11933

CONTROLLED ENVIRONMENT LIVESTOCK PRODUCTION SYSTEM COMPUTER SIMULATION AND ANALYSIS (DAIRY)

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INTRODUCTION

Digital computer simulation was used to investigate the peak, steady energy utilization of a geothermal energy-supported dairy. A digital computer program was also written to assess the lifetime economics of the dairy operation. A dynamic simulation program was written to design water storage tanks under diurnal transient loading.

The geothermal site specified is the artesian spring named Hobo Wells near Susanville, California. The dairy configuration studied is unique, but consists of conventional processing equipment. In the dairy, cattle waste would be used to generate methane and carbon dioxide by anaerobic digestion. Some carbon dioxide would be removed from the gas stream with a pressurized water scrubber to raise the heating value. The product gas would be combusted in a spark ignition engine connected to an electric generator. The electrical power produced would be used for operation of fans, pumps, lights and other equipment in the dairy. An absorption chiller using a geothermal water driven generator would provide milk chilling. Space heating would be done with forced air hot water unit heaters.

The steady state computer simulation designs (sizes) much of the equipment in the dairy based on herd size. A building thermal analysis of all barns is performed based on user-controlled climate and building heat transfer parameters. The fluid transmission piping is sized and insulation thickness is selected for hot water pipes, using an optimization approach based on thermodynamic availability. The user has control of pipe length, flow rate, temperatures and the model network of pipes to be used.

Computer runs were made for a 200 milking cow dairy (412 animals) for a particular dairy layout (building orientation and piping network) and building design. A winter run was used to size pipes and some other equipment. A summer run shows the energy utilization of the designed dairy under summer climate conditions.

The program is written in BASIC and is very well documented. The report includes an extensive user manual to aid in the application and/or alteration of the simulation.

The 412 animal dairy has been laid out and drawn to scale showing all functional components. A list of equipment specifications for this dairy has been included.

Energy utilization studies under peak load conditions revealed no energy limitations of the system. Only a small fraction of the available energy flow from the geothermal reservoir would be required. The generated electrical power allows the dairy to operate with near energy independence.

The economic analysis of the 200 milking cow model dairy has been determined to break even in about the second year of operation; however, it becomes cost and return equal to the conventional type operation in about the seventh year. Given the cost of investment normally involved in dairy operations, seven years is not unreasonable, since the net gain over the conventional system continues to widen over time for the non-conventional model.

The model dairy operation simulation, the subject of this study, is not conceived to be at maximum efficiency. Further analysis and experimentation with manure recycling as a fraction of the feed input ova transplant system, complementary activity such as greenhouse or fish culture operations, have not been included to determine the possible benefit for either the conventional or non-conventional dairy operation. It is thought that any of these activities would favor the non-conventional system economically. The latter is likely, since a good deal of the necessary capital is in place for non-conventional dairy operations that would also be adequate for various selected complementary operations.

THE C.L.R. CONSORTIUM

The C.L.R. Consortium is an organization established in 1976 by research scientists at California State University, Chico; Lassen College, Susanville, California, and the University of Nevada, Reno, Nevada. It was established for the purpose of bringing together certain technical and scientific competencies. A second and equally important reason is the fact that the service area of the three institutions party to this consortial arrangement is believed to hold vast geothermal, solar, wind and biological energy resources. The Consortium was also mindful of the increasingly important roll that imported fuel energy plays in the current and future economy of the United States. The impact of imported oil on the balance of payment is clearly expected to have serious effects on the United States standard of living, the continued economic growth, and, finally, the continued survival of basic American institutions. Continued growth and development is dependent on the ability of the American system of inventiveness to achieve suitable substitutions for imported energy resources.

The Consortium, due to its unique organizational arrangement, has a flexibility that makes possible involving the vast resources of the three institutions in almost an unlimited variety of research, teaching and public service activity. The Consortium has access to both undergraduate and graduate students to assist in its research and teaching effort. This sort of arrangement also makes possible the development of a trained cadre for any new technology being involved.

THE REPORT

The C.L.R. project titled "Controlled Environment, Livestock Production System Computer Simulation and Analysis (Dairy)" was an attempt at exploring practical ways for using low heat geothermal brines in the operation of a livestock enterprise. The underlying objective for this project, as well as for projected future work, is to achieve some optimum level of fossil fuel energy independence in various agricultural and food processing activity. There were numerous livestock or farming activities considered at the outset of the project; however, it was determined by the C.L.R. investigators that the modern dairy enterprise would be the most manageable for simulation. The reason that the dairy enterprise would work well as the candidate activity is the fact that there is significant control over both imputs and outputs. This characteristic for control had to exist for both engineering and economic feasibility analysis. In effect, the candidate activity had to have a high level of measurability (Quantification) when operated under traditional or non-traditional methods of dairying. From the economic point of view, the procedure for investigation was to make simple activity cost comparisons as part of the total analysis--a sort of partial budgeting.

The commercial dairy operation has other characteristics that made it attractive to the research team. Modern dairy farming is highly concentrated, which means that land resources required are small when compared with most other livestock enterprise activitiy; also, the practical substition of machines for human labor is continuous and is currently rather substantial. The introduction of new or innovative technology seems more possible with the dairy operation as compared with cattle or hog operations. For example, it would be a good deal more difficult to introduce the practice of superovulating high yield animals in the commercial beef operation, yet, in the modern commercial dairy, this practice could produce substantial economic gains. It has become increasingly clear that future gains in dairy efficiency are tied to germ plasm management. Included are almost all of those traits that contribute to increased economic returns such as increased milk yield, high fat test, and increased milk fat production. Not so obvious, but also contributing to economic benefits and also related to dairy genetics, is efficiency in feed conversion, disease resistance, longivity, and other characteristics that contribute to technical and economic efficiency.

From an engineering point of view, the dairy enterprise also presented some advantages over other livestock activity. The dairy operation lends itself to quantification. That is "the numbers" are known and can be related to considerations of space, structural or building needs, and, above all, to energy demands. It was the opinion of the research team that if the dairy simulation could be made to function, it would serve as a useful method for investigations involving other animal agricultural activities. [See: Figure 1 - Geothermal or Waste Heat Flow System (Energy Cascade) - Model A.].

The simulation approach to economic and engineering analysis has obvious advantages. It makes possible the determination of feasibility of high capital and operationally expensive production activities at fairly low costs. Simulation is an effective partial substitute for what would otherwise involve substantial capital cost for scale development of a suitable dairy model for testing alternative operation techniques and practices. In this study, the simulation method was used to investigate the peak, steady energy utilization of a geothermal energy supported dairy.

It was also intended that a dynamic simulation program would be written to determine the variable energy demand for the model dairy. However, the final outcome was a fairly limited application of the dynamic simulation program. It provides simulation for purposes of design of water storage tanks under diurnal transient loading. A digital computer program was also written to assess the lifetime economics of the dairy operation and a 20-year cycle was used.

SIMULATION FINDINGS

The model dairy used in the study is unique, but consists of conventional and readily available equipment. In the model dairy, the waste materials are used to generate methane and carbon dioxide by anaerobic digestion. Some carbon dioxide is removed from the gas stream with a pressurized water scrubber to raise the heating valve of the scrubbed methane gas. The methane gas produced is burned in a spark ignition engine connected to an electric generator. The electric power generated is used to operate fans, pumps, lights, milking machines, and other essential equipment in the dairy.

The steady state computer simulation designs (sizes) much of the equipment in the dairy based on herd size. [See: Plot Design A-E]. A building thermal analysis of all barns (out buildings) is performed based on users-controlled climate and building heat transfer perimeters. Fluid transmission piping is sized and insulated thickness is selected for hot water pipes, using an optimization approach based on thermodynamic availability. The user has control of pipe length, flow rates, temperatures and the model network of pipes used.

In the steady state simulation, computer runs were made for a 200 milking cow dairy operation. Total animals in dairy operations is 412. A winter run was used to size pipes and some other equipment. A summer run shows the energy used by the model dairy under summer climatic conditions.

The outcome, for the engineering design as determined by simulation is that under peak load conditions there was no essential energy limitations in the model (non-conventional) dairy. A goal of the study was to identify, and model for computer-aided simulation, a configuration of a dairy system which appeared to have economic and technical promise, when thermally assisted by geothermal water from particular reservoir. The specific geothermal site where temperatures and chemical characteristics affected this design was the Hobo Wells site near Wendel, California. It is an artisian hot spring with flow of approximately 1200 liters/min. (317 gal./min.) and a temperature at point of eruption of 99^{o} C (209^{o} F.).

As a point of reference, based on an ambiant condition of 27^{o}C (80^{o} F.), this is an energy flow of 3.6×10^{5} KJ/min. (3.4×10^{5} BTU/min.) using current electricity costs in the Wendel, California area of about 0.05 $/Kw/hr. This energy has a value of about $/min., or 7,000 $/day. Basing the value of a low grade energy source on the cost of a high grade energy is not normally correct, but if all heating and cooling were to be done with electricity (along with all the usual electric power applications, such as lights, pumps, and fans) with conversion efficiencies of 100%, this procedure would be correct. However, one determines a value for geothermal internal energy and it is apparent that it is worth investigating applications for it.

In any event, the geothermal dairy required only a small fraction of the available energy flow from the Hobo Springs source. The direct application [See: Plot Plan A1] of geothermal fluids along with the geothermally assisted methane production for electricity generation makes the model dairy essentially energy independent.

The engineering and economic concept of "Controlled Environment" conveyed to the investigators the idea that two distinct functions are involved: first, that the physical environment could, in some measure, be controlled to enhance the production of milk, meat and replacement animals; and, second, that resources flowing into the system could be managed with the same output goals but that the inputs could be from different or non-conventional sources. For example, as is pointed out above, the model commercial dairy operation is made energy independent of outside gas and electricity by the geothermally assisted methane generation system and by direct application of geothermal fluid.

From the economic point of view, the benefits accrueing are of three sorts: first, the substitution of a currently under-employed energy resource (conservation) for an energy resource that is becoming increasingly more valuable and scarce, second, the quality of the environment is favorably and most directly effected by the conversion of the dairy manure to a non-offensive organic soil builder, that does not attract flies, rodents and other nuisances. The latter is one of the very attractive spin-offs considering the location and technically concentrated nature of the dairy operation; third, the residue produced from methane operations have potential uses or imputs to selected complimentary activities. For example, organic waste produced by the digestion process could be used in the production of greenhouse products as a growing media--a greenhouse tie-in to the dairy may be economically very attractive.

The question of value of the digestion waste becomes important when waste disposal costs, and possible alternative uses are considered. It is likely that the processed manure would be an acceptable consumer product for garden soil uses or other uses. These issues are still to be resolved. It needs to be kept in mind that the manure from the dairy has other uses than to generate methane gas. The selection of the methane activity is simply a choice of one of several alternative uses for the manure in the model configuration. For example, some researchers have indicated that with certain treatment, dairy manure can be used as feed. It has been suggested that as much as one-half of the total ration in some feeding routines could be from the manure source. The economic and engineering questions raised by this alternative are important from the point of view of both technical and economic efficiency. Which of the several alternatives produces the best returns in energy and dollar revenue?

For example, assuming that one-half of the feed for dairy cows could be from manure of the milking herd, and assuming that about 6,000 pounds of feed is required per non-milking dry cow, then it is possible to value the trade-offs between alternatives. The following uses, current alfalfa hay prices as the basis for calculation of the trade-off:

a. Alfalfa hay-delivered: $75/ton
b. Amount of roughage feed required per non-milking cow: 6,000 lbs.

Total manure 1.5 ton equivalent (Ensilaged)	$ 75.00
Total alfalfa hay 1.5 ton equivalent (Deliv.):	112.50
	$187.50
Value of transport:	22.50
Total*	$210.00

Under this arrangement, manure would have a value near or equal to transported alfalfa hay. Processing of manure would add some cost. However, since geothermal water is abundantly available, the material could be dried and stored probably at very competative costs. It suffices to point out here that the digester operation to be competative would need to produce about $65 worth of power per ton of 90% dry manure.

As stated earlier, an advantage of investigating a geothermal energy-controlled dairy is that much reliable economic information is readily available for conventional operations. It was recognized early in the analysis (comparisons) that the significantly large capital investment requirement of the non-conventional dairy would influence, or perhaps completely offset any gains made by the energy substitution. The economic benefits also might be small enough that the dairy activity would not be the first activity to be developed by potential investors when compared with some of the alternatives included in Figure 1. However, this in no way detracts from the use of the dairy model in the simulation. In fact, the computer program generated information that shows the dairy to recover all costs in the second year of operation. However, in comparing the model with the conventional dairy, cost and return equality is not achieved before about the seventh year.

CONCLUSIONS

The research by C.L.R. clearly indicates that computer simulation has potentials for making significant contributions in the design and planning of candidate activities in an energy cascade such as shown in Figure 1. It is also evident that even though the current computer simulation programs work, there is a continuing need for simplification and standardization. There is also the need to adapt the computer simulations to different technical configurations. The adaptations should be developed for additional activity in the model (non-conventional) dairy, but should also be extended to include the various geothermal assisted activities shown in Figure 1.

The on-site geothermal technology is designed to accomodate currently available on-shelf hardware. The system is designed to energize the non-conventional dairy, using geothermal fluids. It was determined by simulation programming that the dairy can be energy independent of outside fossil fuel resources. The geothermal fluid was also determined to be effective energy for optimizing temperatures on the anaerobic digester. The digester is capable of producing enough high quality bio-gas (methane) to generate about 29 H.P. continously. The combined geothermal and bio-gas resource would insure energy for the model dairy. The latter would not be effected by delivery curtailments, inflation, or power failures in the commercial delivery systems.

The simulation runs indicate the following technical outcomes:

1. At peak load conditions, all but 6% of the electrical energy requirements are met by the methane digester/scrubber/engine-generator power production system. During most of the operations time, the full electrical requirements of the model dairy are met by the on-site energy system.

2. About 19% of the electrical energy produced by the on-site engine-generator is required to operate the power production system, as currently designed.

3. The current Hobo Wells (specific reservoir) production is capable of providing enough thermal fluids to operate 15 dairies of the size and configuration as described. The dairy requires between 6 and 7 percent of current artesian flow, and this at peak energy load conditions.

4. Calculations indicate that without the digester and related power production system, the peak electrical requirements of the system would decrease by 17%, but the electrical energy supplied by a public utility would increase by 93%.

5. Total peak energy demands of the model dairy are supplied as follows: Five(5)% is from the power generating system, one half of one (.5)% purchased from outside suppliers, and ninety-four and one-half (94.5)% is supplied direct from the geothermal reservoir. This mix would be considerably different on an average day. It might be expected that normally no outside energy would be required and the geothermal demand would also be much less. Further investigation might indicate that stand-by power for peak periods or other energy demand overload could be met with tank stored fuel gas.

6. Without the geothermal resource, the dairy would require 23,000 BTU/min. from commercial or other sources at peak periods. It is likely that without the geothermal energy, the Hobo Wells or any other Honeylake geothermal site would not be used for dairy production.

The comparative economic analysis indicates the following results:

1. The conventional dairy operation is able to produce 100 lbs. (45.36 kg) of milk for $8.93, and $9.49 for the non-conventional system. The 56¢ difference in the first year is probably sufficiently large to discourage investment. This suggests that if new or

innovative systems are to be established in any enterprise with the objective of conserving scarce fossil fuels, a system of investment credit allowances will have to be made to provide sufficient incentives for conversion and investment in the new technology.

2. In the dynamic analysis, two possible conclusions were reached:

a. With non-linear price increases, the proposed (non-conventional) system was the least cost system for the 20 year period of operation.

b. If linear price increases are expected, then the least cost system is the conventional dairy operation.

3. The investment requirement (excluding livestock) for the non-conventional dairy is established to be about seventy-seven percent greater than for the conventional dairy - $535,000 as compared to $303,000.

4. Operations cost per cow are of two sorts: fixed and variable. The total cost for the conventional dairy was determined to be $301,000 per year, and $325.00 for the non-conventional dairy.

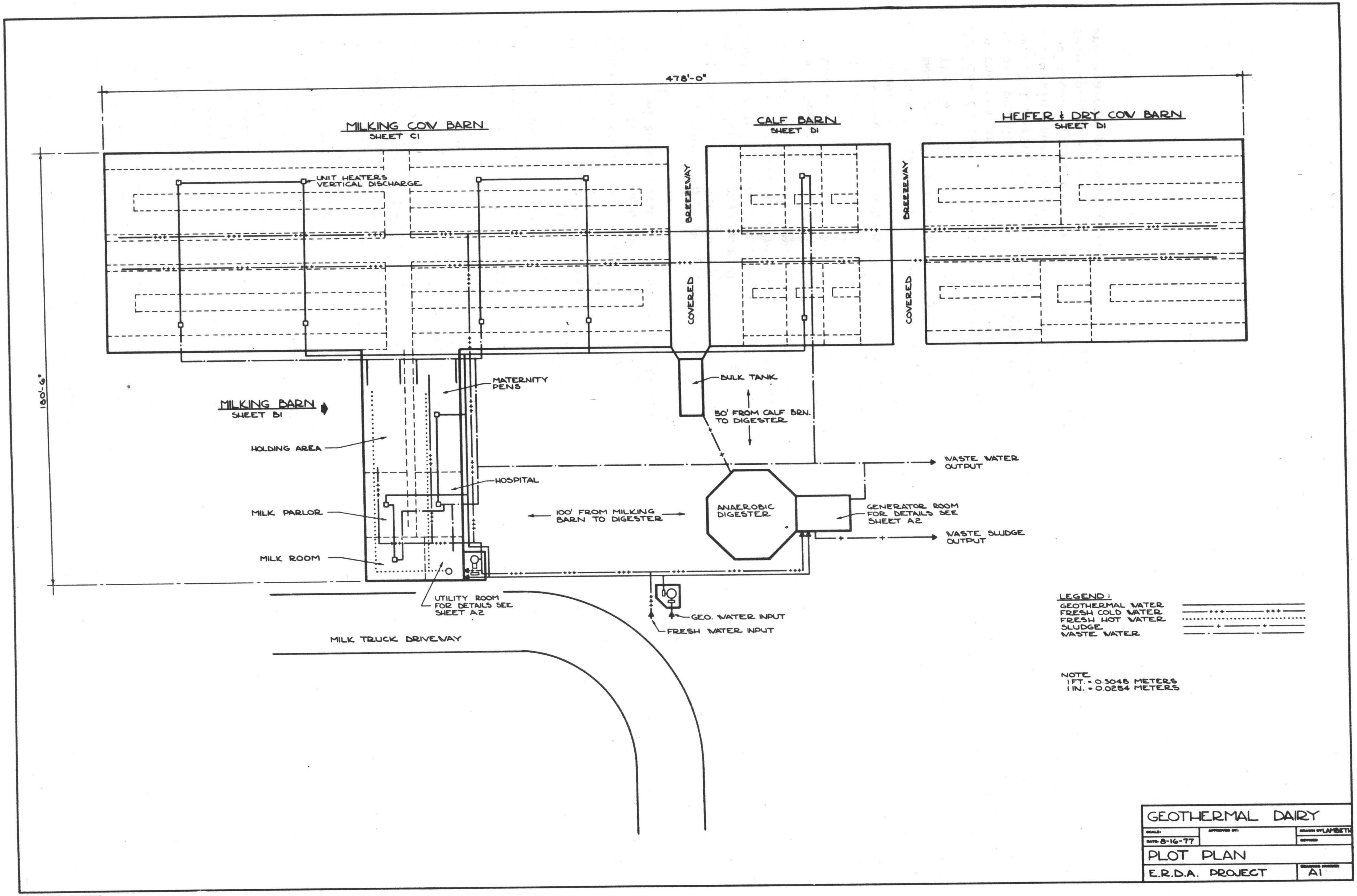
5. The two dairys become cost equal in about the seventh year of operation. In the seventh year, it is projected that costs for producing 45.36 kg. of milk will be about $15.00. In that same year, net revenue is estimated to be between $0.50 and $1.83 per 45.36 kg.

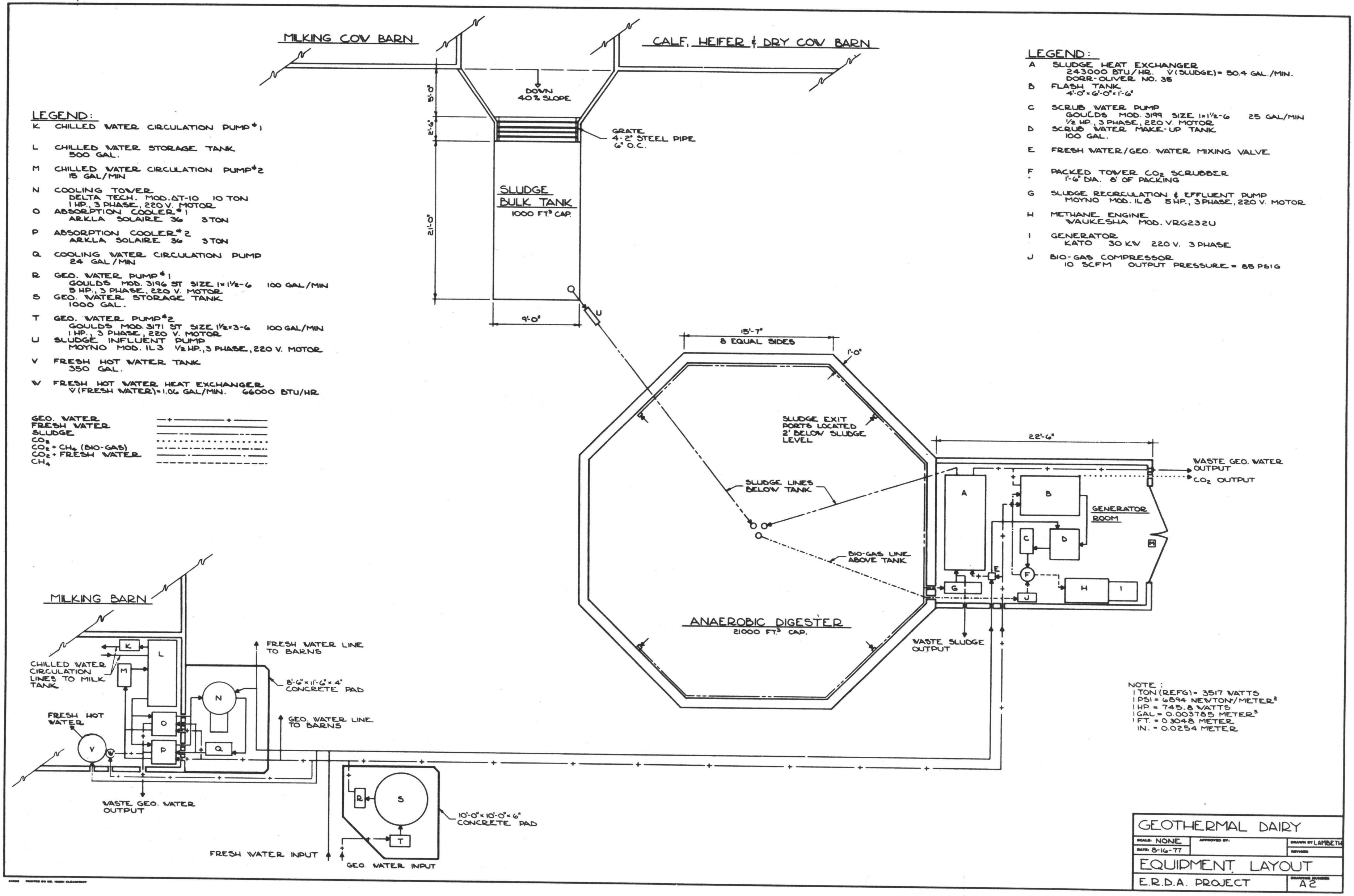
6. It is determined by separate linear programming that for both dairy operations the major operations cost variable is feed. The analysis indicates that there is sufficient justification for further research with the objective of finding useful solutions to:

a. Waste disposal - manure and other waste.

b. Efficient feed energy utilization. There is some good evidence that dairy manure can be processed to be used as a feed substitute (roughage)--currently as much as 50% of the ration could be from this source.

7. The current analysis is currently limited in the number of activities that could properly be included as either complimentary or parallel activity. It is likely that some activities, such as greenhouse operations, could contribute to a substantially different revenue production between the conventional and non-conventional dairys.


478'-0"
MILKING COW BARN
SHEET C1
CALF BARN
SHEET D1
HEIFER & DRY COW BARN
SHEET D1
UNIT HEATERS
VERTICAL DISCHARGE
BREEZEWAY
COVERED
BREEZEWAY
COVERED
180'-6"
MILKING BARN
SHEET B1
MATERNITY
PENS
BULK TANK
50' FROM CALF BRN.
TO DIGESTER
HOLDING AREA
HOSPITAL
WASTE WATER
OUTPUT
MILK PARLOR
100' FROM MILKING
BARN TO DIGESTER
ANAEROBIC
DIGESTER
GENERATOR ROOM
FOR DETAILS SEE
SHEET A2
WASTE SLUDGE
OUTPUT
MILK ROOM
UTILITY ROOM
FOR DETAILS SEE
SHEET A2
GEO. WATER INPUT
FRESH WATER INPUT
MILK TRUCK DRIVEWAY
LEGEND:
GEOTHERMAL WATER
FRESH COLD WATER
FRESH HOT WATER
SLUDGE
WASTE WATER
NOTE
1 FT. = 0.3048 METERS
1 IN. = 0.0254 METERS
GEOTHERMAL DAIRY
DATE 8-16-77
DRAWN BY LAMBETH
PLOT PLAN
E.R.D.A. PROJECT
A1


MILKING COW BARN
CALF, HEIFER & DRY COW BARN
DOWN
40% SLOPE
GRATE
4-2" STEEL PIPE
6" O.C.
5'-0"
2'-6"
21'-0"
9'-0"
SLUDGE
BULK TANK
1000 FT³ CAP.
U
15'-7"
8 EQUAL SIDES
1'-0"
22'-6"
SLUDGE EXIT
PORTS LOCATED
2' BELOW SLUDGE
LEVEL
SLUDGE LINES
BELOW TANK
BIO-GAS LINE
ABOVE TANK
ANAEROBIC DIGESTER
21000 FT³ CAP.
WASTE SLUDGE
OUTPUT
WASTE GEO. WATER
OUTPUT
CO₂ OUTPUT
GENERATOR
ROOM
A
B
C
D
E
F
G
H
I
J
LEGEND:
A SLUDGE HEAT EXCHANGER
243000 BTU/HR. V̇(SLUDGE) = 50.4 GAL./MIN.
DORR-OLIVER NO. 35
B FLASH TANK
4'-0" × 6'-0" × 1'-6"
C SCRUB WATER PUMP
GOULDS MOD. 3199 SIZE 1×1½-6 25 GAL/MIN
½ HP., 3 PHASE, 220 V. MOTOR
D SCRUB WATER MAKE-UP TANK
100 GAL.
E FRESH WATER/GEO. WATER MIXING VALVE
F PACKED TOWER CO₂ SCRUBBER
1'-6" DIA. 8' OF PACKING
G SLUDGE RECIRCULATION & EFFLUENT PUMP
MOYNO MOD. 1L8 5 HP., 3 PHASE, 220 V. MOTOR
H METHANE ENGINE
WAUKESHA MOD. VRG232U
I GENERATOR
KATO 30 KW 220 V. 3 PHASE
J BIO-GAS COMPRESSOR
10 SCFM OUTPUT PRESSURE = 85 PSIG
LEGEND:
K CHILLED WATER CIRCULATION PUMP #1
L CHILLED WATER STORAGE TANK
500 GAL.
M CHILLED WATER CIRCULATION PUMP #2
15 GAL/MIN
N COOLING TOWER
DELTA TECH. MOD. ΔT-10 10 TON
1 HP., 3 PHASE, 220 V. MOTOR
O ABSORPTION COOLER #1
ARKLA SOLAIRE 36 3 TON
P ABSORPTION COOLER #2
ARKLA SOLAIRE 36 3 TON
Q COOLING WATER CIRCULATION PUMP
24 GAL/MIN
R GEO. WATER PUMP #1
GOULDS MOD. 3196 ST SIZE 1×1½-6 100 GAL/MIN
5 HP., 3 PHASE, 220 V. MOTOR
S GEO. WATER STORAGE TANK
1000 GAL.
T GEO. WATER PUMP #2
GOULDS MOD. 3171 ST SIZE 1½×3-6 100 GAL/MIN
1 HP., 3 PHASE, 220 V. MOTOR
U SLUDGE INFLUENT PUMP
MOYNO MOD. 1L3 ½ HP., 3 PHASE, 220 V. MOTOR
V FRESH HOT WATER TANK
350 GAL.
W FRESH HOT WATER HEAT EXCHANGER
V̇(FRESH WATER) = 1.06 GAL/MIN. 66000 BTU/HR
GEO. WATER
FRESH WATER
SLUDGE
CO₂
CO₂ + CH₄ (BIO-GAS)
CO₂ + FRESH WATER
CH₄
MILKING BARN
K
L
M
N
O
P
Q
V
W
CHILLED WATER
CIRCULATION
LINES TO MILK
TANK
FRESH HOT
WATER
FRESH WATER LINE
TO BARNS
8'-6" × 11'-6" × 4"
CONCRETE PAD
GEO. WATER LINE
TO BARNS
WASTE GEO. WATER
OUTPUT
R
S
T
10'-0" × 10'-0" × 6"
CONCRETE PAD
FRESH WATER INPUT
GEO. WATER INPUT
NOTE:
1 TON (REFG) = 3517 WATTS
1 PSI = 6894 NEWTON/METER²
1 HP. = 745.8 WATTS
1 GAL = 0.003785 METER³
1 FT. = 0.3048 METER
IN. = 0.0254 METER
GEOTHERMAL DAIRY
SCALE: NONE
DATE: 8-16-77
APPROVED BY:
DRAWN BY LAMBETH
REVISED
EQUIPMENT LAYOUT
E.R.D.A. PROJECT
DRAWING NUMBER
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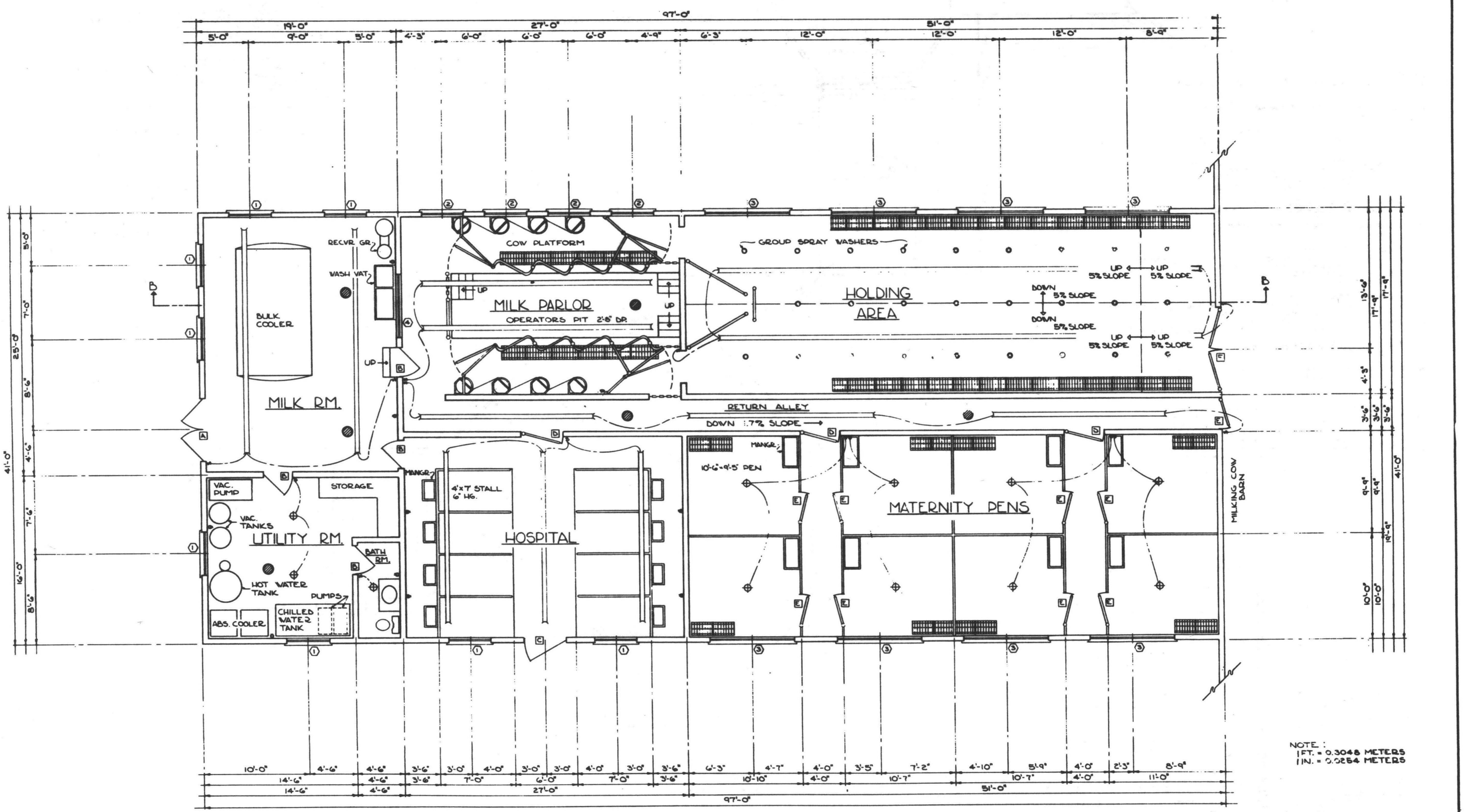


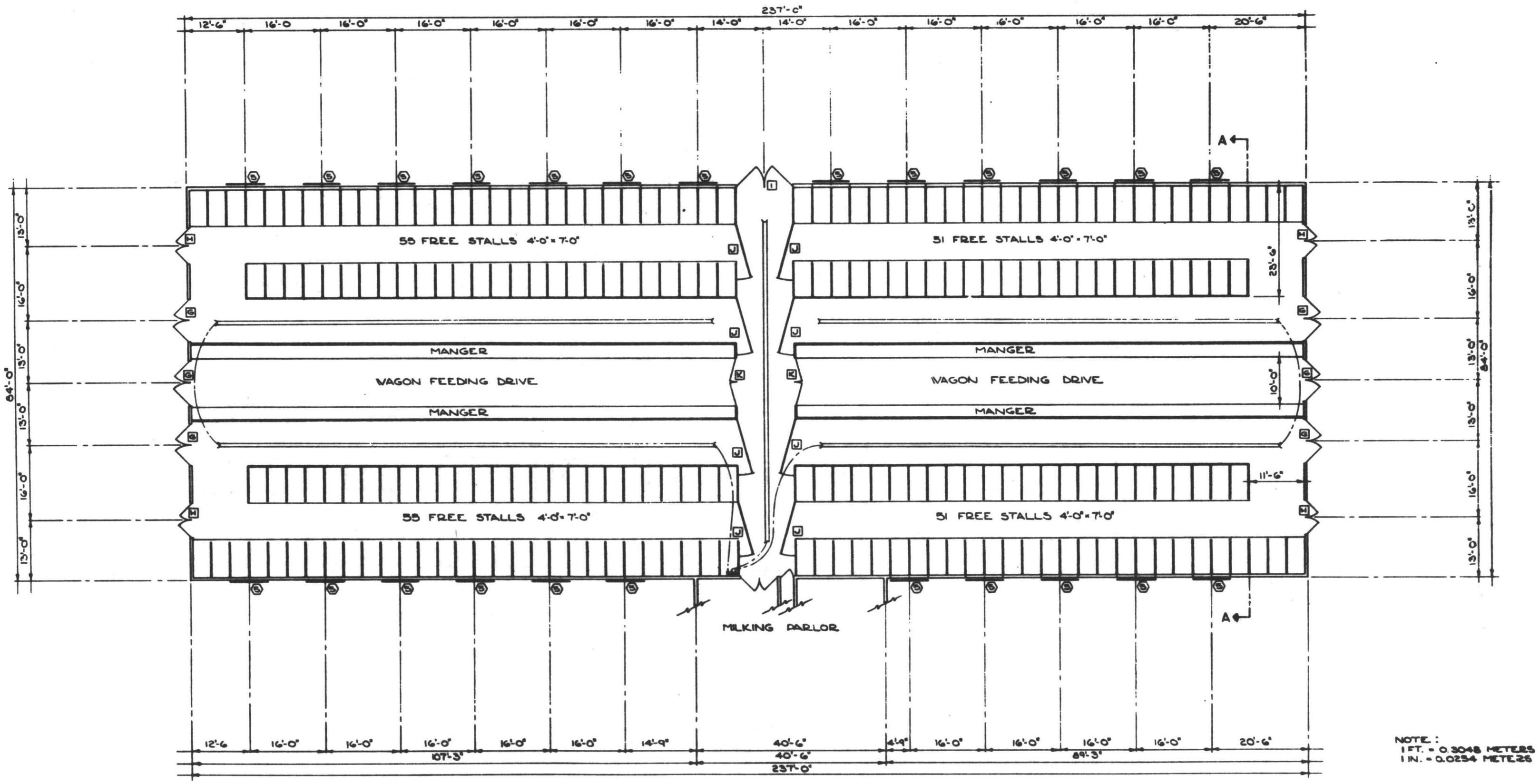
FLOOR PLAN

GEOTHERMAL DAIRY

DATE 8-16-77 — DRAWN BY LAMBETH

MILKING BARN

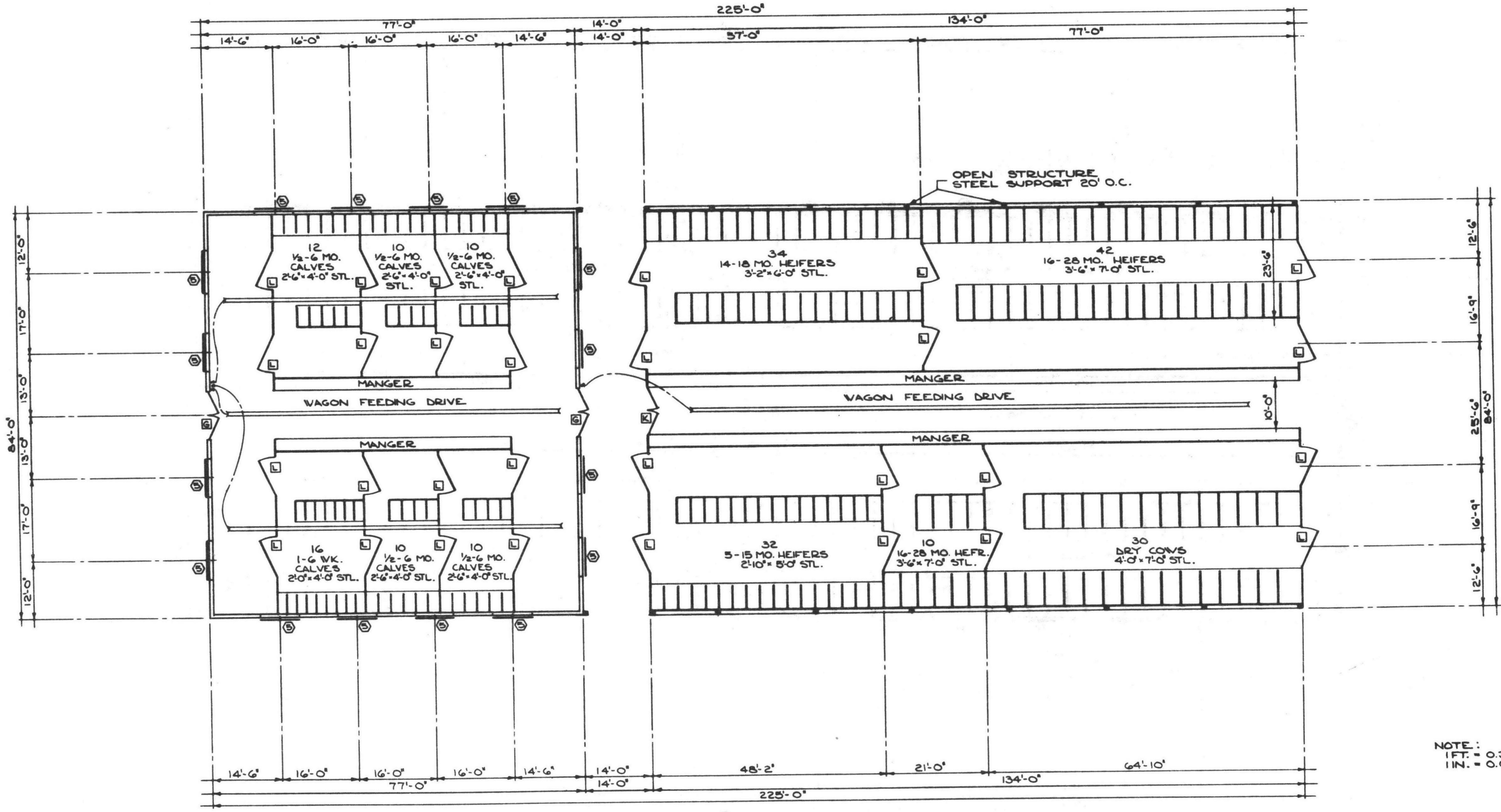
E.R.D.A. PROJECT — 81



NOTE:
1 FT. = 0.3048 METERS
1 IN. = 0.0254 METERS

FLOOR PLAN

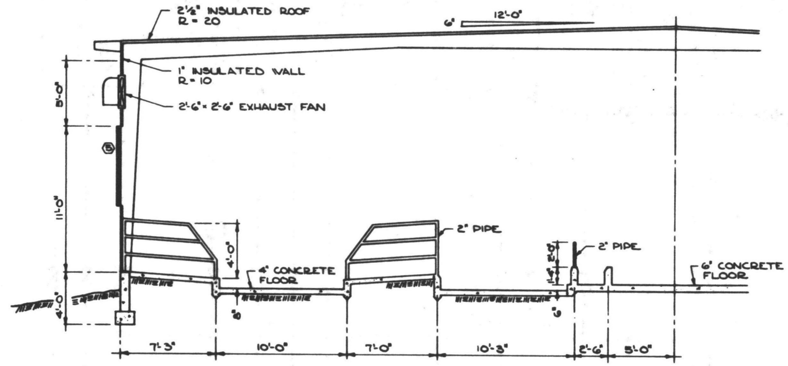
GEOTHERMAL DAIRY	
DATE 8-16-77	
MILKING COW BARN	
E.R.D.A. PROJECT	C1



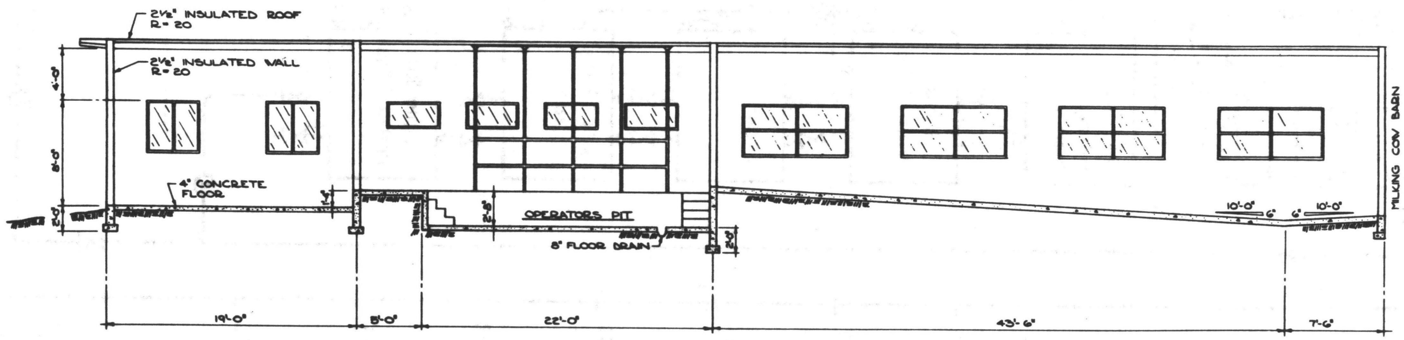
FLOOR PLAN

NOTE:
1 FT. = 0.3048 METERS
1 IN. = 0.0254 METERS

GEOTHERMAL DAIRY
DATE: 8-16-77
DRAWN BY: LAMBETH
CALF, HEIFER & DRY COW BARN
E.R.D.A. PROJECT
D1



SECTION A-A



SECTION B-B

NOTE:
1 FT. = 0.3048 METERS
1 IN. = 0.0254 METERS

GEOTHERMAL DAIRY
DATE 8-16-77
SECTIONS A-A & B-B
E.R.D.A. PROJECT
E1

Fig. 1 GEOTHERMAL OR WASTE HEAT FLOW SYSTEM (ENERGY CASCADE) MODEL A