Department of

Agricultural Engineering

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Halifax, Nova Scotia

DESIGN, CONSTRUCTION AND TESTING OF AN ENERGY EFFICIENT INNOVATIVE-FARMSCALE ANAEROBIC DIGESTER

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Proposal submitted to

Energy Research and Development in Agriculture and Food

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1. INTRODUCTION

1.1 Energy from Biomass

Modern civilization and its economy have become dependent upon a prodigious consumption of energy derived mostly from the burning of fossil fuels. These traditional sources of energy, which we rely on for 80 percent of our needs, are rapidly depleting. Our population is growing and the demand for energy is increasing rapidly. Historically, our per capita demand for energy has increased by 60-80 percent in each generation.

Therefore, we must practice conservation in every possible way and increase exploration to find alternate energy resources to meet our increasing demands. As Chappell (1979) indicated, we must exit to a situation called "mini-mix"; mini representing minimum demand through conservation and mix meaning a mixture of energy sources so that turning one tap off will not take the whole country down.

Concern for the rapid depletion of conventional sources for liquid and gaseous petroleum fuels combined with the rapid escalating prices has increased since the oil embargo of 1973. Smith (1980) reported that the fuel prices increased annually by 22 percent between 1972 and 1978 and by 29 percent in 1979. Conceivably, various alternative renewable energy technologies are being investigated that may help to alleviate this nation's dependence on petroleum. One such alternate energy source is biomass which is becoming increasingly important.

Energy price and supply and their effects on the production cost have been of increasing interest to Canadian farmers. However, agriculture has the potential for replacing some of the purchased energy with energy from on-site renewable biomass. Such biomass energy sources could be the residues from plants and the manures from animals. While energy required to operate the farm sector is theoretically available in adequate quantities, it will be the economics and management problems associated with the introduction of a new fuel technology and matching the fuel supply with demand for that fuel.

Fuels from biomass could be used for space and water heating of farm house and animal shelters, grain drying and as fuels for heating greenhouses, with their high energy demands in cold weather. The latter is particularly important if Canada is to reduce its imports of horticultural off season crops.

1.2 Energy from Anerobic Digestion of Animal Manure

Animal manure constitutes a significant resource, with energy, in the form of biogas, as one of the key end use prospects. Another end use of importance is the use of manure as a nutrient source to replace expensive energy consuming commercial fertilizers. Use of various manures together with treated crop residues as animal feed would also reduce the demand for feed production. These uses have also indirect energy ramifications.

Point sources of manure from feedlots, dairy operation, hog barns, and poultry operations can be considered. In total it is estimated that substantial quantities of solid material are available. Procos and Ben-Abdallah (198'2) reported that Canadian farmers produce 19,404,899 tons of dry matter in the form of animal manure. This could produce 30.27'2 x 10^7megajoules* without losing its fertilizer potential.

Table 1. Animal waste produced in Canada (Procos and Ben-Abdallah, 1982).

Province	Animal waste (ton dry matter)
Newfoundland	19,349
Prince Edward Island	150,623
	211,371
Nova Scotia	171,153
New Brunswick	3,054,498
Quebec	4,560,847
Ontario	1,704,189
Manitoba	3,455,675
Saskatchewan	5,189,478
Alberta	887,716
British Columbia	
Canada	19,404,899

* 1i kg of manure produces 15.6 megajoules (Ben Abdallah, 1982).

2. OBJECTIVE

The overall objective of the program of which this proposal is a part, is to use the innovative design concept of anaerobic digesters (tested on a pilot plant scale and proven to be technically and economically feasible) to design, fabricate, and test a farm scale anaerobic digester. This proposal concentrates on identifying and solving the scale-up and operational problems encountered when transferring the technology from a pilot plant scale to a farm scale.

The specific steps to accomplish the overall objectives are:

1. To design, construct, test and monitor an innovative farm scale anaerobic digester.
2. To determine the feed value of sludge from the digester by running feeding trials on hogs and beef cattle raised on the farm. The feeding trials are designed to generate the following informations:

   (a) the best form of feeding the sludge,

   (b) the optimum percentage of sludge in the feed ration,

   (c) the effect of sludge fortified feed on animal health, and

   (d) economic gains ($ savings) derived from sludge fortified feed.
3. To determine the fertilizer value of the sludge through land application trials. These trials will generate the following informations:

   (a) the best method of application,

   (b) the nutrient value in the sludge that is available for plant assimilation, and

(c) the amount of savings ($ value) over chemical fertilizers.

4. to determine the characteristics of the supernatant from the digester in relation to pollution potential and end use.

5. to assess the net energy balance of the system in order to determine the economic feasibility of the proposed design under field conditions.

3. BACKGROUND

The utilization of microbial process to treat agricultural waste has been a common practice for many years. An anaerobic treatment is a biological process that proceeds in the absence of oxygen. Controlled anaerobic decomposition results in a gas containing 60-70 percent methane (CH_4) and 30-40 percent carbon dioxide ($C0_2$). However, small quantities of hydrogen (H_2), hydrogen sulfide (H_2S), ammonia (NH_3) and water vapor may also be present.

The anaerobic digestion process has been simplified by Pos et al. (1979) into two stages of fermentation. In the first stage acid forming bacteria convert complex organic materials into organic acids. These acids are then converted into methane and carbon dioxide in the second stage by methanogenic bacteria.

Nevertheless, from a kinetic point of view, anaerobic digestion may be carried out in three stages. In the first stage, complex mixtures of carbohydrates, fat, protein and their breakdown products are converted to less complex soluble organic compounds by enzymatic hydrolysis. In the second stage, the hydrolysed products are converted to organic acids by “acid formers". In the third stage, the organic acids are converted to methane and carbon dioxide by "methane formers."

Evidently, the significant energy potential in biogas has attracted the attention of many researchers to do research in the digestion process. Parameters such as digester design, loading rate, retention, time and operating temperature and their

Table 2. **Composition of biogas**
(Hashimotal et al., 1979)

Constituent	Concentration
Methane	50 - 70%
Carbon dioxide	30 - 40%
Moisture	30 - 160 mg/l
Hydrogen sulfide	5 mg/l

Table 3. **Typical biogas production rate for various classes of livestock and poultry manure (Lapp, 1979).**

	Biogas production	
Class of livestock	m^3/day/1000 kg of body weight	m^3/day/m^3 of digester volume
Dairy cows	3.28	1.1
Beef cows	2.66	1.3
Hogs	2.62	1.1
Poultry	6.21	1.3

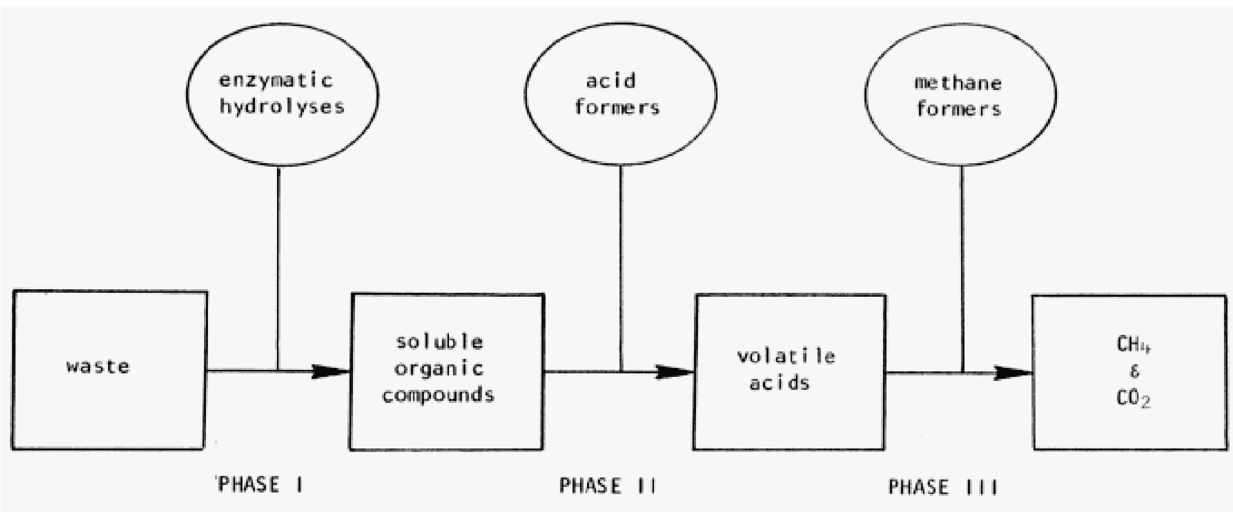

Figure 1. Simplified process for methane production.

effects on the energy yield and system efficiency have been investigated. The climatic restrictions on operation and energy balance during the severe Canadian !winters have been the main thrust of these studies.

Several studies (Hashimoto et al., 1977; Van den Berg et al., 1974 and 1981; Kroeker et al., 1976; Lapp et al., 1975; Lapp, 1979, Pos et al., 1979; Singh, 1977; Van den Berg and Lentz, 1979; and Welsh et al., 1977) have been carried out to investigate the technical and economical feasibility of producing methane gas from animal manures and food processing wastes by anaerobic digestion. Although the process has proven to be technically feasible, the economic feasibility has been seriously constrained by the cold ambient temperature in the Canadian winter. Temperature is an important environmental factor influencing the growth and survival of microorganisms. When temperature increases the growth rate of microorganisms increases resulting in higher methane production per unit volume of digester. There are however three groups of anaerobic bacteria: psychrophilic, mesophilic and thermophilic. The growth of phsychrophilic bacteria is very slow and a long time is required to stabilize the waste; thus a retention time of one year may be needed (Singh, 1977). In the mesophilic range, methane gas production is significant due to higher activity of bacteria resulting in solid retention times in the range of 5-30 days (Blanchard, 1983). The rate of reaction in the thermophilic range is faster and retention times lower than 5 days have been obtained (Singh, 1977).

Table 4. Environmental and operating factors affecting methane production.

Environmental factors	Operational factors
1. pH	1. Composition of organic substrate
2. Alkalinity	2. Concentration of substrate
3. Temperature	3. Retention time
4. Volatile acid concentrations	4. Organic lcading rate
5. Nutrient availability	5. Degree of mixing
6. Toxic materials	6. Heating and heat balance

Table 5. Typical temperature range for various bacteria (Brock, 1974).

	Temperature° C	
Group	**Range**	**Optimum**
Psychrophilic	-2 - 30	12 - 18
Mesophilic	20 - 45	25 - 40
Thermophilic	45 - 75	55 - 65

Singh (1977) and Hashimoto et al. (1979) have indicated that the economics of most digester systems have dictated operation in the meshophilic range.

4. PREVIOUS EXPERIENCE WITH ANAEROBIC DIGESTERS

Experiences of the investigators with anaerobic digesters are as follows:

4.1 <u>Computer Simulation</u>

Computer simulation was used to estimate the energy inputs required for anaerobic digestion of swine manure and gas energy produced during the digestion process. Digester design parameters included: digester operating temperature (DOT), solids retention time (SRT), and influent total solids concentration (TSC). Buried and above-ground digesters were considered and the following set of circumstances were employed:

1. Manure produced from 2000 growing and finishing hogs.
2. Continuous loading of manure to the digesters.
3. Digester operating temperatures of 20, 28 and 35ºC.
4. Solid retention times of 10, 20, 30, 45 and 60 days.
5. Influent total solids concentrations of 3, 6, 9 and 12 percent.
6. Influent temperatures similar to those of normal year records .
7. Intermittent mixing by gas circulation.
8. Cylindrical digesters with varying heights and diameters.
9. Air temperatures for a normal year records.
10. Soil temperature for a normal year records.
11. The digesters were made of concrete and had wall, roof and floor thickness of 25, 15 and 15 cm respectively.

12. The digesters had insulation of 3.8 cm of urethane and 0.64 cm of fir plywood around the walls and 7.5 cm of urethane roof. No insulation was used under the floor but the bottom of each digester was at or below the soil surface.

The energy input into an operating digester is required to;

(a) increase influent temperature,

(b) replace heat losses from walls, roof and floor,

(c) mix the digester contents,

(d) pump the influent and effluent, and

(e) replace heat lost with biogas produced.

The energy required to pump the influent, while dependent upon total solids concentration, is also a function of the location of the digester in relation to the whole manure system and therefore was not included in the analyses. Furthermore, energy lost with biogas was found to be in the order of 0.1 percent of the total energy losses from pilot-scale anaerobic digester and was also neglected.

Biogas production was predicted on the basis that microbial methanogenesis is a time and temperature dependent phenomenon. Equations were developed using SRT and DOT as the rate governing parameters. Biogas production rates were expressed on a unit solids added basis thereby taking into account the variations in TSC of the influent. The time, temperature and other reaction rate coefficients were obtained from the literature and from ongoing pilot-scale studies at the University of

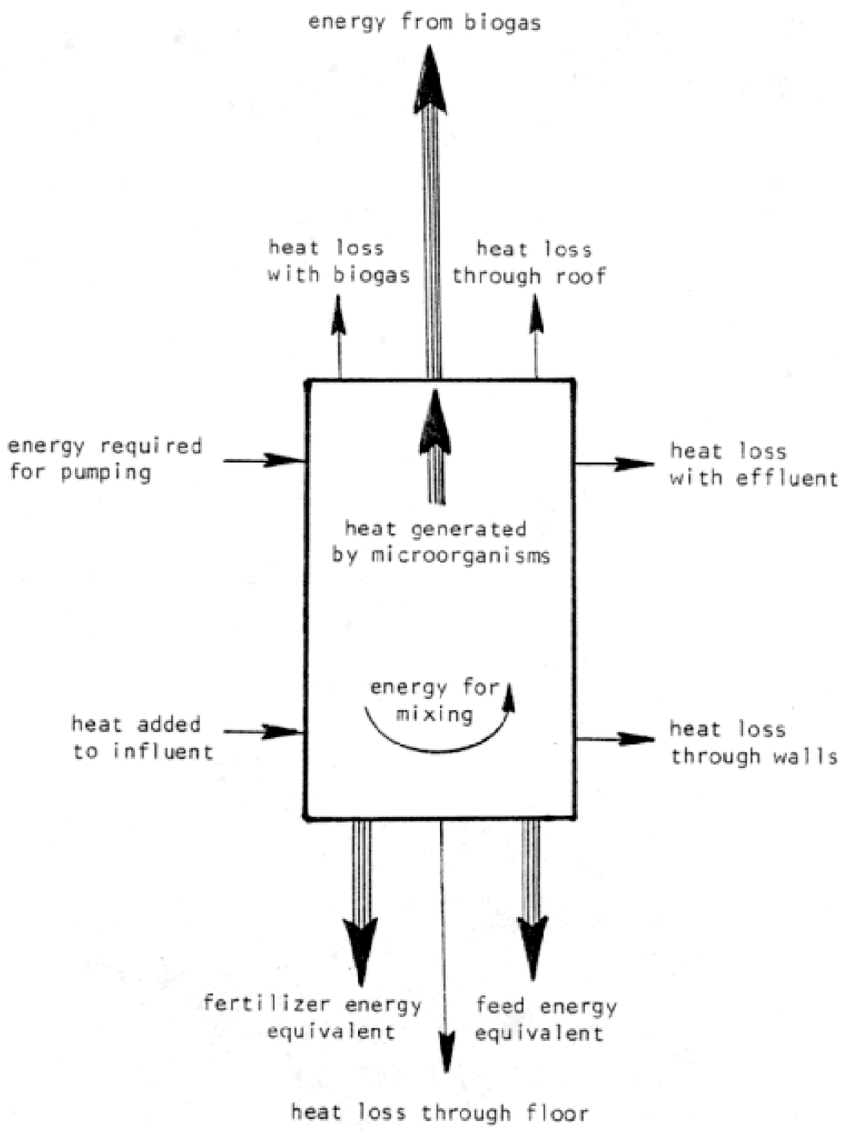

Figure 2. Energy balance for anaerobic digester.

Manitoba. The mathematical model did not account for the possible inhibitory effect of free ammonia or of fatty acids which could occur as a result of digester over loading.

The study concluded the following:

1. Digester operating temperatures developed a thermal bulb region in the surrounding soil which elevated the soil temperature around the digester walls and floor.
2. At all the digester conditions influent heating consists of 60 percent of the total annual energy input to the system.
3. Energy required to replace heat losses from walls, floor and roof of the digester were in the range of 5.7 to 33 percent of the total annual energy requirement.
4. Mixing energy requirement ranged from 0.4 to 9.3 percent of the total annual energy requirement.
5. The amount of energy saved by burying the digester under the ground was small when compared to an above-ground digester of identical structure and insulative character.
6. Annual energy production showed a multilinear relationship among DOT, SRT, and TSC. The effects of these parameters in order of relative influence were TSC > DOT > SRT.

4.2 <u>Floating Gas Cap, Pilot Plant Anaerobic Digester</u>

Dr. Ghaly while, heading the Agricultural Engineering Department at University of Zambia ton a CIDA supported project), has initiated a research and development program on biogas technology in Zambia. The

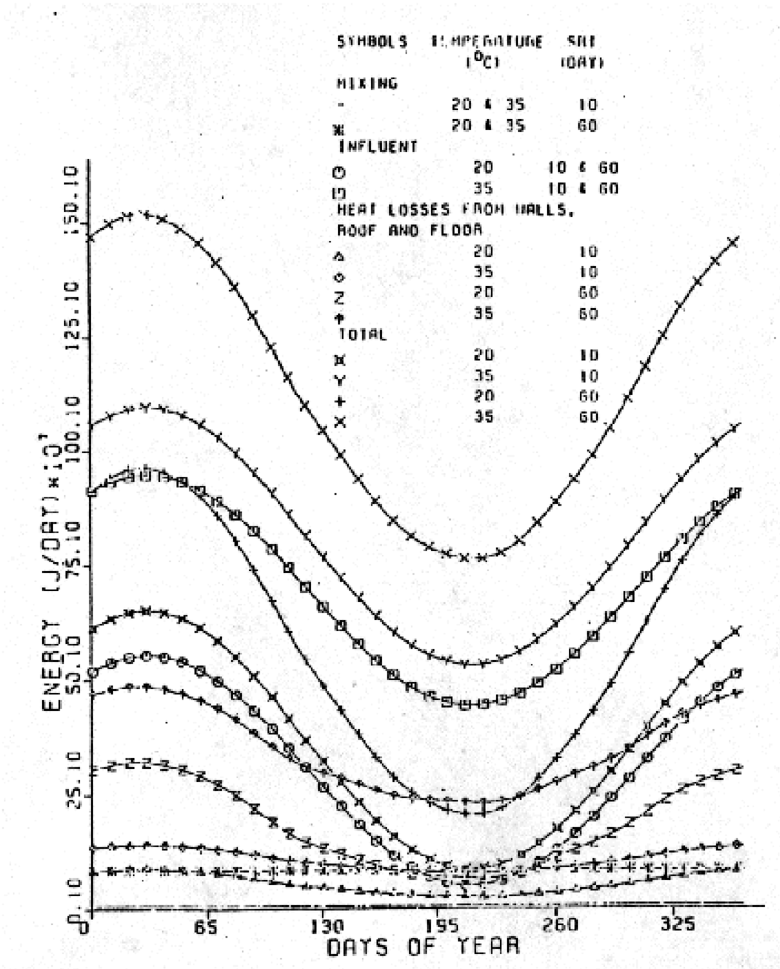

Figure 3. Predicting energy required for digester operating at 12% solid concentration.

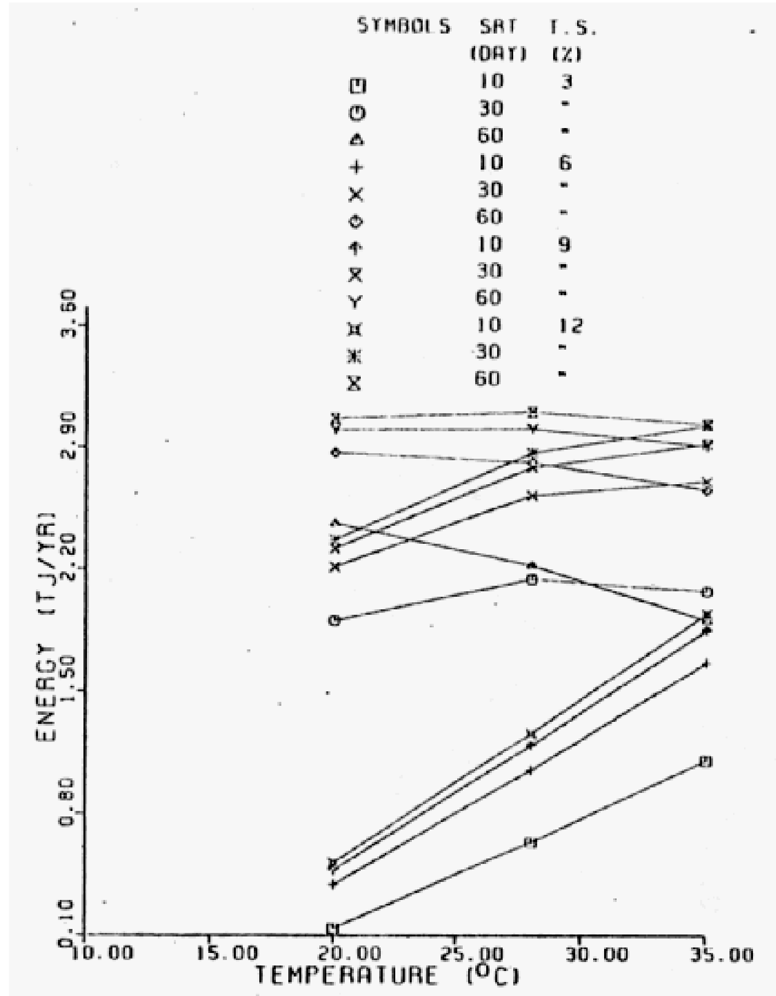

Figure 4. Effect of temperature on cumulative net energy production.

main objectives of this research were:

(a) to design, construct and operate a biogas system suitable for the tropics,

(b) to monitor the changes taking place in the digester, while in operation, and make the necessary control,

©) to identify the design and operating problems, and to improve the design and management of the system, and

(d) to make recommendations as to the potential of the biogas production in rural areas of Zambia.

A floating gas cap biogas plant was designed and installed in this study. The system consisted of two large 16 gauge galvanized mild steel drums, one inverted into the other. The system was water sealed and delivered gas at constant pressure which was collected in the gas cap. The gas cap was painted with bituminous based black paint in order to heat the digester through utilization of solar energy. The digester compartment was partitioned by a vertical wall up to 2/3 of the digester height. The fresh manure was added to the digester on a semi-continuous basis. The entering fresh slurry to one compartment displaces the digester material into the second compartment which in turn expels the supernatant via the outlet tube. Furthermore, as the fermentation process proceeds, the gas pressure builds up and causes the gas cap to rise. Eventually, the gas is conveyed through gas pipes for domestic use.

The following were concluded from the study:

1. The digester system alleviated some of the fuel problems, by

providing energy source from available waste materials.

(a) Methane was used for cooking and lighting - a properly adjusted air jet gave a blue smokeless flame of about 800ºG.

(b) Poultry broaders for young birds were modified to work on methane gas at the field station of the University of Zambia.

(c) kerosene refrigerator units were converted to work on methane gas.

2. The digester slurry was used as a fertilizer. The organic content was reduced by 90% and the sludge had a higher fertilizer value than the raw manure. There was only 1 percent loss in nitrogen.

3. The biogas supported the reforestation program currently carried out by providing an alternative form of fuel to the use of wood which has been depleted in Zambia.

Zambia depends for its energy requirement on unreliable oil supply due to its geographical location, being isolated from the seashores. Furthermore, the cost of gasoline has been increasing at a faster rate, reaching $1.40 per liter in 1980. A lack of cheap and adequate fuels hampers the development plans and retards the quality of life.

Although, biogas is the most reliable and convenient alternative source of energy yet the Zambian culture discourages the local farmer from using animal manure for biogas production because the task is considered to be undignifying. Therefore, recommendations were made to the Government of Zambia to take an active role in supporting the production of biogas through an extension program to generate awareness and interest among Zambian farmers. A credit facility must also be provided to alleviate some of the capital costs.

4.3 Fluidized Bed Anaerobic Digesters

A suspended-particle, fixed-biomass fermentation system for animal waste was designed and tested. Cuboids composed of particulate nylon-fibers (1.5 x1.5 x 0.75 cm) were used as support particles for the retention of the symbiotic population of anaerobic bacteria responsible for methane production. The bacteria attached to the surface of the nylon fibers were held within the interstitial voids of the cuboids that had a 96.5 percent porosity.

A particle suspension test vessel having the same dimensions as of the fermenters was designed, constructed and used in this study. The test vessel was equipped with a variable speed motor for driving the particle suspension impellers of varying sizes and geometries. A tachometer and specially designed dynamometer were used to test particle suspension input-energy-mixing requirements. A series of suspension tests with the nylon-fiber cuboids were performed over a range of mixing speeds from 50 to 500 rpm. A set of interchangeable mixing devices were tested. These were: baffles, six bladed-disc turbine impeller of four diameters, draught tubes of varying lengths and diameters, impeller shrouds and stator ring. The results of these tests were used to design a suspended particle, anaerobic fermenter.

Four 25-liter mechanically-mixed anaerobic digesters were designed and fabricated. The digesters were equipped with hydraulically operated continuous loaders. Two digesters were operated as mechanically agitated, fixed-biomass suspended-particle fermenters, while the other two were operated as continuous, stirred tank fermenters to serve as control. The study was carried out using dairy manure of 5.9% total solids. The digester operating temperature was maintained at 35°C. The daily loading rate increased by reducing the hydraulic retention time from 25 to 2.5 days over a six week period.

The continuous stirred tank fermenters began to fail at a 5 day retention time while the suspended-particle fixed-biomass digesters maintained a high rate of performance.

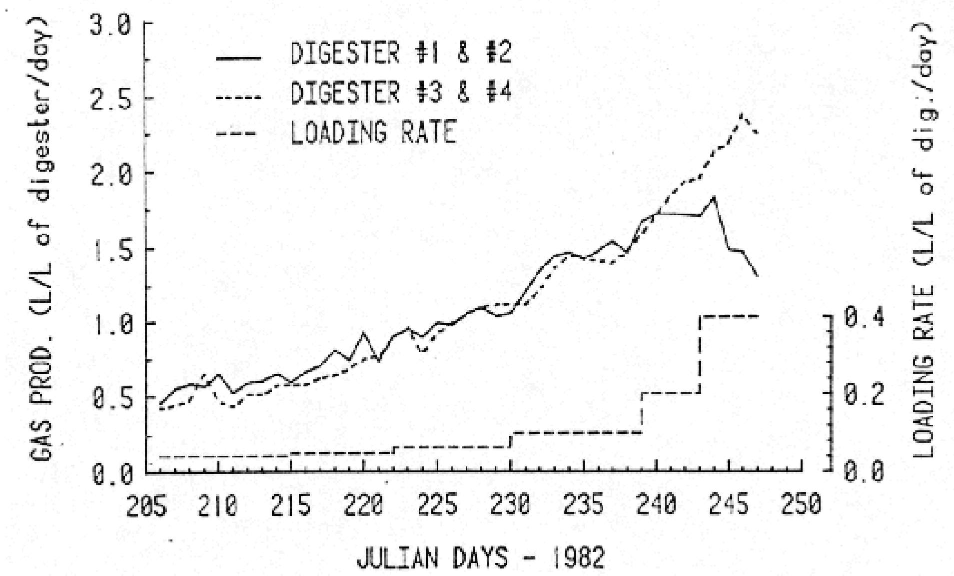

Figure 5. **Average daily gas production of digesters 1 & 2 and 3 & 4.**

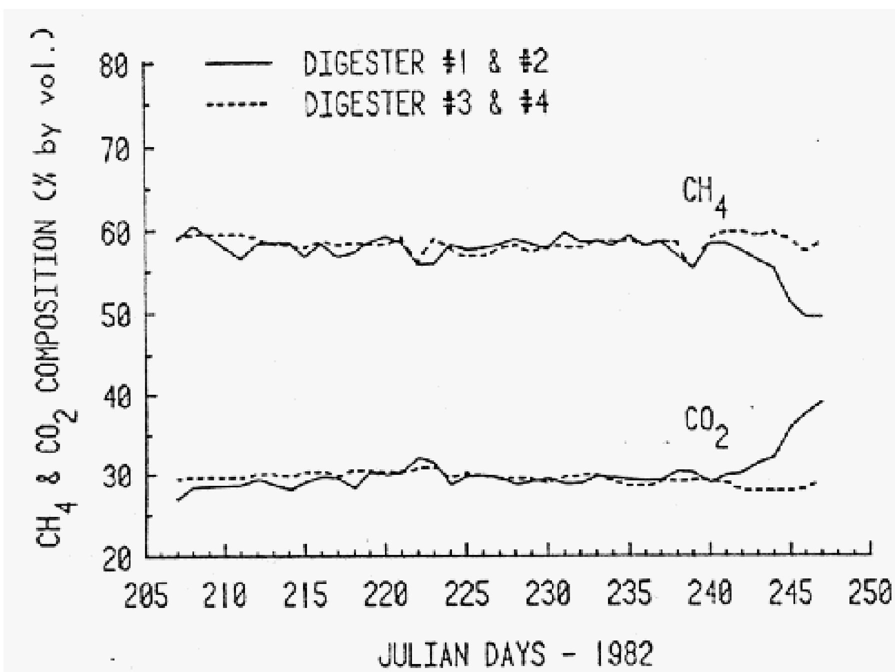

Figure 6. **Average daily gas composition of digesters 1 & 2 and 3 & 4.**

5. ONGOING RESEARCH ON ANAEROBIC DIGESTERS

The current research program includes the following:

5.1 Modelling of Dynamic Population in Anaerobic Digesters.

Continuous culture is a system of cell growth into which nutrients are continuously added and from which the spent culture is continuously removed. At steady state the viable population of cells is kept constant, and the removal of dead cells from the system is balanced by new cell growth. Nevertheless, the steady state parameters of a continuous bioreactor have been well characterized.

However, methane digesters are almost never operated on a completely steady continuous basis for practical reasons. A dynamic model is therefore necessary to correctly predict the gas production quantity and quality, and the biomass yield. A non-steady state parameter of a single stage continuous bioreactor is described by two simultaneous first order differential equations. A dynamic model is being obtained by the numerical solution of these differential equations using a computer. The computer model will be tested experimentally and parameters such as maximum specific growth rate (u), substrate saturation constant (K_S) and yield (y) will also be determined.

5.2 Recovery of Methane and Single Cell Protein from Cheese Whey

The suspended-particle, fixed-biomass fermentation system used for the production of biogas from dairy manure is modified and used for the production of biogas and single cell protein from cheese whey. The results will be compared with those obtained from continuous stirred tank fermenter and non mix sludge separator fermenter of the same size.

5.3 Innovative Design for Anaerobic Digesters.

The computer simulation study (Section 4.1) showed that heating the digester influent constitutes 60 percent of the total energy input to the system; mixing accounts for another 9 percent, and heat loss through walls, floors and roof accounts for 9 to 30 percent. The annual energy production showed a multi-linear relationship among total solids concentration (TSC), digester operating temperature (GOT) and solid retention time (SRT).

An innovative design for anaerobic digester was proposed and tested on a pilot plant scale of 100 liters. The design reduces both the capital and operating costs and increases the yield and efficiency of the system, making the farm scale digester economically feasible.

The design allows the system to operate at low temperature range of 20-30 ºC, yet maintaining the retention time at 10-30 days. There is no mixing required and the fresh manure is continuously added to the digester. The effluent from the digester is odour free, has no air or water pollution potential, and can be applied onto the land using a sprinkler irrigation system even in winter. It could also be used to clean the barn.

Two types of sludge are produced from the system, one could be refed directly to the animals while the other can be used as fertilizer. The latter can be stored until needed for land application in spring with minimum storage space requirement. The system has the capability of retaining the required, active microbial population, thereby increasing the biogas yield and system efficiency.

The digester sludge compares favourably with raw manure in its fertilizer value because the inorganic nutrients (minerals) pass through the system undepleted. The amount of nitrogen available for plant assimilation is increased by the conversion of protein to ammonia.

Pathogenic bacteria such a Salmonella and Erucella are destroyed during anaerobic fermentation reducing the risk of reinfection so that the sludge could be fed directly to the animals or applied onto the land after which animals could graze sooner than it would be possible after raw manure application.

6. STUDY SCOPE

In order to make the anaerobic digester economically viable, installation and operation of the system in conjunction with a livestock enterprise must be based on advantages gained from the digester as a component of the total farm-energy system. Benefits related to manure handling, environmental improvement through odour control, fertilizer nutrient recovery, animal feed production and water pollution reduction in addition to the biogas production must be considered. The odour control in particular is very important in Quebec, Ontario and British Columbia, where many hog operations are located in heavily populated areas and environmental quality legislation restricts operation. This is presently reaching crises proportions in Quebec and British Columbia.

The emphasis in this proposed study will be on the farm scale mesophilic digester. To accomplish the objective stated in section 2, the information obtained and the experience gained from the operation of an innovative anaerobic digester will be utilized to design a farm scale system.

6.1 Advantages of the Proposed Digester Design

The advantages of the proposed design are:

1. It eliminates the agitation problem believed to be a major difficulty in the operation of mixed digesters.

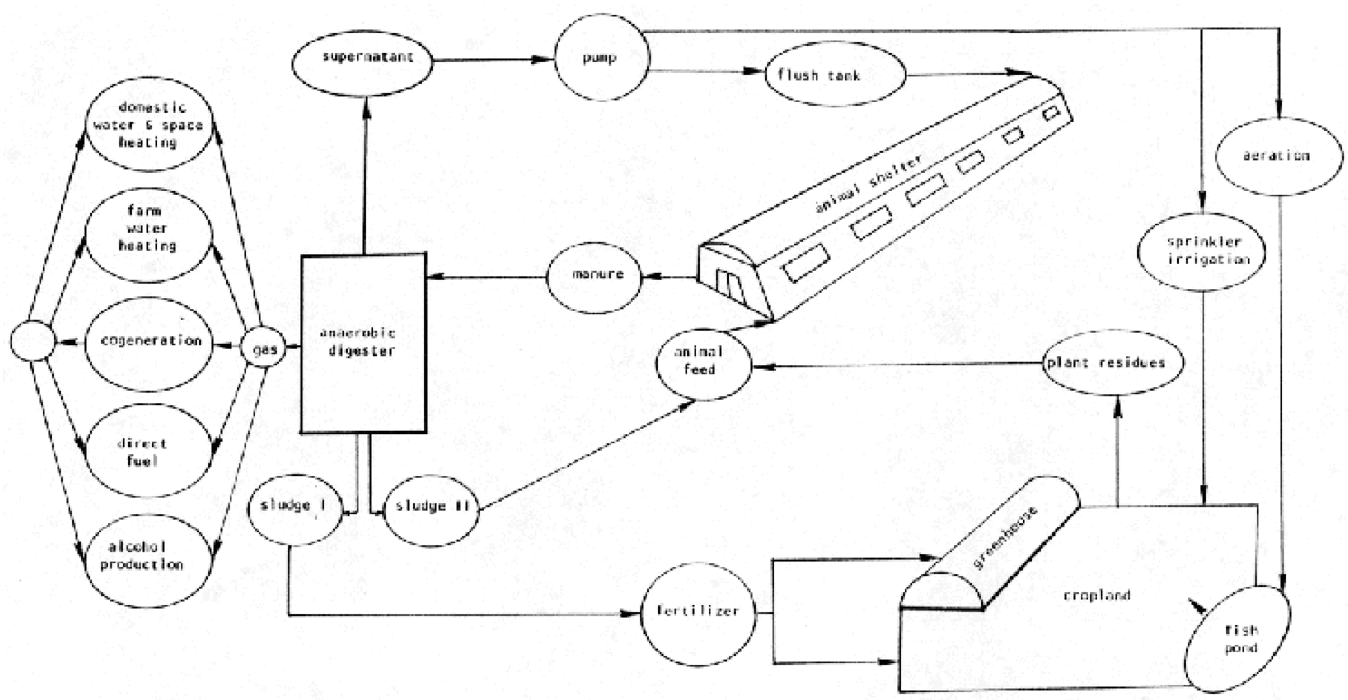

Figure 7. An efficient farm-energy system through biodigestion.

2. It solves the sedimentation and sludge return problem which limits the performance of the anaerobic contact process.
3. It helps to maintain the methane producing bacteria from acids in the system at a high concentration and in an active state thereby reducing dependence on growth for maintaining the culture and need for long retention time.
4. It operates at low temperature thereby saving on energy input. Nonetheless, the choice of a digester temperature within the mesophilic range depends upon the digester design and operating parameters. The "net energy produced" rather than the total gas energy produced will be used as a criterion for selecting the operating temperature of the farm scale digester within this range. Hawkes and Horten (1981) have found that gas production with the temperature is not linear. Therefore the extra methane produced by raising the digester temperature a few degrees may be offset by the increased heat input required. However, the heating system design in this study will be used as a back up system for extremely cold days and at the start-up
5. The major thermal investment for anaerobic digesters would be required to elevate the loading slurry temperature from ambient temperature to operating temperature. This difference is usually 20 ºC and could be as high as 30 ºC depending on the handling techniques. The handling facilities used in this project will be such that this difference in temperature is kept below 5ºC.

6.2 Proposed Tasks

The following tasks will be carried out.

Task 1. Design of Farm Scale Anaerobic Digester for 1300 Hog Operation in Annapolis Valley, Nova Scotia.

There are 196 specialized hog farms in the province of Nova Scotia. Furthermore, hogs are also raised on another 567 mixed farms. Commercial hogs marketed in 1953 were 224,000 accounting for farm return of $31.6 million or 14 percent of the total agricultural production in the province.

A commercial farm operation (Bonda Swine Farms, Ltd., Middleton) owned and managed by Mr. Jacobus De Swart and his wife was selected for this study. The number of hogs raised at any time on the farm is 1,300. A farm scale anaerobic digester for this farm will be constructed taking the following into consideration:

1.	Total number of animals	1,300 animals
2.	Average manure production	4.340 kg/animal/day
3.	Average total solids production (10%)	0.434 kg/animal/day
4.	Average volatile solids (85%)	0.370 kg/animal/day

Design plan has been prepared and the proposed digester size is 58.81 m^3. The digester will be constructed from concrete and will be insulated.

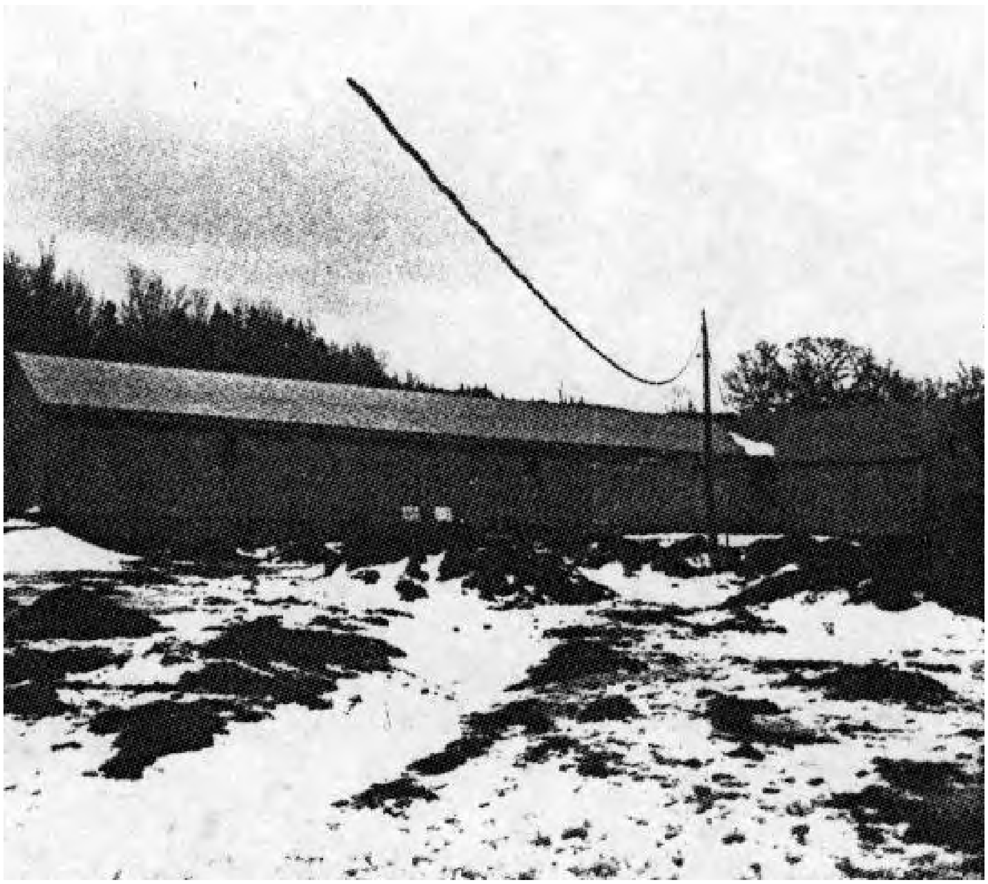

Figure 8. **A swine building housing 1300 pigs on Bonda Farm Limited, Middleton.**

Figure 9. **A beef cattle building housing 600 cows on Bonda Farm Limited, Middleton.**

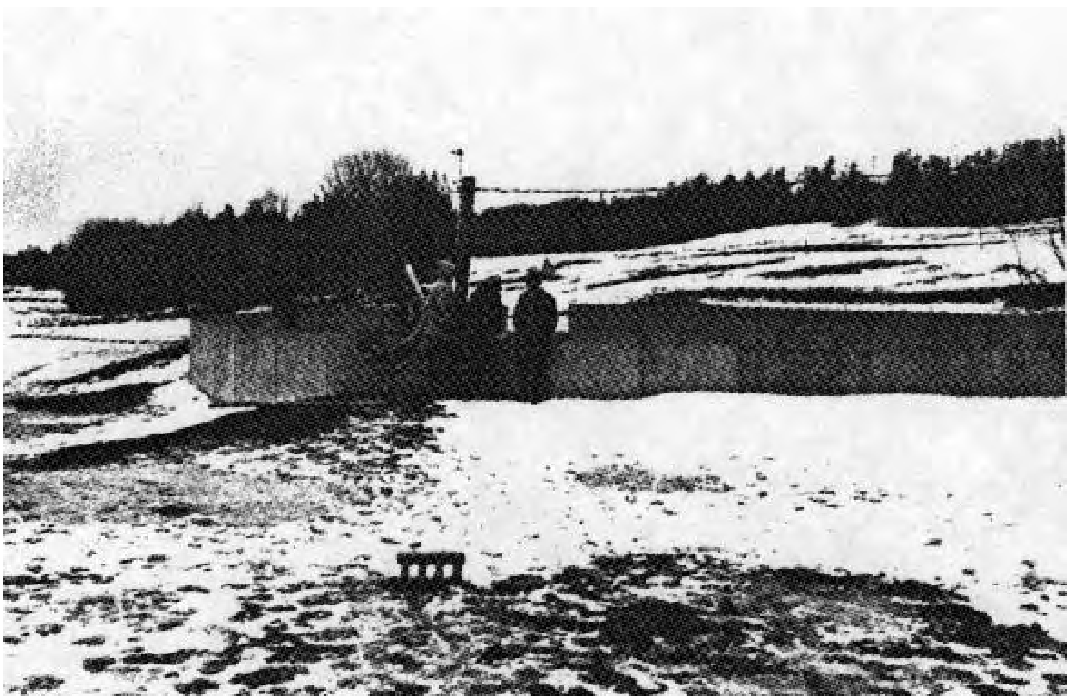

Figure 10. **The manure storage tank on Bonda Farm Limited, Middleton.**

Table 6. Manure production from various classes of animals on DeSwart Farm.*

	Animal Weight		Number of	Daily manure production per animal				Total daily manure production			
Class o f Animal	**lb**	**kg**	**Animals**	**lb**	**kg**	**ft^3**	**L**	**lb**	**kg**	**PG^3**	**L**
Nursery pig	40	18	150	2.3	1.05	0.038	1.08	345	157	5.7	162
Growing pig	65	30	250	4.2	1.91	0.070	1.98	1050	477	17.5	495
Finishing pig	150	70	300	9.8	4.45	0.160	4.53	2940	1336	48.0	1359
Finishing pig	200	90	430	13.0	5.91	0.220	6.23	5590	2541	94.6	2679
Gestate Sow	275	125	120	8.9	4.05	0.150	4.25	1068	486	18.0	510
Litter	375	170	40	63.0	15.00	0.540	15.30	1320	600	21.6	612
Boars	350	160	10	11.0	5.00	0.190	5.38	110	50	1.9	54
Total			1300					12423	5647	207.3	5871
Weighted Average	157.5	71.6		9.56	4.34	0.159	4.32				

* constructed from information taken from the farm owner and MWPS, 1980

Task 2 - **Construction of Digester and Manure Handling System and installation of Instrumentation**

The design plans and specifications for the anaerobic digester will be given to a construction company and the work will be contracted out to the company. Drs. Ghaly, and Singh will supervise the construction phases to make sure that the construction is carried out according to the specifications.

The manure handling system will be constructed by the farmer. Plans and specifications will be handed out to him. The cost of the manure handling system is paid by the farmer in full.

Instrumentation and measuring equipment will be installed by the technical staff under the supervision of Drs. Ghaly and Singh.

Task 3 - **Operation and Data Collection**

The system will be operated and data will be collected by Mr. C. Esau (Engineer) and Mr. J. DeSwart (Farmer). The data will be analyzed and interpreted so that any necessary modification and control could be performed in time.

The temperature, pH, ORP, alkalinity, NH_3 and acid concentration will continuously be monitored.

Five retention times (10, 15, 20, 25, 30 days) and three loading rates (2.5, 5.0 and 7.5 kg VS/day/m^3) will be studied to determine the optimum operating condition that will produce the highest biogas yield and best net energy balance. The system is designed in such a way that no mixing or heating is required, but any necessary modifications which will result in energy saving will be considered.

Task 4 - <u>Chemical and Microbial Analyses</u>

Chemical analyses will be performed on the inflow, overflow, sludge I and sludge II. Tests such as BOD, COD, TK-N, Org-N, Amm-N, NO_2^-, NO_3^-, P, K, etc. will be carried out on a daily basis. Gas analysis will also be carried out on the biogas.

Task 5 - <u>Assessment of Nutritional and Fertilizer Values of the Sludge</u>

Feed trials will be carried out by Dr. Anderson (an animal nutrition specialist, Animal Science Department, Nova Scotia Agricultural College) on pigs and cows of various age groups to determine the effect of using the sludge as a supplementary feed, and to determine the optimum feed/sludge ratio. Economic analysis will be performed to determine the amount of saving on animal feed in dollar value. The health aspects of the animals will be considered in this study.

Fertilizer trials will be carried out by Professor Khan (Professional Agrologist and Special Lecturer, Agricultural Engineering Department, Technical University of Nova Scotia) to determine the fertilizer value of the sludge for vegetables and field crops. The amount of nutrient readily available for plant assimilation will be determined. The best method and time of applying the sludge to the land will also be determined. Nutrient loss due to sludge storage in winter will be assessed. The amount of savings on chemical fertilizer in dollar value will be determined. The saving on the capital and operating costs of sludge storage, handling and disposal as compared to raw manure will be determined.

Task 6. **Analyses and Interpretation of Results and Report Writing**

The results obtained from the digester, feeding and fertilizer trials wilt be analysed. A thorough economic analysis on the whole system will be carried out. The final report will then be prepared and submitted.

Task 7 - **Technology Transfer**

As mentioned earlier that there are 196 specialized hog farms and 567 mixed farms raising hogs in Nova Scotia. Several commercial hog operations are found in the Annapolis Valley area. Some of these farmers have expressed interest in adapting the technology if proven successful.

The extension engineer (Mr. Bishop, Engineering Division, Nova Scotia Department of Agriculture and Marketing) has been involved in technology transfer from various research projects to local farmers. He has also been continuously involved in research projects including the design and testing of manure handling, storage and treatment facilities and several other energy projects. Mr. Bishop has expressed keen interest in the project and helped providing some valuable informations required for writing this proposal. He will invite the farmers to the project site so that a demonstration on the operation and management of the system and economic gain from it could be given to them.

7. MANAGEMENT PLAN AND PROJECT SCHEDULE

A detailed project plan has been prepared and summarized !n Figures 11 and 12. The total project is scheduled to be conducted over a three-year period. Six copies of the final report will be submitted at the end of the project.

8. FACILITIES, CAPABILITIES AND PERSONNEL

The waste management laboratory of the Agricultural Engineering Department at TUNS has been recently formed to consolidate the rapid}, expanding R&D efforts in the area. Facilities in Civil and Chemical Engineering Departments at TUNS are available for use by the applicants. In addition to the standard instruments for chemical analysis, gas-liquid chromatograph, spectrophotometer, leco-furnace and high pressure liquid chromatograph are also available in these laboratories.

The team assembled for this project combines a diversity of scientific and engineering backgrounds necessary to meet the challenges presented. Detailed resumes of the key personnel are incorporated as Appendix A.

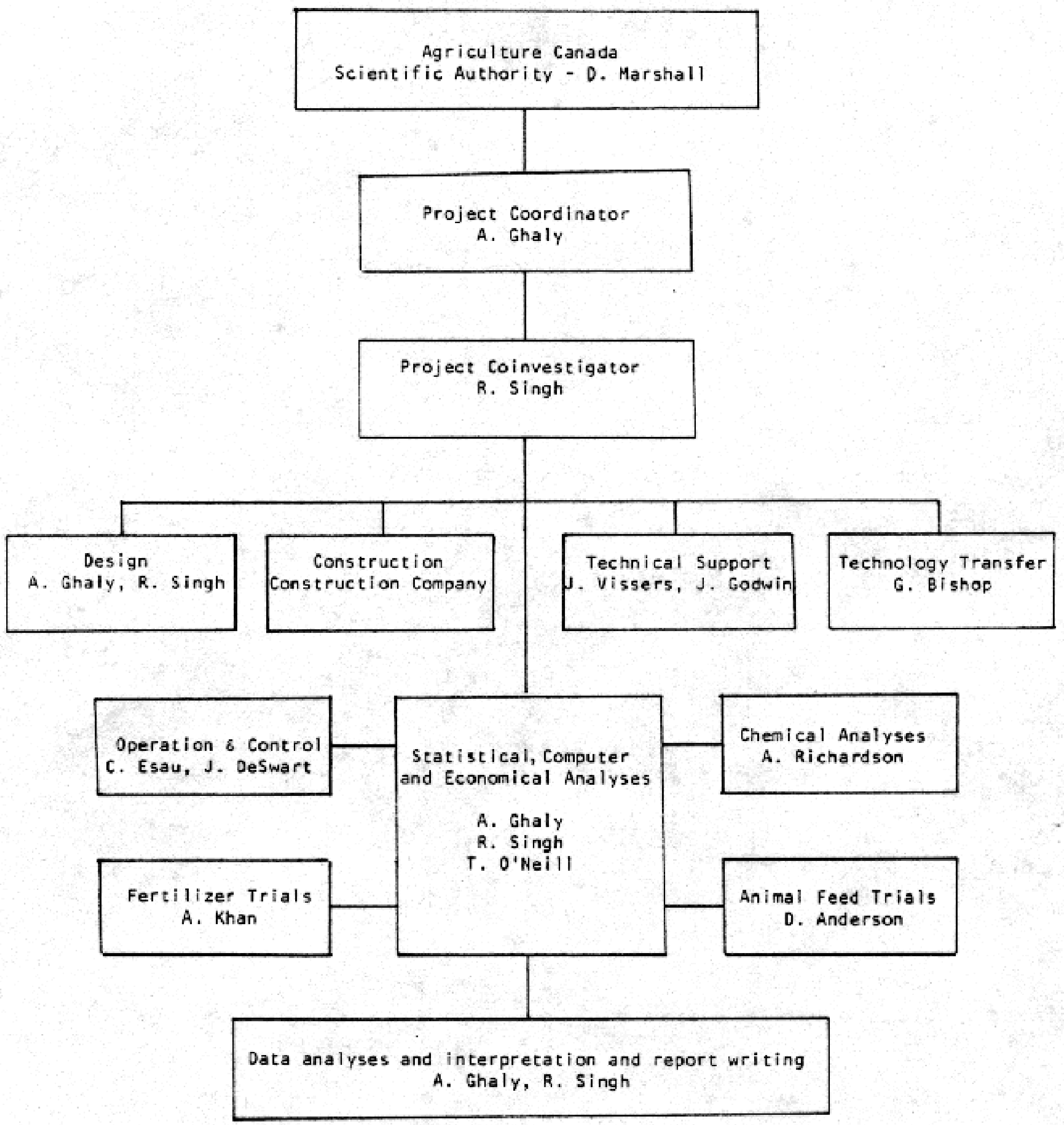

Figure 11. Organization chart.

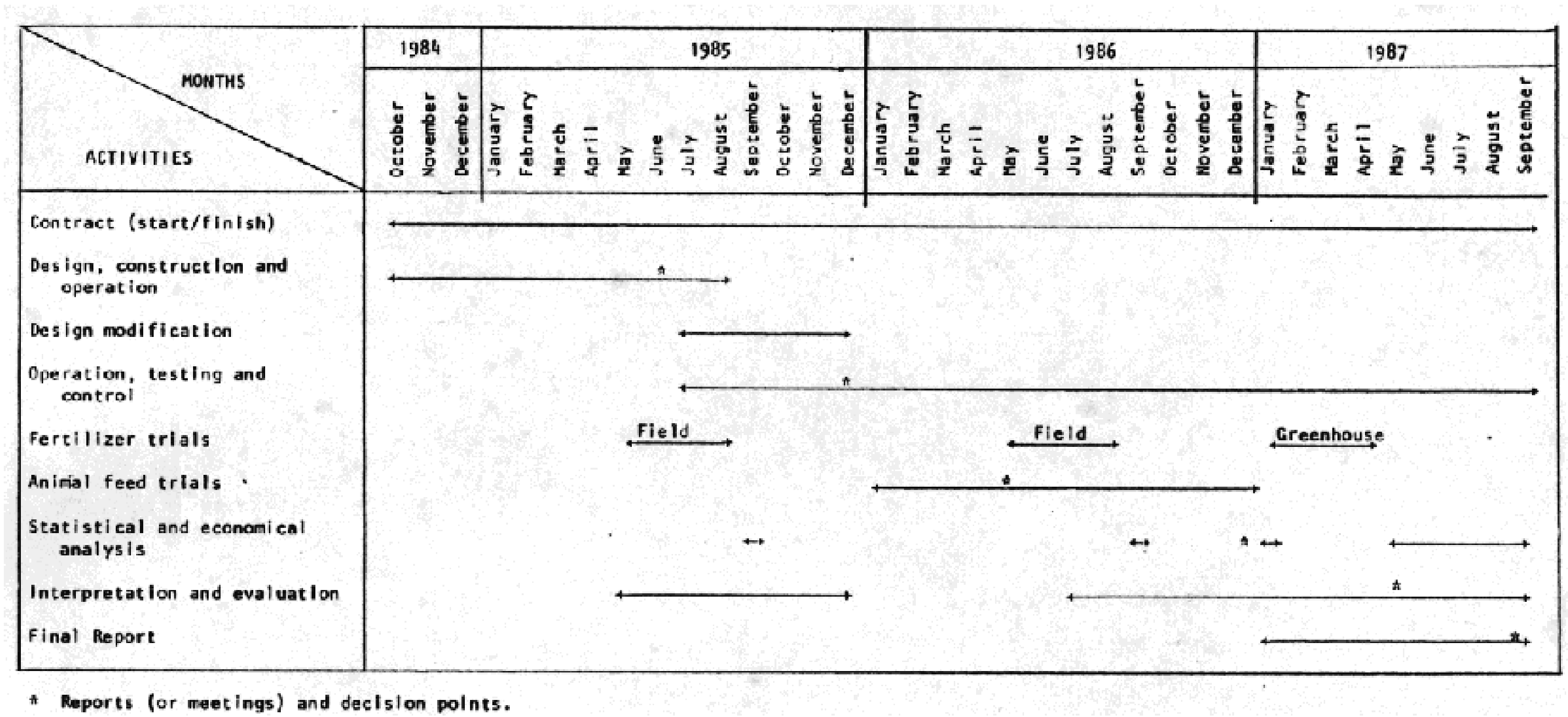

Figure 12. Time plane.

9. BUDGET PROPOSAL

Hourly rates are based upon 1596 working hours per year. Benefits of 10% and total overhead charges of 30%. of salaries and 2% of travel and direct materials are calculated.

9.1 Total Requested from ERDAF

I - Direct Labour, including benefits at 10%		
(a) Research Associates (1 1/2 man-year equivalent) (G. Esau)	$42,900	
(b) Lab Technician (2 man-year equivalent) (A. Richardson)	$26,400	
(c) Technologists (3 months equivalent) (J. Vissers, J. Godwin)	$11,825	
(d) Secretarial services ($75/day for 20 days) (L. Weatherhead)	$ 1,500	
Sub-total Item I		$82,625
II - Professional support at actual cost, without mark-up		
(a) Animal nutrition specialist($150/day for 40 days) (D. Anderson)	$ 6,000	
(b) Plant and soil science specialist ($150/day for 40 days) (A. Khan)	$ 6,000	

(c) Economist	
($200/day for 15 days)	$ 3,000
(T. O Neill)	
(d) Electronics and instrumentation engineer	
($150/day for 10 days)	$ 1,500
(G. Park)	
(e) Design, planning, data analysis and report writing	
($200/day for 60 days + $150/day for 60 days)	$21,000
(A. Ghaly, R. Singh)	
Sub-total Item II	$37,500

III - <u>Material and Supplies</u>

(a) Chemicals, glassware, tubing fittings, film, charts, etc.	$ 10,000
(b) Printing and miscellaneous supplies	$ 1,700
(c) Long distance telephone calls, supplies and other sources of technical information	$ 1,600
Sub-total Item III	$13,300

IV - <u>Direct charges at actual cost</u>

(a) Acquisition of specialized sources of information	$ 600
(b) Computer services	$ 2,000
(c) Travel expenses to consult with scientific authorities and to the project site	$ 5,000
(d) Rental fees for the use of specialized measuring and control facilities	$ 9,000

(e) Construction (including insulation material and labour)	\$ 42,000
(f) $C0_2$ scrubber	\$ 2,000
(g) Heating system	\$ 1,000
(h) Pumps	\$ 1,500
(i) Hypelon (flexible biogas bag)	\$ 1,500
(j) Miscellaneous supplies	\$ 2,000
Sub-total Item IV	\$67,100

V - Overhead

(a) 30% of Item I	\$ 24,788
(b) 2% of Items III & IV)	\$ 1,578
Sub-total of Item V	\$26,366
<u>TOTAL REQUESTED FROM ERDAF</u>	\$226,791

9.2 <u>TUNS Contribution</u>

(a) Laboratory space (\$200/month for 24 months)	\$ 4,800
(b) Professional fees (\$350/day for 60 days) (A. Ghaly, R. Singh)	\$21,000
(c) Technologists (3 month equivalent)	\$11,825
(d) Secretarial services (\$75/day for 40 days)	\$ 3,000
(e) Travel expense	\$ 2,000
(f) Overhead (30% of salaries + 2% space & travel)	\$10,584
<u>TOTAL TUNS CONTRIBUTION</u>	\$56,569

9.3 Farmer's Contribution

(a) excavating	$ 300
(b) manure handling system	$ 4,000
(c) gas tank	$ 9,200
(d) furnace	$ 1,800
(e) electricity generator	$32,500
(f) compressor	$ 5,000
TOTAL FARMER'S CONTRIBUTION	$53,500

9.4 Total Project Cost

ERDAF	TUNS	FARMER	TOTAL
$226,791	$56,209	$53,300	$336,660

9.5 Cash Flow for Requested Amount

	Yea r ($)		
Item	**1**	**2**	**3**
Research Associate	14,300	14,300	14,300
Lab, Technician	-	13,200	13,200
Technologists	7,825	4,000	-
Secretarial Services	400	500	600
Animal Scientist	-	3,000	3,000
Agrologist	-	3,000	3,000
Economist	-	-	3,000
Electronist	1,500	-	-
Professional fees	7,000	7,000	7,000
Material supplies	7,000	3,000	3,300
Direct charges	60,000	5,100	2,000
Overhead	8,098	9,762	8,506
SUB TOTAL	$106,123	$67,862	$57,806
TOTAL		$226,791	

10. FINANCIAL STATEMENTS AND REPORTS

Invoices will be submitted every three months and are to be accompanied by brief progress reports. Detailed reports (and/or meetings) will be submitted at decision points indicated in time plan. A draft of the final report is to be submitted to the Scientific Authority for review before the final report is prepared. Six copies of the final report will be submitted.

11. SCIENTIFIC AUTHORITY

The Scientific Authority of the project is to be Mr. D. Marshall, Engineering and Statistical Research Institute, Research Branch, Agriculture Canada.

12. DECLARATION

1 - "If this proposal is accepted, we agree to the inclusion of General Conditions DSS1053(11/82), a copy of which is now in our Possession"

2 - "The Government's 6&5 (%) program is acceptable to us".

Project Coordinator

Dr. A.E. Ghaly

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