will be a winner and the first of a series for the Canadian plains. How many other projects can guarantee a secure fuel supply for 20 large prairie farms, feed over 1,000 head of cattle, produce a liquid product that can be used for feed and fertilizer, utilize waste, create jobs and show a healthy profit?

Northwest Food and Fuel's David Malcolm

60 kW concentrator cures concrete blocks



By CHRISTOPHER POPE
TOPEKA, KANSAS

SOLAR PARABOLIC dish development makes another gain with the scheduled June startup here of the sole industrial test facility to be funded under the Department of Energy-sponsored Jet Propulsion Laboratory solar thermal program.

The automatic-tracking 864 square-foot Power Kinetics reflector unit will power a small, commercial, boiler-sized receptor to produce about 60 kW, or 174.5 lb/hr. of industrial process heat. The $500,000 mirrored machine, recently rated 80 per cent efficient at peak collection now stands in the workyards of Capital Concrete Products here, which plans to use it to pressure-cure some 8,000 concrete blocks daily.

"This is a test, not a demonstration," a JPL official points out, noting contractors already successfully corrected various problems with plumbing-line freeze-ups and wind damage. Says Scott Hauger of Applied Concepts, Inc., the Virginia-based project installer: "In my opinion, it's the best design that's available today, and the best in the near future for industrial applications."

Meanwhile, DOE turns its parabolic trough program to the private sector. Two government/industry cost-shared parabolic trough technologies manufactured by Solar Kinetics Corp. of Dallas—considered "benchmark engineering jobs" at 50,400 square-feet each—are to begin operation within the month.

The Caterpillar Tractor manufacturing plant in San Leandro, California and the U.S. Steel Chemical Plant in Haverhill, Ohio will host the projects.

VII. Recommendations for Additional Work

The system assembled and tested represents a tremendous development effort which with small modifications can be a fully commercial system. The following additional work would allow confidence in a plant which does not require the use of condensing coils and the resulting rejection of low grade heat:

1. Use of a hermetically sealed system which uses a heat pump with a refrigerant instead of the alcohol vapor recompression. With the existing system, contamination of the crankcase oil, corrosion of the cylinder walls and valves during shutdown, and the requirement to have a liquid elimination system on the inlet of the compressor require greater operator care than a sealed system.

2. Addition of a stillage pump would allow greater flexibility in system design.

3. Use of a larger steam coil in the reboiler and use of a 10 HP compressor would allow up to 30 gallons per hour alcohol delivery with well under 10,000 Btu per gallon heat input requirement.

4. Addition of an alcohol burner directly on the reboiler section would eliminate any need for a steam boiler and require less than 5% of the system alcohol output. Such a system would

also be very easy to automate and would greatly simplify installation and operation of the still.

LISTING OF FIGURES

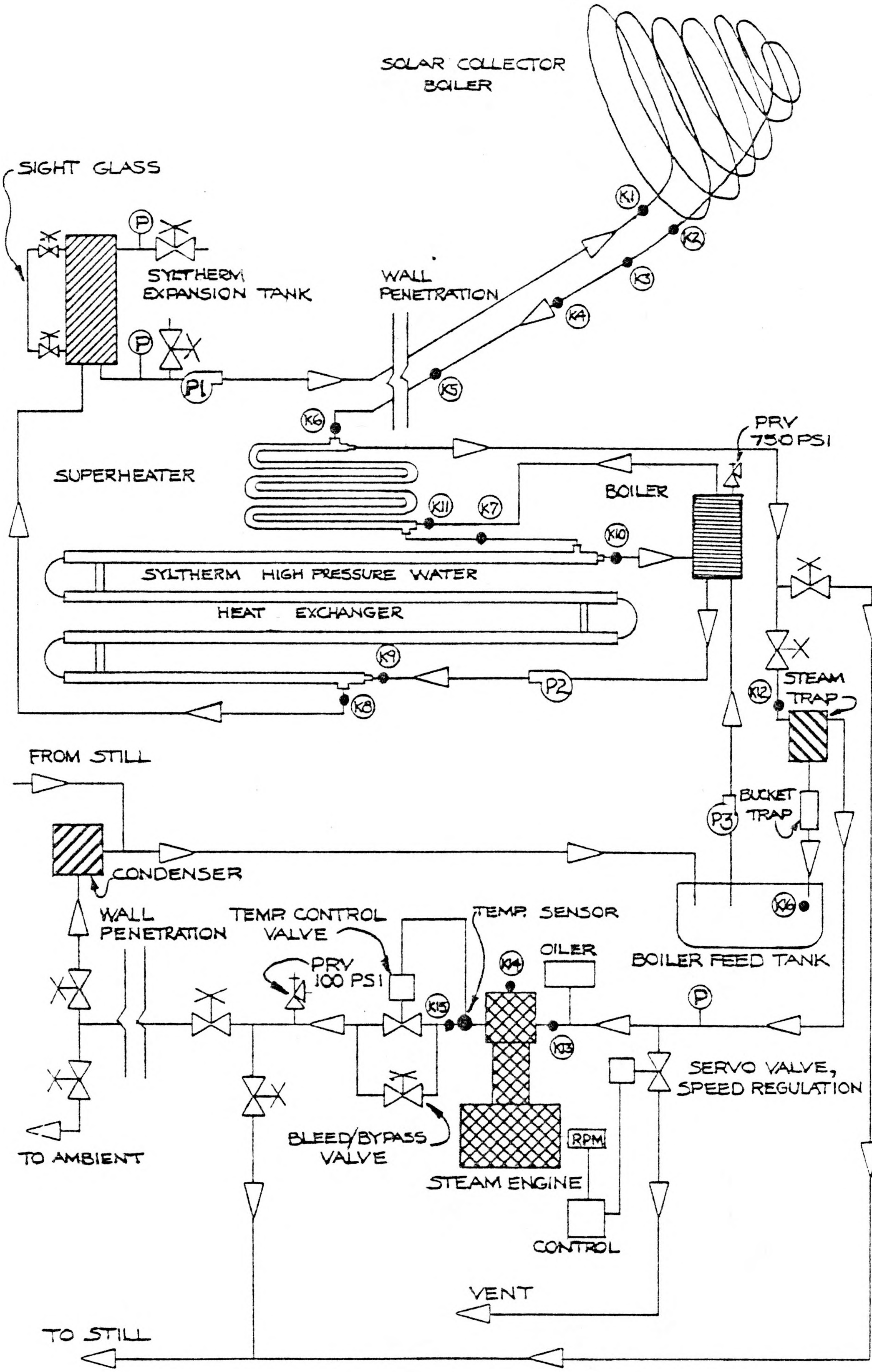


FIGURE ONE
SYLTHERM, HIGH PRESSURE
STEAM LOOPS

● (K) = "K" TYPE THERMOCOUPLES

FIGURE TWO
DISTILLATION COLUMN AND
ASSOCIATED FLUID LOOPS

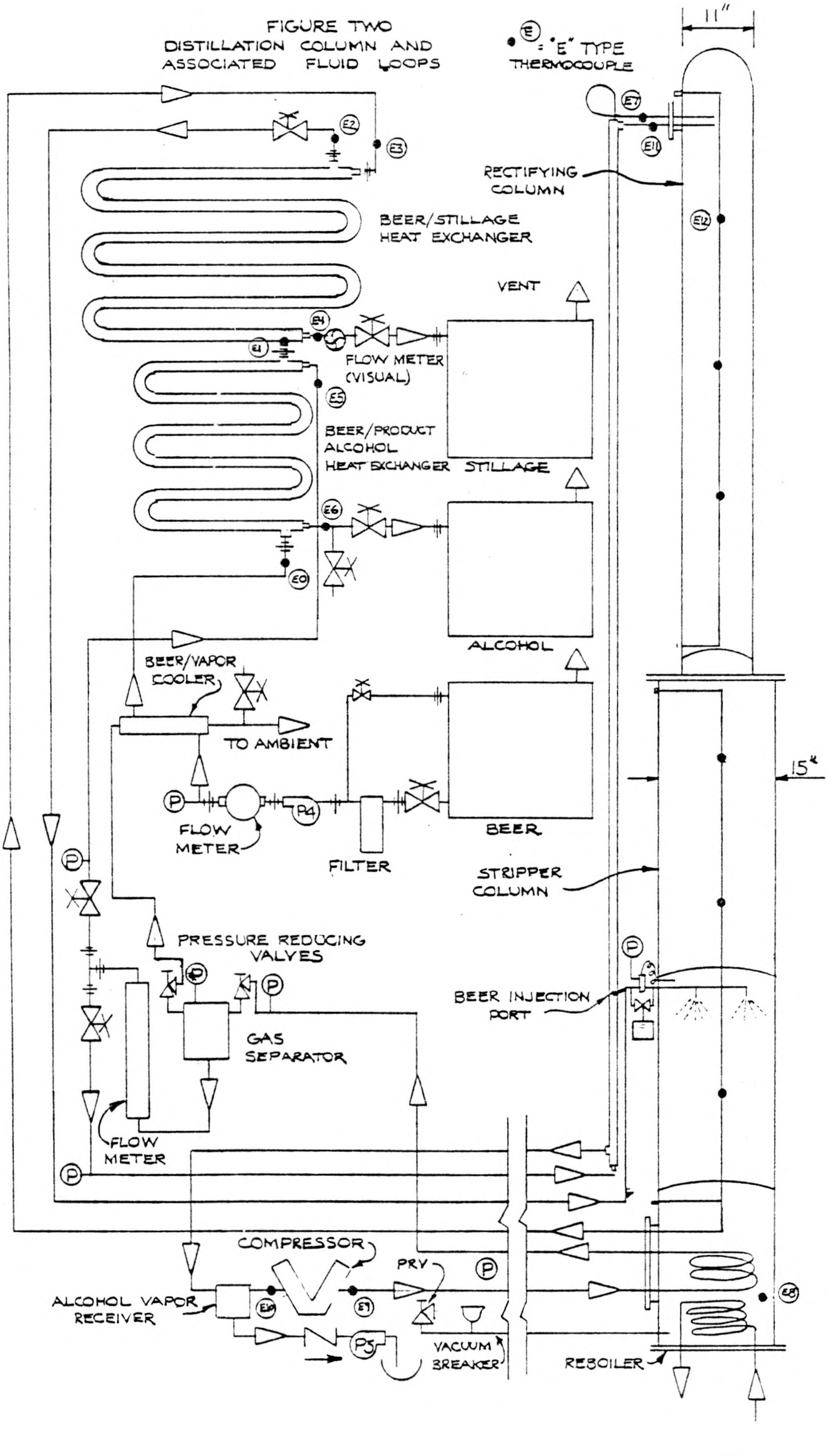


Figure 3

TYPE "K" THERMOCOUPLES

K_1	Receiver in
K_2	Receiver out
K_3	Start foil insulation
K_4	Foil/regular insulation junction
K_5	Regular insulation end
K_6	Superheater out - Syltherm
K_7	Superheater in - Syltherm
K_8	Syltherm/water heat exchanger out
K_9	Water in/Syltherm heat exchanger out
K_{10}	Water out/Syltherm heat exchanger out
K_{11}	Steam in/superheater
K_{12}	Steam out/superheater
K_{13}	Engine in
K_{14}	Engine HP-LP crossover
K_{15}	Steam out/engine
K_{16}	Boiler feed sump

Figure 4

TYPE "E" THERMOCOUPLES

E_0	Beer into alcohol heat exchanger
E_1	Beer into stillage heat exchanger
E_2	Beer out of stillage heat exchanger
E_3	Stillage into stillage heat exchanger
E_4	Stillage out of stillage heat exchanger
E_5	Alcohol in alcohol heat exchanger
E_6	Alcohol out of alcohol heat exchanger
E_7	Alcohol out of vapor/reflux heat exchanger
E_8	Reboiler
E_9	Compressor out
E_{10}	Compressor in
E_{11}	Alcohol vapor in vapor/reflux heat exchanger
E_{12}	Distillation column