OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

We regret that [illegible] the pages [illegible]

[illegible]

L94

07133

Distr.
LIMITED

ID/WG.233/3
16 September 1976

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Meeting of Selected Heads of
Research Institutes

Vienna, 18 - 22 October 1976

REPORT ON THE ACTIVITIES OF THE BRACE RESEARCH INSTITUTE AND THEIR RELATION TO DEVELOPMENT AND TECHNOLOGY TRANSFER 1/

by

T.A. Lasand*

* Director, Field Operations, Brace Research Institute, Macdonald College of McGill University, Québec, Canada.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.76-4793

CONTENTS

BACKGROUND

Major James H. Brace left the residue of his estate to McGill University, under the terms of his will, following his death in April 1956. The technical activities of this endowment, commonly referred to as the Brace Bequest, are controlled by the Dean of the Faculty of Engineering of McGill University, Montreal, Québec, Canada, who is advised by a Committee consisting of the Chairmen of departments within the Faculty of Engineering.

A two year study was made by the Director of Planning, the former Dean of Engineering, R.E. Jamieson, who surveyed the entire field of possible operations for the Bequest and submitted his findings in September 1959. This report, accepted by the Committee, formed the basis for further work under the Bequest.

The current organization was finalized in January 1961, and given the name Brace Research Institute. Its first director was Dr. G.T. Ward, who remained with the Institute from November 1960 to June 1971. During this period, the Institute established its Experiment Station in Barbados in 1961, as well as undertook its principal technical developments.

Following a major review of activities, a new policy has been established since June 1972. This has divided the operation into two separately budgeted divisions, whose activities are closely interlinked.

The first part is headed by T.A. Lawand, as Director of Field Operations. He is responsible for developing contacts with those areas and communities which would profit from the expertise developed by the Brace Research Institute and for marrying these needs with the appropriate funding agencies. His staff currently consists of an administrative assistant, design and contracts engineers, and secretarial and library staff.

The second is directed by Dr. G.L. d'Ombrain, Director of Research for the Institute and constitutes a funding agency for research contracts in fields appropriate to the terms of the Brace Bequest. Funds are available for research and development and for bringing to the campus experts in the solar and wind energy fields. Research and development is not restricted to McGill University, Faculty, although it is hoped that they will take an active part in attacking the challenging problems presented by the need to develop Appropriate or Intermediate Technology for the less developed areas of the world.

I. BASIC POLICY OF THE INSTITUTE

Since its inception, the Institute has followed a consistent policy directed towards the fulfillment of the aims set down by Major Brace. He specified that the money should be used "for the purpose of providing for and carrying on research for the development of methods or means of eliminating or reducing the salt content of sea water so that it may be used economically and effectively for irrigation, and with due regard to the foregoing primary purpose, for purposes of research into methods of irrigation or other means for making desert or arid land available and economically useful for agricultural purposes".

It was his desire that the results of this research would be made freely available to all the peoples of the world. The Institute has and is continuing to fulfill his wishes. The policy decision made in 1959 was to concentrate on the problems of water and power scarcity affecting individual persons and small communities in arid, developing areas.

During the interim the Institute has built up a facility, the value of which is to some extent unique, given its relatively small size. It maintains an active interest in the field of water desalination. It is now recognized as one of the leading international research centres for solar and wind energy utilization, especially with regard to solar distillation, and for the development of wind turbines. As an extension of its work on various methods of saline water conversion, the Institute has begun research into controlled environment agriculture as a means to reduce the water requirements of plants in arid areas. It has undertaken studies on the use of greenhouses in colder climates. In addition, it is a centre for information on Appropriate Technology.

Although the Institute concentrates primarily on the technological aspects of Appropriate Technology, it is fully recognized that the "tool" or "system" developed is only one facet of the problem. Full appreciation must be made of the cultural, social, political context in which the equipment is to function in order to establish its appropriateness to the community it will serve. It is essential to recognize that for a technology to be appropriate it must be directed towards the betterment of the community, in both its direct and indirect implications.

A particularly valuable asset is the Brace library containing collections of reference material on desalination, solar energy and wind power utilization. Individually each is considered to be amongst the most comprehensive and thoroughly indexed source of information available in its respective discipline. More recently extensive information has been gathered on greenhouses agriculture and Appropriate Technology. The Institute's library now possesses significant material in both these fields.

The policy of the Institute, with regard to both cooperation with sister research organizations and developmental work in the field, is outwardlooking with an emphasis on the resolution of the pressing problems facing the poorer and rural populations of less developed areas.

The basic philosophy has been to develop saline water conversion, pumping and other energy consuming equipment utilizing as much as possible local energy, material and human resources so that the technology can find identity with the infra-structure of the local community.

This policy was adopted in order to secure participation of the indigenous population in all phases of the construction and assembly of the equipment. This ensures continuity by developing their ability to handle its operation and maintenance.

The equipment developed is characterized by its simplicity and facility of maintenance. Stocks of simple replacement components ensure continuity and dependability. The annual operating costs are comprised primarily of the amortization of the capital investment, a fair proportion of which is made up of local labour and material charges.

This basic type of undertaking is generally referred to as Appropriate Technology. The premise is to find solutions to the problems of hundreds of millions of people whose everyday life is little affected by modern technological achievements. The people lie outside the mainstream of development. The objective is to provide them with an option, an alternative so that they may resolve their own technological problems with systems, methods, energies and materials under their own control. In making use of what is, by and large, locally available and, in particular, in adapting the technology so that the individual villager himself feels part of the overall achievement, Appropriate Technology takes into account that facet of the human equation so often neglected - the dignity of man. For

whatever we design, construct or discover, the final proof and justification of its merit is its acceptability by man.

What is the case for Appropriate Technology? In particular, why should an organization such as the Brace Research Institute adopt this approach to the problem of underdevelopment? There are several reasons.

The first is financial. Research and development and even field applications are relatively inexpensive. Hence, it is possible, even with a modest outlay, to come up often with simple technical solutions to the problems of the rural populations of the Third World.

The second is scale. Because of its very nature, dealing with small villages and peasant farmers, developments are themselves on a small scale. This is within the scope of a relatively small organization such as the Brace Research Institute. Also the scale of these activities mean that funding can often be more easily found so that in effect a wider approach can be realized with a more direct involvement of the local inhabitants.

II. RESEARCH AND DEVELOPMENT

Review of Research and Development Program:

The research and development thrust of the Institute can be said to have five main aims:

a) saline water conversion for community water supply
b) the utilization of solar energy
c) the utilization of wind energy
d) arid zone development
e) Appropriate Technology

Naturally, there are certain overall objectives towards which the Institute is striving, and limitations of personnel and funding dictate the degree to which these are tackled in any given year. These are years of transition between the old mode of operation and the new in which the Institute functions on two separately budgeted halves dealing on the one hand with research into problems advancing the basic body of knowledge and on the other hand developments and application. They are of necessity often intertwined. Hence, for the moment, the basic projects funded by the Institute are listed as well within this section. The Institute staff has participated fully in almost all of these projects so as to assist in the initiation of the programs.

A. Desalination - Water Supply: In keeping with the wishes expressed in the will of Major James Brace, the Institute has maintained an active program of research and development in the field of saline water conversion. Following the terms of reference laid down in the report of the Committee of Planning, under Professor R.E. Jamieson, the emphasis continues to be on the development of small scale water systems for use by peasant farmers or by small rural communities in isolated, arid areas. The source of energy being investigated is usually solar or wind energy, which keeps the annual operating cost of the installation at a low level, the principal annual charge being the amortization of the capital investment. The energy available from the sun and the wind is used in the production of fresh water and of the power which is always associated with this water supply. The principal form of desalination which has been under investigation for a number of years is solar distillation. Studies in this area range from the continued evaluation of a number of previous installations in the West Indies to the integration

of solar stills in house roofs, and their use in greenhouses being developed for arid areas.

One of the large solar stills in Haiti continues to serve the needs of an ever growing body of people in a remote offshore island. As a result of a contract awarded by the Canadian International Development Agency, the Institute has undertaken studies in design optimization of solar stills. As well, the construction of solar distillation units has been closely examined so as to realize the best possible value for the capital investment. Studies have continued, therefore, at increasing productivity while adapting the construction of the units to conditions in developing areas. Construction techniques and material adaptation have been investigated with a view to establishing prefabricated solar still components. An effort is being made to encourage Canadian manufacturers to take up the production of the final designs. The components are being made available directly to consumers in arid areas or through the offices of the Canadian International Development Agency, which may eventually use this equipment in Foreign Aid Programs. Asbestos cement, fibreglass, aluminum and butyl rubber have been among some of the material components tested for the prefabricated assemblies.

With this in mind, a program of experimental investigation was begun on the development of very basic, simple family-sized solar stills using as much as possible local building material. Solar stills were made with brick framework and soil-cement blocks, for this purpose. A number of prototype units were built and operated for the summer at the Macdonald College test facility. Experiments were started using clay as a solar still basin liner, similar to those of solar evaporation salinas used for salt production.

The Institute has continued to develop its expertise in the field of small community water supply in arid areas, in particular where desalination has some potential. Increasingly, requests are being received in the Information Service of the Institute for advice along these lines. The basic premise is the investigation of overall water supply systems which incorporate desalination processes in satisfying the community's water demand. Full utilization of naturally available water, such as rainwater or saline ground water, is made in assessing the community's real water supply-demand characteristics. In this manner, the true potential of the desalination plant can be determined as well as a proper definition of its role in the overall water system.

Conventional desalination systems - in particular vapour compression and reverse osmosis - have been examined in the past with a view to their utilizing the mechanical shaft power of the Brace prototype wind turbine. A close watch is being kept of developments in this field though specific work in these areas is not currently in progress at the Institute.

It is increasingly evident that research and development in the fields of desalination are definitely entrenched in industry. University researchers in this field are playing a minor role or are consulting to industry, as desalination becomes more feasible and applied.

B. Solar Energy Utilization. Two fields of research for power development have been undertaken with a view to application in arid areas - solar ponds and solar powered organic fluid rankine cycle engines. Both are related to the production of power in arid areas and could easily be utilized in remote, lesser developed regions for the provision of heat, the generation of electricity, the pumping of water and the like. The principal researchers are from within the Faculty of Engineering of McGill University. A prototype solar pond has been at the field testing station at Macdonald College and has been operated during the summer months since 1974. The maximum temperature attained in the bottom of the pond was 80°C to 90°C. The unit has now been covered by a Brace greenhouse to extend its period of operation.

An organic fluid rankine cycle engine was purchased from SOFRETES, (Société française d'études thermiques et d'énergie solaire), Montargis, France as part of a collaborative agreement for the development of this technology. The objective of the program is two-fold. The first is to test and improve the performance of this unit. In the laboratory it is powered by a conventional heat source. It is hoped as well to eventually combine the solar powered non-convective solar ponds with these engines with the view to their use for continuous water pumping or electrical generation for developing areas. It is hoped as well, to eventually be able to test this system in a specific application under village conditions in a developing area.

Work continued on the improvement of the Brace flat plate solar cooker in order to reduce the friction loss in the disengaging space between the solar collector and the cooking assembly. Several models of solar steam cookers have been developed and tested with a view to increasing their effectiveness and reducing the overall cost. New models of cookers are being tested to cook directly within the collector.

Work has continued in close collaboration with the Group de Recherche sur les Serres Maraichères based at Université Laval on the improvement of the Brace designed greenhouse. This unit, designed for colder climates, is aligned on an east-west axis facing the Equator. The side opposite to the Equator, is inclined, insulated and lined with a reflective inner layer. The performance of the unit located at Université Laval continues to be monitored closely and exhibits significantly reduced heating costs. In addition the productivity on tomato crops has been shown to be continuously higher than the adjacent control greenhouses operating under similar conditions. While the Canadian aspect of this project is to extend the growing season, reduce the heating requirements and increase productivity within the greenhouse, the use of these structures has also been realized in overseas areas. Not all developing regions are necessarily blessed with warm climates. The high plateaus of the Andes, parts of North Africa and the plateaus and highlands of Central Asia are a few of the regions wherein developing arid areas are also subjected to colder climatic conditions. Bearing these aspects in mind, the use of controlled environment agriculture can permit the exploitation of land, which might otherwise be unproductive. One particular advantage of a greenhouse is the overall reduction in water consumption which is essential in arid lands.

Other Institute activities have been the design of greenhouses to be placed on the roofs of buildings in urban areas of northern cities such as Montreal. The objective is to investigate the technical, economic and social parameters affecting the use of flat rooftop areas in cities for the cultivation of gardens, the use of cold or hot frames and greenhouses. The program is in its second year of operation.

During the summer of 1974 a collaborative program of investigation was undertaken with the Shelter Systems Group of the School of Architecture of McGill University, on the experimental solar and wind powered house at the Macdonald Campus. All the environmental parameters necessary for the operation of the facility were measured. Some improvements were undertaken on the water and electric supplies; the roof of one of the sections of the house was insulated. During the winter months, wood stoves of various designs, as well as flue heat exchangers were tested. During the winter some solar walls were built at the Macdonald College experimental house in order to verify their performance under Canadian conditions. These have now been fully tested during cold weather operation. Together with the

Shelter Systems Group, a contract was obtained to design and build four environmentally adapted houses for Québec's Indian (Canada's native peoples) populations. The Institute looked after the design of the solar collector and heat storage systems, all of which were fully integrated into the design of houses whose orientation and thermal characteristics were studied to be compatible with the climatic conditions prevailing at their locations. One house, designed for the Côte Nord region of the province consists of a 40 m^2 vertical wall solar air heater collector in a house with approximately 120 square meters of surface area. Warm air is stored in an insulated rock pile located in the basement. During its first year of operation it is estimated that the solar system provided roughly 60% of the total energy needs of the house. Hydro Québec, the public utility providing electricity in the province of Québec, has undertaken a joint evaluation program with the Institute of the performance of the house, both thermally and with regards the solar system. The Côte Nord house is located at Manitou College, La Macaza, Québec, about 200 kilometers north of Montreal.

The Institute has maintained its interest in solar agricultural drying as a method of utilization of a renewable energy source, combined with a mechanism of preservation of surplus produce. Several solar dryers were operated over the past few years, particularly the cabinet dryer which was exhibited in conjunction with a solar still and a solar steam cooker at the Habitat Forum, held in conjunction with the United Nations Habitat Conference in Vancouver, Canada, June 1976. A small greenhouse has also been converted into a low temperature drying chamber, during the harvest season with interesting results indicating the possibility of combined operations. The solar cabinet dryer has been used as a food warmer and food pre-heater which can provide significant amounts of energy for cooking purposes if adequately used. A manual on solar agricultural dryers is under preparation and the first part, a series of case studies on solar agricultural dryers has been published in December 1975.

C. Wind Energy Utilization: An increasing number of requests for information was handled by the Institute, due to the growing interest in alternative energy sources. Many requests for commercial equipment both in the solar and wind energy fields were referred to Budgen & Associates, affiliates of the Institute, who have expanded their agency representations.

Tests continued on the wind electric generator manufactured by Lubing Maschinenfabrik of West Germany, which powers the experimental house on the Macdonald Campus. This supplies electrical energy through a D.C. storage system for power and lighting purposes to the experimental low cost dwelling located at the site.

Improvements in the design of the 10 metre diameter Brace prototype wind turbine were finalized. Plans and Specifications have been revised in particular with respect to improved towers and transmission systems. A joint program for the installation of one of these windmills at the Research Centre of Hydro Québec, for the production of electricity, is underway. It is hoped these investigations will not only be of benefit to efforts in Canada, but will also be applicable for eventual use overseas.

An 8 metre diameter sail windmill has been developed by the Institute in conjunction with Windworks, Wisconsin, U.S.A. A number of improvements have been initiated and the windmills operating characteristics have been examined. These tests are continuing especially with regards to improving the method of attaching the sails and controlling the windmill during its operation. Through student projects in the Department of Civil Engineering, a wooden tower has been designed for this unit as well as an improved fan tail design. Also a number of simple pumps have been designed which can be fabricated directly in developing areas and powered by this windmill. Detailed plans and specifications for this unit will be available for distribution to areas where they are needed overseas. The windmills are suitable for use in North America as well, and might well find application in drainage pumping on farms in the Eastern portion of the Continent.

A survey has been undertaken of commercially available windmills and a report is being prepared to make this information available. Windworks has been loaned some Institute instrumentation to permit them to test not only their prototype windmill but also some commercial equipment hooked in directly to utility grids using modified inverters. These tests which are continuing will also be able to expand our knowledge of the operation of such systems.

Work was continued on the development of the Savonius Rotor windmill. Some new structural support systems have been developed which eliminate the need for guyed support. In addition three different configurations of rotors have been built and tested.

As part of the Québec Indian Housing system discussed earlier a windmill generating electricity and electrical storage system have been designed and built. A tubular steel windmill tower has been designed and fabricated for an Elektro wind electric generator.

D. Arid Land Development - Surveys and Reports: The Institute continuously focuses some of its activities on problems related to arid land development in accordance with the terms of the will of Major James Brace. Some of these activities have included the development of closed cycle greenhouses combining solar stills with greenhouse agriculture in order to make use of available saline water in arid areas and the reduced water consumption normally required in arid areas. In addition, some support has been given to associated groups at the University working on low cost sanitary disposal systems which are designed to reduce overall water requirements in housing in developing areas.

The Institute has increasingly been asked to undertake surveys in various developing areas either for the Canadian Government of Canadian Institutions or at the request of local Governments, and International Agencies. Among the surveys undertaken for the United Nations have been an investigation of the use of solar distillation on the Turks and Caicos Islands in the West Indies, an investigation of the potential of renewable energy resources for the Chaco district of Paraguay, and a feasibility study for the establishment of a rural energy centre using renewable energy resources for Sénégal. An earlier study undertaken in Sénégal examined the existing research and development effort of local Institutions in the field of renewable energy resources. A similar more extensive study was undertaken in Canada on the use of renewable energy resources at the request of the Canadian Government's Ministry of State for Science and Technology.

III. PROBLEMS UNDER CURRENT INVESTIGATION AT THE BRACE RESEARCH INSTITUTE

A. Saline Water Conversion:

1. Evaluation of Existing Solar Stills in the Field. The long-term performance characteristics of small and large solar stills in the West Indies is continuing.

2. Solar Still Optimization and Prefabrication. In this on-going study the performance parameters of solar stills have been optimized to increase the ratio of productivity to capital investment. Satisfactory designs have been developed for prefabricated manufacture for eventual use in developing arid areas. Small prefabricated units are undergoing field-testing in Haiti.

B. Wind Power:

1. Improvement of 10 HP Wind Machine. Modification to the design of the Brace windmill for pumping deep wells and impounded surface waters have been finalized. Plans have also been submitted to the manufacturers for the generation of electricity using the Brace Wind Machine.
As a result of an agreement with Hydro Québec, the public utility for Québec, a joint program was undertaken to produce a 10 metre diameter windmill which will be installed on the roof of the Institut de Recherches Electriques du Québec, at Varennes, Québec. This windmill will drive an electrical generating system in an experimental rig. The windmill blades of reinforced fibreglass have been manufactured under licence by Epothane Limited of Montreal. A new 14 metre structural steel tower has been designed specifically for this purpose. New upper bearing rotational heads, transmission shafting and braking systems have been incorporated in the windmill design. A large bearing with an external rack placed on top of the tower permits full rotational ability. An engaging pinion gear powered from an electrical source will turn the head out of the wind during periods when the mill is non-operational. The blades are counterweighted to ensure that the centre of gravity of the rotational upper section falls directly over the centre of the tower. A truck rear axle differential is used to transmit the horizontal shaft power developed by the airscrew to a vertical shaft driving the electrical generating equipment located at ground level.

2. Wind Electric Generation. A 400 watt wind-electric generator of the Lubing type is being operated at the Macdonald Campus test facility to provide electricity for a solar/wind powered experimental house. The electrical control mechanism and operational problems with blades and bearings were investigated.

3. Electrical Power Transmission for a Free-Running, Fixed Pitch Windmill. The static and dynamic properties of an electric power transmission system for a windmills has been investigated. Two reports, Brace Research Institute Technical Reports Nos. T.94 and T.95 have been written and an M. Eng. thesis has been prepared by A. Memarzadeh.

The project is based on the concept of windpower as in inexpensive source of low grade energy for poor or remote communities. It is assumed that the power will be used, except for very minor quantities, as and when available for rather mundane tasks such as heating or pumping water. Minimum cost and maximum reliability are considered to be of prime importance. Accordingly a fixed-pitch free-running windmill is envisaged driving a three-phase permanent magnet alternator through appropriate gearing. The alternator output is transmitted to the load over a short, (maximum length about 1 km) low-voltage transmission line to the load; either resistors for heating or a squirrel cage induction motor for driving a pump.

The work has addressed itself to the following points: optimum windmill configuration, steady state properties of the system with heating and pumping loads and dynamic performance of the system with varying loads and with wind gusts of various frequencies. A mathematical model of the system has been developed and shown to be accurate. The multibladed fan type windmill has been shown as good as if not better than an optimized aerodynamic type application. Heating loads have been shown to present no problems. Pumping loads need some adaptation to the transmission system characteristics. The system has been shown to be dynamically stable.

4. Construction and Evaluation of a Sail Type Windmill. In collaboration with Windworks of Mukwanago, Wisconsin, a low speed sail windmill has been developed for use in rural developing areas of the world. A prototype was fabricated at the Brace Research Institute during the summer of 1974 and installation was completed by December. Preliminary plans and specifications, as prepared by Windworks, have been modified taking into account the fabrication and installation experiences at the Institute.
A 42 foot high (12,8 metres) octahedral module tower was subjected to a 3-dimensional computer analysis to compute the stresses in the tower. Computer evaluation revealed that the windmill tower meets CSA standard specifications.

In addition full plans and specifications for a wooden tower have been developed for this windmill. The wooden tower can be made out of both rough cut logs or commercially available lumber. The tower is designed to withstand winds up to 100 mph (160 km/hour).

A study of the fan tail shape and design was undertaken. Plans and specifications have been made available for a triangular shaped tail which minimized stress and increases the tail efficiency.

An experimental test program was undertaken to determine output torque and power characteristics, as well as behavior under different types of loadings.

The windmill can be used for water pumping, electrical generation, sawing wood, and operating agricultural equipment. A ground level rear axle has been installed as a power take-off on the vertical shaft from the windmill. The windmill has been used to operate some farm machinery such as a chaff cutter and a shredder.

A detailed study was undertaken on how to modify the sail configuration to improve performance as well as a control mechanism on the tail to regulate the unit under high wind loads.

5. Savonius Rotor Program. Three Savonius rotors of various configurations were fabricated during the summer of 1974 and erected at the experimental field station in early winter. Three different tower designs were employed in order to make a comparative evaluation of their structural stabilities. In addition a study was undertaken on the effect of geometric variations in the Savonius rotor on its performance under natural wind conditions. Experiments have been performed on eight configurations of 70 inch (178 cm) high rotors to determine the optimum offset and suggest the approximate power production capability.

One of the rotors was hooked up to power a Vergnet foot pump which has been used increasingly in various African locations. The premise is that while the foot pump is effective, if a simple windmill could be used to power it during wind periods, this could increase the available water. Hence, a bell crank attachment and transmission system were developed and tested under field conditions.

A laboratory study using the foot pump as a working component also investigated the development of an optimum operating transmission system between the rotor and the foot pump. This system has been built and tested under lab conditions.

C. Solar Heat and Power

1. An Investigation of the Contribution of Solar Energy in Heating Greenhouses in Colder Regions. An investigation is being made of heating loads of greenhouses in Québec with a view to re-designing the classical greenhouses currently in use in order to maximize the luminosity input and minimize thermal losses. An experimental greenhouse of approximately 40 m^2 was built at Laval University and tested during the period November 1973 to present. Results have been extremely encouraging.in that the heating costs have been reduced and the yields of produce increased in relation to conventional greenhouses. Several test greenhouses have been built at the Macdonald Campus experimental station.

A program of testing different transparent cover materials has been undertaken. Among interesting materials tested were - a double walled, rigid acrylic sheet, a double walled translucent polyproplene - polyethylene copolymer, and a specially formulated U.V. resistant polyethylene film which is relatively opaque to reradiation from the interior of the greenhouse. Several reflective linings have been tried from aluminized mylar film, to reflective acrylic sheets to white and aluminum painted surfaces.

Some work has been undertaken into the design of night shades and combined heat storage systems, all with a view to energy conservation.

2. Solar Powered Organic Fluid Rankine Cycle Engine Systems. The pumping of water for human and animal needs as well as irrigation is basic to the development of arid areas. Given the high cost of conventional fuels one option is solar powered pumping systems. The most successful of the installed solar pumping systems are those made by the SOFRETES Company in France, with applications in Africa, Latin America and elsewhere. As a result, in 1974 an agreement was made to purchase and test one of their small organic fluid Rankine Cycle engines, complete with heat exchangers, condensors and lubricating systems. The unit was installed inside in the Mechanical Engineering Laboratory and tested using butane as a working fluid. Using steam as a heating fluid, and operating between source temperature levels of 55°C to 95°C, the engine developed the equivalent of 0,3 Kw to 1,4 Kw of

mechanical shaft power. This occured over a source to sink temperature difference of 30°C to 70°C. Over the range 0,7 Kw to 1,4 Kw equivalent, the Rankine cycle efficiency varied from 1,6% to 3,0%.

3. Study of Potential of Solar Ponds for Energy Collection. Non-convective solar ponds have been proposed as an effective collector of solar energy. Convection is prevented by means of a salt concentration gradiant which maintains a stable density gradient. The incident solar radiation is absorbed throughout the depth (about 1 meter) and on tha black absorbing bottom of the pond. Because of the absence of convection it is possible to develop high temperatures exceeding 90°C in the lower layers of the pond. Energy may be extracted from the hot layers and used - possibly for the operation of organic fluid Rankine cycle engines. Analytical studies were continued to investigate the characteristic times for molecular diffusion to erase the initially established salt concentration gradient.

A theoretical study of the heat transfer from the bottom of the solar pond into the underlying soil was completed.

Work has been underway for several years on an analytical analysis of the performance of the solar pond. This model makes use of a previous finite difference numerical model and is considerably more economical to employ.

Tests on a small 4 meter diameter solar pond at Macdonald College are conducted during the summer months since the summer of 1974. Despite the poor weather conditions, often experienced in the Canadian summer, temperatures of about 80°C have been achieved in the pond. Heat has been extracted from the pond during warmer periods of the year. During the spring the pond is used to provide warm water for watering adjacent greenhouses.

In order to improve its overall performance and protect the surface from snow and ice, a Brace type greenhouse, dimensions 5 m x 5 m was built over the solar pond during the summer of 1976. The solar pond will be monitored over the winter months to determine the effect of the greenhouse on its performance. Eventually, the warm water can be used to supply process heat for refrigeration or heating, or operate thermal powered engines.

4. Improvement of Solar Cookers. In view of the fact that cooking of food comprises nearly four-fifths of the basic energy requirements of villages in arid areas, the replacement of part of the firewood necessary to meet this demand through the use of renewable solar energy is very appealing. In the mid 196[illegible]'s, the Institute developed a flat plate solar steam cooker and in recent years efforts have been made to improve its performance. These have been principally through:

a) improved efficiency of the flat plate collector;
b) improved insulation of the steam chamber cooking area;
c) the development of a system whereby the cooking chamber can be placed within the house and the orientable solar collector outside the wall facing the Equator.

It has been demonstrated that, if used effectively, the cooker can on a sunny day provide all of the cooking requirements of a normal sized family. The cooker boils, stews or steams food, which is the method used in more than four-fifths of the cooking in the world.
Additional investigations are underway to develop a simpler solar cooker where the cooking is performed directly in the solar collector.

5. Roof-Top Greenhouses. A program has been initiated, in conjunction with the Minimum Cost Housing Group at McGill School of Architecture and the University Settlement of Montreal, to install open air gardens and greenhouses on several rooftops in the downtown Montreal area. The project is being funded by the Ministry of State for Urban Affairs under the Canadian Urban Demonstration Program. The project comprises three major components: the installation of seasonal open air container gardens on individual balconies and rooftops in addition to a communal garden on the roof of the University Settlement; the fabrication and installation of several family sized greenhouses for extended season cultivation on the University Settlement and neighborhood roofs; the design, fabrication and installation of a community scale greenhouse for year round crop production on the roof of the University Settlement.
This project is being undertaken to illustrate the feasibility of utilizing rooftop waste-lands as practical crop growing areas in a northern climate. The Institute has also participated in the design and installation of a heat exchange system whereby waste heat from the building's boiler stack is to be recycled through the cold frames during colder weather periods. This system has been designed by S. Albert and Company from Montreal.

6. Quebec Indian Housing. In conjunction with the Shelter Systems Group of the School of Architecture of McGill University, the Institute has been involved with the design of four prot· type environmentally adapted houses for different areas inhabited by the Indian population living in the Province of Quebec. One of the houses has been occupied since December 1975, and incorporated a 40 m^2 vertical wall solar air heater collector, connected to a rock pile storage . The thermal performance of thie house is urrently be ng evaluated by researchers of Hydro Quebec in conjunction with Institute Staff Members. Several simple solar collectors for house heating made of rock piles with transparent covers have been developed which could be used in those areas where cold weather conditions prevail during winter months, though these conditions are generally not a major energy consumer. These simple rock collectors might prove useful in areas lying between the Mediterranean type climate and the tropics, where short, but often cool, winter periods can cause discomfort within the dwelling of the rural poor.

D. **Arid Land Development**

1. Potentialities of Closed Environment Agriculture for Water Conservation in Arid Areas Water consumption by the respiring plant is reduced both by maintaining the atmosphere at high humidity and by reducing the heat load through shading, reflection and selective filtration of portions of the solar radiation spectrum not required for plant growth, the excess energy being used in a solar still to provide an auxiliary supply of fresh water. This project was undertaken in collaboration with colleagues at the Middle East Technical University, Ankara, Turkey. A doctoral thesis on this subject submitted by V.V. Tran was accepted in March 1975. This work combines low cost solar stills with greenhouses for a family unit producing food and water.

2. Low Cost Sanitary Technology. Recognizing that improved low cost sanitary disposal systems in developing areas are necessary for amerliorating health standards and reducing water consumption, the Institute has collaborated with the Minimum Cost Housing Group, School of Architecture, McGill University in producing new designs for compost privies, testing a Clivus - Miltrum toilet and preparing a guide on waste disposal systems. The Institute has provided this group with several grants to assist them in preparing these studies. Some of their principal reports are:

   a) "A Survey of Alternative Waste Disposal System - The Problem is No. 3", A. Ortega and W. Rybczynski, Minimum Cost Housing Studies, School of Architecture, Faculty of Engineering, McGill University, July 1973.

   b) "New Developments in Moldering and Composting Toilets", by W. Rybczynski, Solar Age, Volume 1, Number 5, May 1976, 4 pp.

E. Surveys and Reports

1. Survey of Potential of Renewable Energy for Canada. At the request of the Ministry of State for Science and Technology, Ottawa, a survey of the potential of renewable energy resources (direct solar, wind and biomass energy) was undertaken. A research and development program in these fields was also recommended. As part of this work, a submission was presented to a United States of America Senate Committee on Renewable Energy Resources.

2. State-of-the-Art Survey of Commercially Available and Experimental Windmills. All known manufacturers have been requested to assist with literature, plans and specifications and performance characteristics of their wind machines for electrical generation and pumping. This is intended to facilitate performance evaluations of the numerous wind machines available, including those currently under research and development. The investigation has been categorized under the following headings:
   1) Review of the commercial wind generators now in production.
   2) An assessment of the capacities under various wind conditions.
   3) Cost of such machines, related to their performance.
   4) Present state of wind generators under R & D projects, and prospective useful potentials, with estimated costs.
   5) A review of all data, and suggested direction of future investigations.

3. Storage of Solar Energy. A review of means of storing solar energy has been carried out with emphasis on thermal energy storage. Sensible heat storage in water or fine gravel or heat of fusion storage using sodium thiosulphate pentahydrate have been identified as the most promising possibilities taking account of such factors as heat capacity, cost, stability, and the rate at which heat can be absorbed or released. Some proposals for future work have been advanced.

4. Preparation of Leaflet on Factors Affecting Solar House Heating. In view of the recent increase in interest in the use of alternate forms of energy, a brochure is being prepared dealing with the factors involved in supplementing house heating using solar energy. A significant number of enquiries is received for information in this regard. Therefore, the leaflet will stress the importance of adapting the structure to existing environmental factors. In addition, consideration will be taken of the problems of orientation, the efficient thermal design of buildings and the use of solar energy collectors and storage systems.

5. Appropriate Technology Handbook. The Institute has been actively engaged as technical editors for this Handbook on Appropriate Technology. This project has been funded by the Canadian Hunger Foundation through a grant received from the Canadian International Development Agency. The Handbook defines Appropriate Technology and describes the concept in terms of its technological, social, cultural, economic and political ramifications. Several selected case studies illustrate the concept and implementation of Appropriate Technology. The final section of the Handbook lists individuals and groups working in the field, gives a brief catalogue of tools and includes an extended bibliography.

   This Handbook is intended for use primarily in developing countries however, it is also expected to have a spin-off effect for developing areas of the more industrialized countries. French and Spanish editions are being prepared; the French edition by the Institute Staff and the Spanish edition under special agreement with the Universidad José Simeon Canas, El Salvador.

6. Policy and Guideline Paper on Appropriate Technology. In view of the recent international interest in Appropriate Technology as an effective developmental process for developing areas of the world, the Canadian International Development Agency approached the Brace Research Institute in February of 1975 with a request to write a brief policy and guideline paper on the subject. This paper was submitted in April 75. It specified the characteristics of Appropriate Technology, its status in the world today and current trends in its development. Further, the report detailed Canadian capacities and potential, listing many of the known Canadian workers in the field. Overall guidelines were given with respect to the priorities and areas of CIDA concentration.

7. Preparation of a Technical Manual on Solar Agricultural Dryers. A manual is currently under preparation, with funding from the Canadian International Development Agency, covering the theory of solar dryers, detailed descriptions of solar dryer experiments, and construction considerations. Information on experiments on solar dryers from all over the world has been assembled. Theoretical and design sections have been prepared, and contributions have been received by associates in other organizations. A full bibliography has been prepared.

A survey of existing solar agricultural dryers with particular reference to solar dryers either developed in or currently used in emerging areas has been published in English. It has received considerable attention in that the response from around the world has proven very favourable. This is the first part of the Manual to be printed, and French and Spanish language versions are being prepared. The document is intended to serve as a guideline to assist the user and the researcher in developing areas who wish to examine solar drying techniques but who might not have available to them sufficient documentation to enable them to rapidly review the state-of-the-art.

8. Sénégal Report. In April 1975, a Mission was undertaken to Sénégal accompanied by the Director of SOFRETES, France in order to determine the potential of direct solar, wind and biomass energy for the country's future energy requirements. The International Development Research Centre, Ottawa, provided some travel funding for the Institute representative. A report was completed outlining the principal findings of the Mission.

9. Study of the Feasibility of the Establishment of a Rural Energy Centre in Sénégal using Renewable Energy Resources. At the request of the United Nations Environment Programme, the Institute has undertaken a study for the establishment in Sénégal of a rural energy centre. This has been accomplished with the active collaboration of the Délégation Générale à la Recherche Scientifique et Technique of Sénégal. The objectives of the study were to select a small representative community of approximately 500 persons possessing sufficient renewable energy potential - solar, wind and biomass -to meet the basic energy requirements of the village. These requirements are for the pumping and potabilization of the water supply, the cooking energy, and some lighting of the local residences. A survey has indicated that approximately four-fifths of the basic energy requirements are for cooking. Taking into account climatic variations and the availability of excrements from the local cattle, a system of essentially proven technologies has been evolved which will reply to the anticipated demand. It is envisaged that fan mills would be best for water supply with a back-up using electricity generated from biogas digestors, activated by means of accumulated excrement. This electricity can also be used to satisfy the minimal lighting needs. Cooking would be envisaged through a series of solar steam cookers and food warmers, coupled with the use of insulated food containers to reduce the demand for energy. The use of improved smokeless wood stoves would supply the small amount of

energy needed when there were insufficient amounts of solar radiation. All technical and economic aspects have been investigated. The whole scheme has been considered within the realms of appropriate and socially acceptable technologies in order to ensure a maximum degree of local acceptability.

IV. Institute Experience related to Problems of Development and Transfer of Technology

The preceeding sections of this report outlined in some considerable detail the current programs of this Institute in relation to its overall terms of reference. These programs have been dealt with in detail in order that they can be seen in the light of development of emerging areas and the possible need in some instances of transfers of technology. The means available to the Institute, financially, have always been quite limited due in part to a general world wide disregard of the interests of the poorer elements of the population of the world faced with the problems of water, power and agricultural scarcity. It goes without saying that the most appropriate technologies in the long run are those which are nurtured within a society and those that have some element of acceptability. There must of course exist within the developing areas a degree of social consciousness among all classes of society to indeed take an interest in those problems affecting the less fortunate portions of the population.

The Institute has had a wide variety of experience. During its initial and formative years, it was primarily based in Barbados in the West Indies, where we have a research station. This early experience has impressed upon our thinking the necessity of being intimately related to the problems requiring solutions. There are several ways of accomplishing this:

a) through research and development;
b) through a series of typical applications which can serve as demonstrations;
c) through formal education;
d) through encouraging the involvement of local counterpart personnel and organizations who would have similar interests and objectives to that of the Institute. This would apply equally to the practitioners of technology as well as to the local developers and adapters of the technology and the appropriate technological systems.

As a result of this effort, the Institute has become increasingly involved and dedicated to the appropriate technology approach. A history of this involvement and an analysis of the factors leading to the adoption of this methodology are outlined in an earlier report[1]. As a result, the Institute participated in the preparation of a Handbook of Appropriate Technology which of course must be considered as being continuously under improvement and review. To quote some of the more relevant sections of this

report at this time would be useful as it would illustrate the basic philosophy of approach that we have undertaken.

"It was in undertaking these applications in the real world that the need for a more comprehensive approach became evident. Enthusiasm, accompanied by good engineering design did not always suffice.

We had reached a critical crossroads in moving from Research and Experimentation to implementation of technology in developing areas. This necessitated moving beyond the narrow confines of purely technical solution to development, to one which required a broader range of scientific inputs - cultural, social, political, economic, etc. Although we did not recognize it at the time, this led us to the adoption of what is now called an Appropriate Technological approach.

The following hurdles had to be overcome if the goals of the Institute were to be achieved.

a) the technology had to meet the fundamental needs of the community and be recognized as such.
b) for the community to respond and accept, the technology, a sufficient amount of 'animation sociale' of the local population had to be undertaken.
c) the question of economics had to be fully understood and appreciated.
d) the cultural and social values of the local populations had to be considered as an integral part of the introduction process.

In order to accomplish these tasks and achieve some measure of success, the Institute staff as 'practitioners' have evolved, through 'trial and error', some basic objectives in their operations.

a) wherever possible, local technologists should become involved in the development process in all its phase, research, development and application. Hence, the Institute has tried to help local technologists to appreciate the validity of studying the fundamental problems facing their own rural populations. This is essential as they can communicate in the same 'language' as these target communities and generally they understand their cultural and value limitations.
b) local social workers are very important collaborators in getting

the indigenous population to appreciate and accept the technological innovation. For example the installation of a fresh water facility, decreases infant mortality rates leading to problems of birth control. The solution of this latter problem is often beyond the scope and capabilities of the well meaning technologist.

c) economists also must be brought in to provide a more comprehensive enumeration of the costs and benefits as they apply to a given appropriate technology in a local context. In view of past development experience, it is obvious that both the long and short run consequences of a specific technology need to be considered. These economists can hopefully specify more comprehensive social welfare functions, as they apply to given regions of a developing area.

Our experiences as 'practitioners' of Appropriate Technology, led us to appreciate that even the appropriateness of a given technology is not a sufficient condition for its widespread adoption. We have come to realize that no matter how simple, low cost, or how appropriate to the needs and resources of local inhabitants, a new technology must be viewed within the cultural context in which it is introduced. Between the identification of an Appropriate Technology and its successful application, lies the critical problem of cultural adaptation.

As engineers our concern is basically with technology. The technological aspects of a culture determines what is possible or feasible to accomplish. For example, given the variety of existing birth control devices, solving the problem of over population is a relatively simple application of modern technology. Yet, large families continue to subdivide the small incomes of depressed rural communities. Obviously, the question of peoples' values is paramount.

Technology by its very nature is optimistic, presenting what could be accomplished. From experience, it was discovered that the frustrating gap between what is technologically feasible, and what is adopted in practice, most often results from a basic scientific neglect of the critical role played by the other side of the cultural coin--a culture's attitudes and values. Values are simply shared beliefs among people about what is right and wrong. Where technology determines what

is possible, values and attitudes determine what is socially acceptable. The criterion of social acceptability either limits or enhances the probability of adoption and use of a given technology. For example, even though population control is technologically possible, social attitudes toward family size or religious values limiting the use of birth control devices, set limits to technological solutions to over population.

Through the experiences of our field operations throughout the world, we have come to appreciate the critical interrelationship of technology and values in the development and application of appropriate technology. In our own fashion we have come to realise that conceptually Appropriate Technology is no more useful in the development process than an inappropriate technology if it cannot become acceptable to the individuals and groups to whom it is proposed. Applied technological change implies social acceptability. The degree of acceptance and rate of adoption in turn depend upon a thorough knowledge of values and attitudes. Indeed, as 'practitioners' of Appropriate Technology, great emphasis has been placed on an appreciation of the cultural values of the target area population.

'Value or cultural competence' must accompany the development of appropriate technology, and precede its successful applications"(1).

As an illustration of the type of activity undertaken by the Institute in this field, one might sight the relationship with a Swiss worker involved in rural development problems in Nepal. Obviously we have a number of more formal, governmental relationships with different groups and organizations in many developing areas, but an illustration of this particular setup, which is relatively new, will highlight some of the features of our activities. In this particular case, which has been entirely handled by correspondence, use was made initially of the more than 25 Do-It-Yourself leaflets, plans and specifications of the Institute's more popular publications. Later, reference was made to some of the more than 400 scientific, technical and social publications of the Institute. When material was needed which went beyond the scope of our specific publications, reference was made to the vast amount of information available in the Institute's library, which has built up over a nearly 20 year period into a significant amount of data in the field of water supply for small communities in arid areas, the use of solar, wind and biomass energies, desalination of saline waters, greenhouse agriculture,

and a whole gamut of subjects in the general field of appropriate technology for developing areas, with particular reference to small scale agricultural implements and the like. In some instances, our collaborator by correspondence has tried some of the technology, not always with instantaneous success. There has always been an effort to involve, as much as possible, local personnel into these operations in order that they may carry on with these activities at a later date. At a later stage, more specific technological programs have been investigated such as tobacco drying using solar energy. In this instance, the Institute can serve not only as a source of technological knowledge and advice, but also to investigate various sources of funding both in Canada and elsewhere.

A similar situation is also under study with a regional University and the Government of Fiji, on the possible establishment of a rural energy centre using renewable energy resources in the South Pacific, similar to the one forumulated for Sénégal. There are many similar examples, some of which have gone farther into the field of direct application, such as the work undertaken with local church groups in Haiti on the installation of solar stills and cookers. As the Institute has been active in these fields for many years, there are many documented instances of this type of collaboration. Because of a lack of funds and the lack of general interest on the part of most organizations, the Institute has had to rely on the distribution of reports to interested groups and individuals working along similar lines in developing countries. Every effort is made to provide encouragement to each group. Publications are generally sent without charge, though this has placed an undue strain on our limited financial resources.

However, it is felt that the use of literature under the circumstances is the best manner given no specific funding in a particular situation.

Having tried formal education for over 10 years, we have become convinced that this is a role to be done within the developing areas, perhaps with some assistance by outside grants. It is essential that local development education programs in Appropriate Technology and the maximization of the use of local resources be encouraged so that these can make an effective contribution.

V. SUGGESTIONS AND RECOMMENDATIONS

There must be many different roads to the adequate development of emerging areas. The vast bulk of bilateral and multilateral assistance programs deal necessarily with large scale projects which generally enhance development of the local infra-structure. At the same time, there should be a more modest, but equally important effort, directed at alleviating the problem of the vast majority of the population of many of the lesser developed areas of the world. Some UN studies indicate that over eight hundred million people are living under conditions which provide a minimal amount of services, clean water and energy. Some effort must be made using appropriate, well adapted and rational systems to alleviate some of the hardships of these people. In order to stem the flow of the rural populations towards the ghettos of the urban centres, there must be improvements to their living conditions in the rural areas.

Some possible mechanism that bilateral and international programs can become involved in are the following:

a) Encourage the establishment of centres of Appropriate Technology in developing areas which address themselves directly to some of the problems cited above;

b) Support the activities of international centres currently being proposed to act as secretariats for exchanging information in these fields. The author has participated in June 1976 in an international seminar sponsored by the Government of Mexico, with the view to channeling the newly created Centro Tercer Mundo, in Mexico City towards this direction. The Centro was officially inaugurated in September 1976 and efforts like this undertaken independently, in this case by the Government of Mexico, should be substantially assisted by the International community.

c) Establish different journals of communication, in at least 20 to 30 international languages, similar to the UNESCO Courrier, to permit the exchange of information and ideas particularly by persons working in developing areas.

d) Encourage programs of research and development, both in developed and developing areas in the technical, economic, social and political

aspects of appropriate technologies and systems, as well as the interchange of information and personnel between these organizations.

e) Support demonstration programs of technologies responding to the direct needs of the poorer rural populations, particularly where there can be local commercial and industrial participation in increasing the output of these areas.

There are many ways in which development programs and the transfer of technologies can be accomplished. The world has developed numerous systems and significant expertise in a wide variety of subjects which can enhance our basic knowledge and our technologies. In order to apply appropriate technological systems to really help the least fortunate elements of the rural population, there must be committment to this goal. Without this committment, the most well meaning of intentions is often only reduced to academic dialogue.

REFERENCES

1) Lawand, T.A., Hvelplund, F., Alward, R., Voss, J. - A Handbook of Appropriate Technology - A Case Study of its Development, Presented to the Organization for Economic Cooperation and Development, Study Group on Low Cost Technology and Rural Industrialization, Paris, France, 17 to 20 September 1974.

LIST OF RECENT PUBLICATIONS SINCE JUNE 1975

Reprint Articles

Alward, R. - Solar Distillation as Appropriate Technology, Presented to the International Solar Energy Society Conference, Los Angeles, California, 15 pages, 28 July to 1 August 1975.

Byam, L., Gumbs, F.A. - Effect of Irrigation and Nitrogen on the Dry Matter and Crude Protein Yields of "Pangola" Gigetgrass. Agronomy Journal V67, pages 365-369, May-June 1975.

Lawand, T.A., Alward, R., Saulnier, B., and Brunet, E. - The Development and Testing of an Environmentally Designed Greenhouse for Colder Regions, Solar Energy, Vol. 17, No. 5, pp. 307-312, 1975.

Lawand, T.A. et al - Solar Energy Greenhouse: Operating Experiences, Presented to the International Solar Energy Society Conference, Los Angeles, California, 10 pages, 28 July to 1 August 1975.

Lawand, T.A. - Systems of Solar Distillation, Presnted to the International Conference "Appropriate Technologies for Semi-Arid Areas: The Utilization of Wind and Solar Energy for Water Supply", Berlin, Germany, 41 pages, Paper No. 111-IT, 8/75, 15 to 20 September 1975.

Lawand, T.A. - Environmentally Designed Housing Incorporating Solar Energy, Presented to the Dhahran International Congress of COMPLES, University of Petroleum and Minerals, Dhahran, Saudi Arabia, 27 pages, 2 to 6 November 1975.

Saulnier, B., Savage, S., Chepurniy, N. - Experimental Testing of a Solar Pond, Presented at the International Solar Energy Society Conference, Los Angeles, California, 19 pages, 28 July to 1 August 1975.

Hamilton, B., McConnell, R. - Experimental Evaluation of a Solar House Heating System in Québec, Presented to the Joint Conference of the American Section of the International Solar Energy Society and the Solar Energy Society of Canada Inc., Winnipeg, Manitoba, 15 to 20 August 1976.

Lewand, T.A., Alward, R., Saulnier, B., Budgen, H., Brunet, E., - Rural Centre for Africa Using Solar, Wind and Biogas Energies. Presented to the Joint Conference of the American Section of the International Solar Energy Society and the Solar Energy Society of Canada Inc., Winnipeg, Manitoba, 15 to 20 August 1976.

Saulnier, B., Brunet, E., Repellini, A., Lewand, T.A., Alward, R. - A Survey of Solar Agricultural Driers. Presented to the Joint Conference of the American Section of the International Solar Energy Society and the Solar Energy Society of Canada Inc., Winnipeg, Manitoba, 15 to 20 August 1976.

Technical Reports

Chepurniy, N. - Conduction of Heat Transfer from a Heated Disc at the Surface of a Semi-Infinitive Medium, Department of Civil Engineering and Applied Mechanics, 93 pages, June 1975.

Savage, S.B. - Solar Ponds - A Review, Department of Civil Engineering and Applied Mechanics, Technical Report No. 75, -3 (FML), 28 pages, August 1975.

Brace Research Institute Staff - A Survey of Solar Agricultural Dryers, 151 pages, December 1975.

Miscellaneous Reports

Lawand, T. - Brace Research Institute Annual Report, 1974-75, 45 pages, September 1975.

Brace Research Institute Staff and Canadian Hunger Foundation Staff - Appropriate Technology Handbook, 280 pages, April 1976.

Internal Reports

Klein, K. - The Potential for Methane Gas Production from Animal Wastes in a Typical African Village: A Quantitative Assessment, 9 pages, July 1975.

Sachs, B. - Solar Energy Industries Association Expo, 4 pages, 27-29 May 1975.

Sanvido, M. Smith, W. - Questionnaire on Proposed and Existing Windmills, French version, 7 pages, August 1975.

Smith, W - Questionnaire on Proposed and Existing Windmills, English version, 10 pages, August 1975.

Sanvido, M., Smith, W. - An Evaluation of the Mengin Hydro Pompe Vergnet Powered by a Windmill, 22 pages plus graphs, September 1975.

Alward, R. - Wind and Wind Energy in Building Design, 14 pages, 17 November 1975.

Internal Reports - continued..

Blake, S. - A Proposal for Testing and Evaluation of Savonius Rotors of Oil-Drum Construction, 40 pages, April 1975.

Brace Research Institute Staff - Preliminary Report - Part I, Feasibility Study of the Establishment of a Rural Energy Centre, Sénégal, Appendix A-D, 62 pages, 17 March 1976.

Brace Research Institute Staff - Final Report on the Feasibility Study of the Establishment of a Rural Energy Centre in Sénégal, submitted to the United Nations Environment Programme, Nairobi, Kenya, 380 pages, August 1976.

LIST OF STUDENT PROJECTS SUPERVISED BY THE INSTITUTE

Beaulieu, Bernard - Performance Test of the Brace Sail Windmill, submitted in partial fulfillment for the requirements of the B.Sc. degree in Agricultural Engineering, June 1975.

Lim, Hock-Gee, Tashmann, Rully - Preparation of Final Report on Sail Windmill, Department of Civil Engineering and Applied Mechanics, Course No. U76-14, April 1976.

Griffiths, Jennifer M.M. - Energy Efficient Modification to an Existing Home and its Environment, Department of Civil Engineering and Applied Mechanics, Course No. U76-3, April 1976.

Cacchiotti, R., Lanni, G. - The Verification of a Tubular Steel Tower Design for a Wind Electric Generator, Department of Civil Engineering and Applied Mechanics, Course No. U76-21, April 1976.

Gomes, M.N., Henry, Z.A., Soodoo, G.J. - Performance of a Positive Displacement Water Pump Subject to Simulated Windpower, Department of Mechanical Engineering, Mechanical Laboratory II, Course No. 305-463, April 1976.

List of Student Projects - continued..

Armet, A., Nardini, A. - Performance of a Passive Solar Wall, Department of Mechanical Engineering, Course No. 305-464, April 1976.

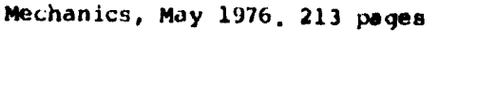
Pasini, C., Ward, M. - An Investigation of the Operation Characteristics of a Rankine Cycle Powered Solar Engine, Department of Mechanical Engineering, Course No. 305-464-D, December 1975.

Master Thesis

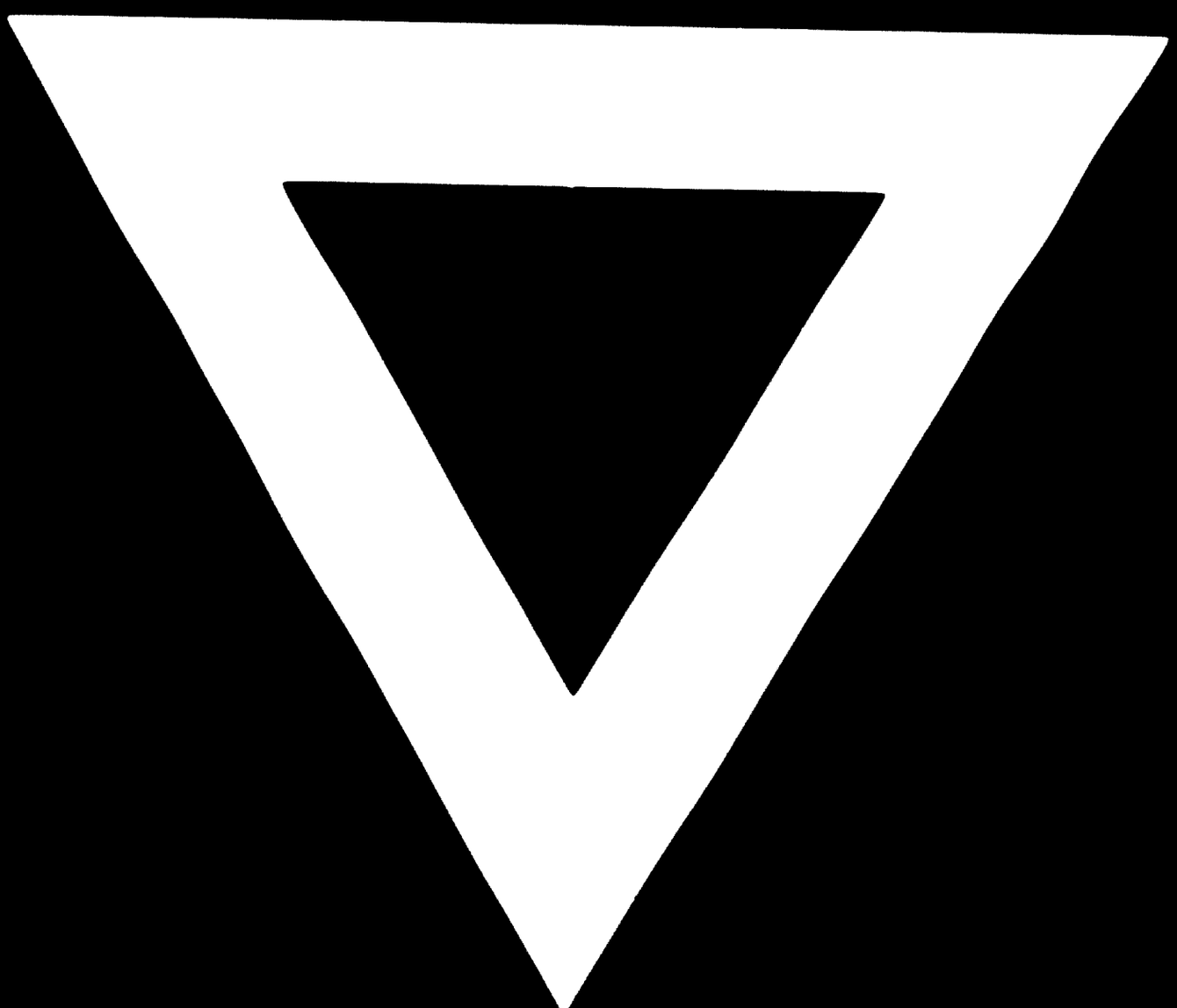
Memarzadeh, M.A. - Wind Power an Inexpensive Source of Low Grade Energy, M.Eng. Thesis, Department of Electrical Engineering, McGill University, June 1975, 145 pages.

Ph.D. Thesis

Chepurniy, N. - Predictive Analysis for the Temperature Development and Performance of Solar Ponds, Department of Civil Engineering and Applied Mechanics, May 1976. 213 pages



C-269



77.06.29