ENERGY BULLETIN

22

olade

Latin American Energy Organization

SEPTEMBER/OCTOBER, 1981

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PUBLICATION OF THE LATIN AMERICAN ENERGY ORGANIZATION

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PERIODICAL FOR
TECHNICAL DISSEMINATION

EDITORIAL

The current year could be called the year of the new and renewable energy sources since the attention of the energy world has been centered on the preparations of the most important world forum on this topic: The United Nations Conference on New and Renewable Sources of Energy that was held in Nairobi, Kenya last August.

The energy demand of the so-called world's energy consumers wich is that sector of the world population that because of its income can have a dependence on hydrocarbons (many times not only for satisfying its basic needs but unfortunately the majority of the times for wasteful purposes) is contrary to the social and economic stability desired and sought especially by the Third World Countries.

It has been demostrated, according to data by OLADE published in their Energy Bulletin N° 16, that the participation of the new and renewable sources in the global energy supply is marginal. This includes on one side hydroenergy which is considered a conventional source and at the other extreme firewood and charcoal which for centuries have been conventional sources and in our countries continue to be even though they are ignored, given the absence of adequate energy planning. Between these two extremes are the resources with less use such as biogas, small water fall, wind energy and other with greater potential such as geothermics. These have not been developed not because their existence was not known but rather because the existing oil dependent energy scheme practically excludes them from the energy supply.

Regarding solar energy which the industrialized countries insist in calling a free source of energy and which they present as a solution to the energy problem in the Third World, it should be seen not only at a much longer term but also with great caution. Behind these slogans lies the greatest technological dependence. This implies that it is free and that without it the development of solar energy is practically negligible.

Within this outlook, OLADE has initiated activities aimed at an integral development of a great number of sources identified by the United Nations Conference within the group of new and renewable energy sources. The criteria of priority is based on the accesible technology and the availability of energy and human resources that make feasible, in the short term, a massive development of these resources within a framework of regional cooperation and within an appropriate energy plan.

OLADE participated actively in the preparation of the Nairobi Conference. The work of OLADE was recognized at that Conference and herein a brief description is given of some of the projects.

GUSTAVO RODRIGUEZ ELIZARRARAS

TOWARDS THE IMPLEMENTATION OF THE NAIROBI PROGRAM OF ACTION IN THE LATIN AMERICAN REGION

DR. GUSTAVO BEST*

INTRODUCTION

The primary objective of the United Nations General Assemply in convening the Conference on New and Renewable Sources of Energy —held during August 10-21, 1981, in Nairobi, Kenya— was to elaborate measures for concerted action aimed at promoting the development and utilization of these energy sources "with a view to contributing to the satisfaction of the future global energy needs, especially those of the developing countries and particularly in the context of the efforts directed at accelerating the development of these countries."[1]

The international community, on launching this initiative, stressed the international nature of the energy problem and pointed out the urgent need to promote a new world energy panorama which would contemplate the diversification of primary energy sources. This energy plurality will be the result of an on-going transitional process and it should be based on conscientious efforts programmed, on the basis of, solid decisions if it is desired to avoid chaos in the supply and demand balance, for this could be a potential threat to the international community.

It is a recognized fact that this energy transition is already underway and that the challenge for humanity is to have this process occur in a peaceful, orderly, and just way.

Since this is a multifaceted subject, due to its very nature and to its relationship with political, economic, and social parameters, the Conference was prepared over a period of almost two years. This preparation consisted of a series of activities aimed at establishing the technical, economic, and social bases and the political philosophy for the deliberations and negotiations to be carried out. It was the first time that all of the international community would come together to discuss the energy transition, and so it was obviously a complex and delicate task. The preparations were also aimed at attracting and strengthening the political decision of the member countries in order to guarantee that the deliberations would be carried out in an armosphere of collaboration in the search for solutions to problems common to all humanity.

REGIONAL PREPARATIONS

The preparation for the Conference consisted of a variety of activities, at the international, regional, and national levels. ECLA and OLADE participated actively in the international preparatory work, serving as links between this, and efforts at the regional level, which are described in detail below.

The regional component has constituted one of the main pillars of the preparation of the Conference and of the implementation of its results, since it is at this level that optimal elements exist for directing

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1) United Nations General Assembly, A/RES/33/148, December 20, 1978.

international collaboration towards the strengthening of actions at the national level. Likewise, in the different regions, there are institutional tools which permit concerted action through existing mechanisms. In the case of Latin America, there is OLADE, which is an invaluable institutional framework for the implementation of regional cooperation.

ECLA, in constant, close collaboration with OLADE, mounted and carried out a program of regional activities aimed at strengthening the positions at both the national and regional levels, which would be channeled into the Conference. The focus of ECLA and OLADE consisted of action on several fronts, which, as a whole, would provide the bases for formulating a regional plan in the area of new and renewable sources of energy.

On the one hand, the establishment of organizational ties or focal points in the Latin American countries —with the Secretariat of the Conference, with ECLA and with OLADE— was promoted through missions whose object was to provide information and technical assistance and to begin to identify the priority activities for the region during the preparatory process. The technical assistance from ECLA and OLADE during this stage was constant, and it undertook to coordinate formulation of national documents in the countries which so requested or in specific technical areas.

Several requests for technical assistance were covered by specialized personnel from both within and outside the region. In 1980 an informal document entitled "Methodological Guide for the Regional Preparatory Process" was formulated and distributed to all of the countries of the region, suggesting national activities which, within the context of the preparatory work for the Conference, would facilitate the channeling of the national positions towards a regional one.

As for the more concrete activities, on the basis of consultations with the governments of the region, a series of documents was elaborated to indicate the degree of knowledge with respect to the new and renewable sources of energy, their potential uses, and activities designed to promote their application.

The documents prepared were on the following topics:

— Biogas	By OLADE
— Geothermal Energy	By OLADE
— Hydro Power	By OLADE
— Small Hydro Power Stations	By OLADE
— Wind Energy	By OLADE
— Solar Energy	By Mexican experts
— Shales	By Brazilian experts
— Peat	By Brazilian experts
— Firewood and Charcoal	By Nicaraguan experts
— Energy Potential of Sugar Cane	By Cuban experts

Three technical meetings were organized with regional experts on the following priority subjects:

— Firewood and Charcoal:	Their Incorporation into Energy Planning and Policy.
Headquaters:	Nicaragua
Co-organizers:	INE Ministry of Natural Resources, Nicaragua Contributions from the FAO and the UNEP.
— The Hydro Power Potential:	Energy Alternative and Industrial and Financial Challenge for Latin America.
Headquarters:	Ecuador
Co-organizer:	OLADE

— Evaluation Criteria for the Financing of and Research on New and Renewable Source of

Energy
Headquarters: Barbados
Co-organizers: Caribbean Development Bank Inter - American Development Bank World Bank Organization of American States.

It is important to note that the formulation of the document in reference, along with the regional technical meetings, constituted a very important step towards understanding the potential of the new and renewable energy available in the region and represented an invaluable storehouse of information for the identification of regional programs. The visits to other countries made by the consultants in charge of formulating the documents aided enormously in identifying the elements for regional collaboration.

With respect to the area of regional information, a seminar was organized in Mexico in which some 25 Latin American journalists were especially invited to participate in discussions on measures for strengthening the contact between the personnel involved in the area of diffusion with the institutional staffs and individuals working in the energy sector.

Throughout the regional preparations for the Conference, a general methodology was developed and applied at the level of policy-making and specific programs. This methodology can be summarized in the following main points. First, the development of the new and renewable sources of energy should be viewed, always, from within the context of a country's overall energy development. Likewise, the energy problem cannot be isolated, it is not the task of one sole sector, but rather a problem set within the most general framework for socio-economic and political development. Second, the potential of a new and renewable energy source should be conceived of as a result of the interaction of three elements: the resources available for each one of these sources, the energy demands or **requirements** for each sector of activity (end use) and the **technologies** available or under study, by means of which the needs can be correlated with the resources. During the preparatory process, the potential of the new and renewable energy sources was viewed not only as a technical factor but also from the perspective of large national objectives such as national self-determination and an assured energy supply, economic growth, the improvement of the population's standard of living, and the protection of the natural resources and environment. Seen from this perspective, the energy potential of the new and renewable sources and their evaluation can enormously enhance energy planning and can serve to orient the energy development programs undertaken by each government.

On the basis of the regional preparatory work described above, ECLA, in close collaboration with OLADE, drafted a preliminary version of the Regional Plan of Action in the Area of New and Renewable Sources of Energy, which was presented to the ECLA member countries at the Regional Preparatory Meeting for the Nairobi Conference, held at the ministerial level in Mexico City during March 19-20, 1981.

This Regional Meeting approved a final document for the Regional Plan of Action in the Area of New and Renewable Sources of Energy, which was circulated among the Preparatory Committee for the Conference and among the Conference itself.

The Plan of Action in question is set within the broad context of the current problems in the areas of energy and socio-economic development in Latin America. It analyzes the potential for developing and utilizing the new and renewable sources of energy and is oriented to achieving the massive utilization of those which have reached a certain degree of maturity. The document propases a group of activities to be undertaken at the national, sub-regional, regional, and worldwide levels, simultaneously directed at creating favorable conditions for a rapid and efficient utilization of the potential of these sources and the implementation of integral programs as an optimal mechanism for accomplishing the objectives, where "integral" is understood to be a program which contains **all** the necessary elements, from research and development to industrialization.

The Regional Plan of Action identifies the following **basic** programs for the region:

- Energy Planning
- Information and Diffusion
- Training and the following **integral** ones:
  - Hydroelectric Development
  - Firewood and Charcoal
  - Production of Liquid Fuels
  - Solar Energy
  - Plant Residues and Energy Efficiency in Agro-industry
  - Geothermal Energy
  - Biogas
  - Wind Energy.

The Nairobi Conference and Its Program of Action.

The international, regional, national, institutional, and organizational preparations culminated in Nairobi with he discussion and eventual adoption of the Nairobi Program of Action and various resolutions related to its implementation. The high-level political participation at the Conference (5 heads of State and more than 100 representatives from the ministerial level, the result of prior political mobilization) the active participation of more than 300 specialists in the topics of the Conference, more than 50 representatives from international and regional organizations and more than 800 representatives from non-governmental organizations, gave the Conference the atmosphere and characteristics of an historical-political event and a technological-scientific congress, all in one.

The Program of Action resulting from the Conference and adopted by consensus is the first step in an international undertaking aimed at a realistic locating of the new and renewable sources of energy within the context of the global energy problem.

Its different chapters deal with the following subjects:

- The energy transition
- The framework for action at the national level (national action)
- Objectives
- Measures for concerted action
- Policy measures
- Specific measures
- Implementation
- Priority areas of action
- Institutional arrangements
- Mobilization of financial resources

The conceptualization of the energy problem at this historical moment and its future prospects relate the subject to broader scopes such as the New International Economic Order and Global Negotiations. Among the most interesting passages contained in the document in this regard, the following are noteworthy:

"The energy transition should be based on technological, commercial, financial, and monetary patterns consistent with the determination of the governments to establish a New International Economic Order, in order to accelerate development and promote an overall balanced development". "In order to facilitate the energy transition, a process should be set in motion to assure the most efficient identification, exploration, evaluation, development, and utilization of the energy resources, including the new and renewable sources. In this context, the potential of the new and renewable sources should be considered as a dynamic variable which would tend to increase with the refinement, development, and popularization of the technologies."

In the chapter dedicated to the measures for concerted action, the Nairobi Program defines the following policy measures as the framework for action:

— Energy assessment and planning
— Research, demonstration, and development
— Transfer, adaptation, and application of mature technologies
— Information flows
— Education and training.

As for specific measures, the Program presents the actions necessary for developing each one of the sources of energy considered by the Conference. Parting from the state of technological advances, the storehouse of knowledge channeled during the preparatory process and the technical dialogue in Nairobi, this chapter identifies the actions necessary for promoting the participation of these sources in the world energy mosaic. The characteristics proper to each source, both from the perspective of its availability and of its potential use, create a great variety of alternatives.

On the basis of the "package" of activities defined, the Nairobi Program of Action follows, then, a converging process in which the priority areas of action are identified and an urgent call is made to formulate and launch programs and projects as soon as possible, as a first step in the implementation of the Nairobi Program. Some of these are presented below.

Resource Assesment and Energy Planning

— International cooperation for the formulation of national energy programs, with the aim that the countries have their energy strategies elaborated within this decade, should they so desire.

Research, Development, and Demonstration
RURAL SECTOR:

— Identification of fast-growing species
— Development of alternatives to the use of firewood, based on other new and renewable sources of energy (NRSE)
— Development of more efficient coal stoves and converters
— Development of gasifiers and thermochemical processes
— Development of technologies for harvesting, conserving, and processing food, based on NRSE.

Urban and insdustrial sector:

— Intensisfication of the research in solar technologies, the production of fuels from biomass, the development of multi-purpose hydro and geothermal projects, and the storage of energy.

Transfer, Adaptation, and Application of modern technologies

— Establishment of national, sub-regional, and regional centers
— Five-fold increase in reforestation over the current figures, in order to effectively cover the biomass demand for the year 2000
— Expanded utilization of hydro and geothermal resources and active and passive applications of solar energy
— Promotion of the use of urban and industrial wastes, for energy purposes.

Information, Education, and Training

— Designation of national, sub-regional, and regional focal points
— Training programs for planners, engineers, technicians, and researchers
— Promotion of information networks integrated at the national, sub-regional, and regional levels.

Implementation and Evaluation

The implementation of the Nairobi Program of Action is based on the launching of a series of activities comprising an operations "system". On the one hand, there is an inter-governmental body whose characteristics were defined in Nairobi and which will serve as a guide and permanent forum for the area. This international entity, provided with its own secretariat, will periodically review and modify the Program, as necessary. It will likewise be the moderator and sensor in the policy-making problems for the area of new and renewable sources of energy, in light of the energy transition. During the first part of 1982, this inter-governmental committee will meet to work towards their final definition and towards the launching of specific programs and actions. In addition, the Conference issued a call for the coordination of the United Nations system in this field and determined that, with a basically decentralized operation, the different organs and agencies will be coordinated by the Director General for International Economic Cooperation and Development. Concrete action is now being implemented to that end. The numerous current and future programs in the energy sector already, carried out or programmed by the U.N. system, are also being analyzed in light of the Nairobi Program.

The Regional Component in Implementation: OLADE and the Nairobi Program

Throughout the preparatory process, during the Conference itself and during the negotiations and definitions for the implementation of the Nairobi Program, the regional component has been stressed as the main element of international cooperation.

Among the priority actions in this area, the Program identifies the following:

— Support to regional programs related to resource assessment, research, development of demostration, training, planning and project identification.
— Call to establish inter-governmental bodies in the field of energy, where none exist.
— Strengthneing or specialized regional institutions.
— Strengthening or establishment of regional information networks which could be connected to international systems.
— Organization of research activities at the regional level.
— Regional demonstration projects.
— Pre-investment activities aimed at the accelerated implementation of NRSE.
— Support for the regional efforts aimed at the transfer and dissemination technologies.
— Activities oriented to the production of capital goods related to the energy industry.
— Organization of technical meetings, seminars, and conferences.

The regional nature of the implementation is facilitated in the Latin American case by the existence of the ideal organization to meet this challenge: OLADE. The Nairobi Program, on pointing out the relationship with other inter - governmental groups, issues a call for the active participation of these in the implementation of the Program, through the identification of activities already underway or planned in light of those identified in the Program. In addition, the Latin American countries present at the Conference ratified their position as set forth at the Preparatory Meeting in Mexico, and they adopted a resolution in which, referring to the Pronouncement of San Jose, the Lima Agreement, and the Latin American Energy Cooperation Program, they invited, the organs and agencies of the United Nations, the international community, and the Governeents, to provide effective financial and technical support for the development of the NRSE in Latin America.

During the upcoming months, appropriate steps must be taken to provide feedback for the Latin American Energy Cooperation Program and the Nairobi Program of Action, so as to achieve an optimum interaction. Surely the long tradition of economic cooperation in the Latin American region will be enhanced by the Nairobi Program and will in turn aid in guaranteeing the effective implementation of the first step of the international community.

SMALL HYDRO POWER STATIONS

Given the need to promote the development of the rural and isolated areas in the majority of the Third World countries, and in light of the growing difficulties associated with the supply and price of oil, it is necessary to mobilize resources and available potential for the adequate supply of energy that will contribute to increasing productivity and providing better living conditions for a broad sector of humanity.

Thus, if a harmonious regional development is desired, it is necessary to establish an energy development model that used the potential of all the available resources.

This article attempts to demonstrate that Small Hydro Power Stations (s.h.p.s.) can contribute to the solution of the energy problems in the rural and isolated areas of our countries.

1. Evaluation of Resources and Demand

Because of its favorable climatological conditions, Latin America has a highly significant hydroelectric potential that has not been explored or quantified.

Thus, the development of these resources is in its first stage, directed in most of the countries to large projects designed to satisfy the energy needs of the large population centers and the national interconnection systems.This frequently leaves the isolated areas without possibilities for an energy supply because of their reduced demand, difficult access, and great distances with respect to the principal consumption centers.

For example, it is estimated that the countries of the region, as a whole, only use 7% of their hydroelectric potential, available on a large scale. In the case of Small Hydro Power Stations, defined by OLADE as those with installed capacities of less than 500 kW, the availale potential is unknown, but it can be affirmed that there is little evidence of small-scale hydro development.

Even though Latin America has taken significant steps in the development of hydroenergy on a small scale, in general it has lacked an integral focus and planning and has promoted specific projects that are not within the context of a coherent evaluation of the available resources at the basin and sub-basin level. However, in the last years, some countries have initiated S.H.P.S. development programs associated with integral resource demand evaluations, among which the efforts of Brazil, Colombia, Cuba, Ecuador, Panama and Peru should be mentioned.

Within the context of the Regional S.H.P.S. Program, OLADE has elaborated planning and evaluation methodologies for resource and energy demand in the rural area, in order to assits the member countries in systematic S.H.P.S. development planning.

In the programs, the evaluations have been geared to the global study of the resources and demand by micro regions and basins, and not to in-depth studies of specific projects. When considering the development of S.H.P.S. in micro regions and isolated areas, it should not be forgotten that the global evaluations of the energy demand and of the resources are closely tied in geographical terms, due to distance limitations for high and low tension lines. In addition, when an attempt is made to interconnect an S.H.P.S. with existing networks, the link must be within the zone where the hydro resources and the transmision lines are located.

It is very important to differentiate between the global evaluation of resources and demand, and the evaluations done in studies for specific projects.

The global evaluation activities should have various characteristics, including:

— Inventories of existing S.H.P.S.: this consists of the identification of the existing and projected plants. An inventory constitutes a useful tool for orienting plans and programs in evaluating the degree of S.H.P.S. development; in determining short-term actions for re-conditioning, re-location and project continuation; and also determining reference indices proper to the country. This inventory can be employed in the study of other existing energy supplies, principally with regard to the extension of existing electrical networks and installed thermo-electric plants.

— Evaluation of resource by hydrographic basins and depresions: In order to have a preliminary estimate of the resources available for S.H.P.S., their magnitude must be estimated according to available data for each basin or depresion.

— Preliminary identification of isolated centers and micro-regions: The evaluation of the resources for S.H.P.S. is closely tied to the need to develop such sources in order to satisfy the electricity needs of small localities. Also, any massive S.H.P.S. development plan should be formulated on the basis of priorities established for the localities and sub-regions which could be electrified by S.H.P.S. The preliminary identification of isolated centers and micro-regions is presented as a group of activities that provide an initial estimate of the magnitude of the problem.

— Preliminary establishment of priorities for the isolated localities and micro-regions that can be electrified with S.H.P.S.: This consists of the establishment of priorities for the areas identified above, based on preliminary criteria with respect to the data gathered. This activity also allows the formulation of annual programs for preliminary studies, work, financing, training, etc.

— Field verification: This consists in verifying the data that will serve as the basis for the preliminary establishment of priorities, followed immediately by the verification of construction feasibility.

— Readjustment of priorities: Based on the previous information, the priorities should be readjusted taking into account criteria such as: size and costs, potential for contributing to rural development, community participation, use of local material and labor, equipment supply capacity, availability of technicians and engineers.

Based on the priorities, the following should be defined: annual project studies, work and financing programs; materials and equipment needs and requirements in terms of technological research and industrial development. This should be understood as a continuous process that integrates the accomplishments from the development of the different programs.

2. Technological Development

Technological research and development is a fundamental tool for the implementation of S.H.P.S., considering that they only require the adaptation and innovation of existing technologies in order to fit them to the conditions of each country.

Technological development applied to S.H.P.S. presents the following advantages:

— Reduction of the unit investment costs, through the application of non-conventional technologies.
— Promotion of the industrial production equipment and materials, maximizing the use of national materials and labor.

— Systematic development of knowledge and training of specialists.

— Greater technical evaluation capacity for the acquisition and operation of equipment and installations.

Various Latin American research institutes, universities and companies are conducting technological research on S.H.P.S., principally in Argentina, Brazil, Colombia, Costa Rica, Mexico and Peru. These countries have developed technologies that are in the stage of practical application, mainly dealing with the construction of dams and water intakes made from non-conventional materials (gabions, soil-cement, etc.), the construction of multipurpose canals, simplified forebay and silt remover designs, use of penstocks made of non-metallic materials (PVC, poliethelyne abestos-cement, etc.), turbines (Pelton, Michell-Banki, Francis and various types of axial flow machines, asynchronous generators and alternators, electric-electronic speed regulators, and modular switch board designs.

The main limitations for technological development in equipping and constructing S.H.P.S. in Latin America are related to the limited sharing experiences, transfer of technology, technical assistance and supply of equipment and materials among the regional countries. The importance of the technological aspects is underestimated by the groups responsible for the development of investment projects; and this is reflected in the sparse utilization of non-conventional technologies in rural electrification projects. This is the product of a misconception about S.H.P.S., which holds that they are just large power stations reduced to scale. In addition, the lack of confidence and under estimated productive potential have led to greater extra-regional supplying of equipment and technology.

Within the region there exists industrial production of equipment and materials, which assures a supply of Latin American origin. However, to date, the trade between countries has been insufficient, mainly due to the limited technical and commercial information on existing production, to the extra-regional financing schemes linked to the supplies originating therein, and to the lack of confidence in the technical quality of the materials and equipment of regional origin.

Moreover, the development of regional equipment and materials production is hindered by market limitations, given the absence of programs for massive implementation and the reduced exchange among our countries.

One part of the Regional S.H.P.S. Program of OLADE is oriented to technology and equipment; and in that regard, the following activities have been undertaken:

— Elaboration of catalogs on research and technological development projects underway in the countries of the region.

— Elaboration of profiles for research and technological development projects which could be undertaken in the region.

— Sharing of experiences and reciprocal assistance between regional research institutions.

— Execution of research and technological development projects of regional interest.

— Elaboration of methodologies for the design, standardization and construction of turbines.

— Directory of regional manufacturers of equipment and materials.

— Technical assistance to the countries in technological research, transfer of technology and equipment production, formulation of development plans and advising for specific projects.

The development of a technological research program on small hydro power stations is considered of high priority for the following reasons:

— It would allow the maximization of the technological development possibilities for equipment design and manufacturing, suitable to the specific conditions of each country.

— It would enable equipment to be produced at low costs, which contributes to reducing the magnitude of the initial investments.

— Equipment design could be adapted to the locally available materials and to the industrial structure of the country.

— It would allow the development and assimilation of non-conventional technologies.

— It would permit the systematic development of technical knowledge and the gathering of relevant information.

— It would facilitate the intensive and systematic training of specialists.

— It would increase the generation of experimental infrastructure and the capacity for evaluating the plants in operation.

— It would improve the capacity to evaluate alternatives for equipment acquisition.

— It would reduce the financial requirements for initiating research.

It is not possible to establish one single pattern for the design of Technological Research Programs on Small Hydro Power Stations at the level of each country. However, several general points can be made whose applicability should be considered in each case. Thus, it should be considered that it is necessary for each country to have definite technological development policies, establishing a framework of priorities for the technological research on equipment.

It is necessary to define the type of institution that sould assume responsability for the technological development of equipment. Aviable scheme in many cases consists of such responsability being assumed by the State Research Institute. The procurement of financial resources for research depends, to a large extent, on the institutional structure that is adopted, in order to guarantee the correct use of the funds, which could be public contributions from industry investment projects.

With respect to bilateral technical cooperation, particular attention and care should be given to the objectives and scope of a program, in order to avoid the disguised sale of technology conditioned to comercial objectives, for if this were necessary, it should correspond to specific negotiaton activities aimed at making purchases of technology under favorable conditions and not to granting exclusivity hidden within an assistance program. Moreover, in all the cases of international technical assistance, mechanisms for the effective assimilation of knowledge should be clearly established.

The technology developed should be oriented to the simplification of the installation, implementation and operation of the equipment so that it will be adaptable to the participation of the local communities in the projects.

Suitable equipment able to function in unfavorable conditions should be developed, in terms of maintenance and operation. The equipment should be as efficient as possible; and a good design will assure a rational use of the hydro resource, reasonable sizes of equipment, reliable operation, and a maximum use of local materials.

According to each country's industrial development policies and the scope of its S.H.P.S. investment programs, the equipment which will be more suitable for technological development should be selected.

3. Current State of S.H.P.S. Development in the Region

Latin America has a long tradition in S.H.P.S. development. Plants of this kind began to be installed in the region during the last decade of the past century; and during the first half of this century, some pioneering efforts were made in the field of technological development. These were primarily motivated by the mechanization of agro-industry (coffee, cacao, sugar, etc.) and by small mining operations, which gave rise to growing energy needs in isolated zones, when the electrification of the countries of the region was just beginning.

However, with the technical perfectioning of internal combustion engines, their greater efficiency, their increasingly lower purchase prices and installation costs with respect to hydroelectric systems, coupled with an energy model associated with cheap fuels and the expansion of the interconnected electrical systems, the interest in S.H.P.S. declined, there were fewer new investment projects and some plants were closed. This was accompanied by a leveling off of technological research activity and of the production activities associated with the equipment supply.

Given the problems arising from the use of fuels based almost exclusively on petroleum and given the latter's scarcity and consequent price increases, the permanent standstill of productive activities and deterioration of living conditions in Latin American rural areas —which has caused, among other great problems, strong migratory pressures to the cities and a poor incorporation of the peasant population into national development— the moment has come when it is imperative to promote the rapid socio-economic development of the countryside. Among other things, this entails the need to satisfy the rural energy requirements. This situation has now caused S.H.P.S. to be considered one of the principal alternatives for supplying energy to the rural area, in light of the enormous hydroelectric potential of the region.

If the development of S.H.P.S. is conceived of in Latin America from the perspective of a massive implementation of projects —so that during the next twenty years these will have an effective impact on rural development based on integral energy coverage— it is not enough to consider the problem simply as an intensive process of plant construction but rather as a global action that also includes: 1) The development and transfer of technology with respect to the equipment and installations and 2) The amplification of the equipment production capacity.

It can be affirmed that at present diverse institutions, universities and companies from the region are developing intense research and technological development activities whose results are in the process of practical application, even though the efforts so far have been limited, hindered primarily by financial restrictions.

Other countries have developed small isolated projects, generally trying to relocate equipment from stations that were abandoned because of interconnections. Even though in the region there are numerous plants that fall within the category of small hydro power stations, an important part of them have been built with conventional technologies and equipment imported from outside the area. In many cases, these plants were conceived of as rural development instruments, which relfect the lack of definite policies in this regard.

It is estimated that Latin America should already have approximately 2000 small hydro power stations in operation. However, this figure constitutes a very small portion of the plants that need to be installed in order to satisfy the rural energy needs in isolated areas that have adequate hydro resources.

As has been mentioned before, there also exists industrial production of equipment and materials in the region, mainly turbines, speed regulators, generators, piping, valves, switch boards, instruments, electrical materials, and building supplies; this implies that regionally it is possible to adequately supply stations with potentials less than 500 kW.

Within the region, the levels of exchange of experience, transfer of technology, and material and equipment supply are very limited; currently, strong this of dependency are maintained extra-regionally with respect to those elements that are not available locally.

Among the limitations to technological development, the following can be mentioned: a) insufficient value placed on the importance of the technological aspects by the entities responsible for the execution of rural electrification projects; b) limited use of non-conventional technologies, the product of an erroneous conception that considers S.H.P.S. as large plants reduced to scale; c) the prevalence of financial schemes tied to the extra-regional supply of equipment; d) the frequent absence of national policies to promote technological development and to regulate the transfer of technology; and e) many countries' industrial characteristics for the satisfactory development of equipment production.

The traditional attitude of underestimating the production potential of our countries also has a negative influence, since the extraregional supplies are considered superior.

4. Economic aspects

Currently, the total unit investment costs for S.H.P.S. fall within US$ 2000 and US$ 5000 per kilowatt installed. OLADE proposes a regional goal of US$ 1000 and US$ 2000 per kilowatt installed, which will require the following:

— Evaluation of the resource and demand at the level of basins and sub-basins, in order to define projects with good techno-economic characteristics and to reduce the requirements for specific studies.

— Promotion of massive S.H.P.S. development in order to have them be more economical, developing joint projects by basin and by mico-regional level.

— Encouraging organized community participation in plant construction.

— Definition of the scope and objective requirements for specific studies in light of the magnitude of the anticipated investments.

— Promotion of non-conventional technologies that reduce costs while maintaning adequate engineering levels.

— Promotion of national equipment manufacturing.

In a manual for S.H.P.S. decision-making, prepared by OLADE and UNIDO, systematic analysis of unit costs is presented and this will be amplified in the S.H.P.S. Costs Manual.

OLADE is preparing a guide for the elaboration of projects which will attempt to define methods and scopes for pre-investment studies in order to reduce costs and facilitate requests for project financing.

The major problems related to S.H.P.S. financing are as follows:

— Insufficient funds available
— Unreasonable requirements for pre-investment studies
— Credits tied to costly supplies
— Few projects in productive activities that require energy
— Economic-financial evaluation criteria that are not compatible with the needs of rural development.

5. Criteria for Massive Application

The regional panorama with respect to S.H.P.S. development demostrates that even though the countries have abundant hydroelectric resources and the development of this type of station presents numerous advantages as one of the solutions to the socio-economic problems of the rural communities, only three Latin American countries have planned the massive implementation of S.H.P.S. In addition, many of the S.H.P.S. installed in the region have been constructed without community participation and with conventional technology and equipment from outside the region.

This indicates the lack of policies and the need for an institutional organization to promote S.H.P.S. development in a coherent and planned way, in line with the reality of the available economic and technical resources. In this regard, a massive S.H.P.S. development strategy has been planned to encompass: 1) The carrying out of activities to eliminate the existing limitations and 2) The execution of S.H.P.S. construction programs in the region, gradually incorporating the results obtained without compromising the final goals.

The execution of a timetable for the massive development of S.H.P.S. in the region should consider the development of technological research activities and the incorporation of local labor and regional materials. Thereby, technological dependency and installation costs would be reduced and there would be a greater degree of professional training.

Considering the above, massive development of S.H.P.S. should consider institutional policies for rural energy development, construction, financing, technology, equipment and materials, training and rates.

Since knowledge of the available hydro-resources is necessary, the following scheme for evaluating resources and demand is proposed: 1) to identify the S.H.P.S. existing and planned; 2) to evaluate the resources by basins and hydrographic deposits; 3) to identify in a first instance, isolated centers and micro-regions; 4) to establish preliminary priorities for the isolated centers and micro-regions that could be electrified with S.H.P.S.; and 5) to verify the basis for the preliminary establishment of priorities and to readjust this based on the previous information.

It is considered convenient for the countries to have a governmental entity dedicated exclusively to the promotion and coordination of S.H.P.S. development and implementation. Among the tasks of this entity would be the gathering of technical information, the realization and coordination of technological development, the planning and construction of S.H.P.S. operation and maintenance, request for financing, the negotiation of the purchase of equipment and technologies available in the region, requests for technical assistance and cooperation, and finally the lending of continuity to the construction of stations, training and motivation of the communities.

When formulating plans and programs for S.H.P.S. development and installation and training, the available financial and technical resources should be kept in mind, as well as the results of the different programs. In addition, the needs should be defined with respect to equipment, labor, and professional and technical personnel.

The planning and programming methodologies should be uniform and the criteria for establishing priorities should be in accordance with the policies proposed.

In the specific S.H.P.S. projects, studies would refer to an analysis of basins and sub-basins, with hydrological, geological, geomorphological, and geotechnical studies whose degree of detail would be related to the magnitude of the investment, in some cases including economic prefeasibility through an indirect analysis of possible rates. Those projects where there is doubt as to whether they should continue or not should undergo a feasibility study examination.

In the case of feasibility studies, the schemes of preliminary designs should permit a quatitative or comparative economic analysis to evaluate S.H.P.S. against other alternative sources to satisfy the demand.

The object of the studies should consist in determining the demand and its variation with time, the available falls, the variation of the ponds and its relation with the demand.

The development of S.H.P.S. projects requires considerable support from the national budget of each country, these projects will generally attend commuinities with a reduced economic capacity. This makes it necessary to maximize the use of energy generated primarily for productive purposes.

In addition, it is necessary to initiate research activities that will lead to reduced engineering and equipment costs, thereby encouraging greater participation by national engineering in studies on S.H.P.S. construction and coordinating the effective participation of the rural community in the construction stage by means of electrification committees.

The creation of funds is of prime importance for rural electrification development based on S.H.P.S.

With regard to S.H.P.S. operation and maintenance, it is recommended to have suitable institutional plans that combine the possibilities of autonomous requests for plants at the local level with technical and organizational support from the electrification entities, for which OLADE has prepared a reference model.

6. OLADE Activities

The Regional S.H.P.S. Program initiated its activities in January of 1980, with the principal objective of promoting the massive implementation of small hydro power stations in the region, as a partial answer to the development of the rural area and isolated zones, taking advantage of one of the most abundant regional energy resources.

The OLADE activities have given particular emphasis to the development of methodologies, manuals and technical documents that can be used by the institutions of the countries to promote S.H.P.S. development. The following is a partial list of these works:

— **"The Hydroelectric Potential: Energy Alternative and Industrial and Financial Challenge for Latin America"**

This document attempts to provide the regional countries with a picture of the hydroelectric potential and the industrial and financial implications that such development can have within the framework of regional cooperation.

— **"Mini Hydro Power Stations: A Manual for Decision -Makers"**

This document presents the regional and extra-regional countries with definitions and guidelines to be considered in the planning and development of mini hydro power stations. It is for entities that make decisions related to planning in this field, at the national and local levels.

— **"The Development of Small Hydro Power Stations in Latin America and the Caribbean"**

This document presents to the regional countries the technical and socio-economic panorama in which small hydro power stations are developed and the bases of OLADE's S.H.P.S. program.

— **"Situation and Prospects of Technology and Equipment for Small Hydro Power Stations in Latin America"**

This publication analyzes the prospects for technological development, transfer of technology and the supply of equipment and materials in order to promote the implementation of S.H.P.S. in the region.

— **"Requirements and Methodologies for the Massive Implementation of Small Hydro Power Stations in Latin America"**

This has as its objective to define the methodologies and concrete actions that the regional countries should adopt to promote the development and massive implementation of S.H.P.S.

8 **"Hydrology for Small Hydro Power Station Projects in the absence of data"**

— **"Synthetic Methodology for the Calculation and Preliminary Specification of Mini Hydro Power Stations"**

— **"Electric-Electronic Speed Regulators for Hydraulic Turbines for Hydro Power Stations"**

— **"Design and Standardization of Michell-Banki Turbines"**

— **"Design Manual for Small Hydro Power Stations"**

This document is in the process of being elaborated and attempts to provide simple methodologies for the design of small hydro power stations, considering the use of non-conventional technologies.

For the formulation of the terms of reference for manuals and methodologies and for the identification of concrete actions that OLADE should undertake, Work Groups have been formed with regional experts. To date, the following Work Group meetings have taken place:

— First Meeting of the Work Group: This meeting, held in Quito, Ecuador, in August of 1979, analyzed the S.H.P.S. development problems in Latin America and the prospects for their solution. A regional development strategy was defined and the guidelines of the regional program were formulated.

— Second Meeting of the Work Group: This meeting was held in Quito, Ecuador, in April 1980, in order to share experiences and define activities related to the technology and equipment for S.H.P.S.

— Third Meeting of the Work Group: This meeting was held in Quito, Ecuador in June 1980, in order to share experiences and define the terms to be considered in the document on: **"Requirements and Capacities for the Massive Implementation of S.H.P.S. in Latin America".**

— Fourth Meeting of the Work Group: This was held in Quito, Ecuador, in April 1981, in order to perfect the terms of reference for the **Design Manual for Small Hydro Power Stations** and to elaborate a document describing its contents in detail.

An OLADE Advisory Group has also been formed; it is composed of various regional experts in the field of S.H.P.S. This group had its first meeting in August 1981 in Lima, Peru, where the general guidelines of the Regional S.H.P.S. Program were revised, the OLADE activities evaluated and opinions exchanged on planning and programming. New guidelines were also proposed for future consideration.

From November 3-7, 1980, the First Latin American Seminar was held in Girardot-Colombia, under the auspices of OLADE and ICEL (the Colombian Institute of Electricity) at which guidelines were established for regional action to promote the massive implementation of S.H.P.S. under the coordination of OLADE.

As a first important step in supporting the training of the human resources required for S.H.P.S. development in the region, OLADE organized the First Latin American Course on S.H.P.S. Design held during September 7-23, 1981, in Lima, Peru. This event was co-sponsored by the Ministry of Energy and Mines of Peru and ELECTROPERU.

The OLADE Permanent Secretariat also gave support to the countries and institutions that required the technical backing of the organization for the development of their national programs. Obviously the scope of these activities has been limited by the available budgetary funds, as well as by the resources that the interested countries have allocated for this program. These activities have been carried out within the framework of Decision 073 of the Eleventh Meeting of Ministers of OLADE, which charged the Permanent Secretariat with soliciting extra-budgetary funds for a permanent technical team to aid the activities of the countries in the massive development of S.H.P.S. In complying with this mandate, OLADE has now formed a small multi-disciplinary technical team that carries out specific support activities in the countries.

Among the principal technical support activities that OLADE has undertaken, the following should be mentioned:

— Technical assistance to INECEL-Ecuador, for the development of its national S.H.P.S. program.

— Technical assitance in the design of the civil structures and turbine of the small station in Cuyuja. A technical cooperation agreement exists between OLADE and INECEL.

— Technical advising to Grenada for its program of S.H.P.S. development, for the formulation of an integral feasibility study already in progress, and for the solicitation of financing.

— Technical advising to Cuba for the development of its S.H.P.S. implementation program. An agreement has been signed between OLADE and Cuba.

— Technical advising to CADAFE - Venezuela, to promote the development of S.H.P.S. implementation programs. The preliminary designs for the small hydro power station in Piñango were made. A cooperation agreement is being elaborated.

— Technical advising to various countries which are planning groups of S.H.P.S. for demonstration and/or applied research purposes.

In general, the support OLADE has given to the countries has entailed the following activities to promote the massive implementation of S.H.P.S. in the region:

— Definition and diffusion of technological development methodologies suitable for the regional countries.

— Promotion of the sharing of technology among the countries through technical assistance and the exchange of regional specialists.

— Diffusion of the best technological alternatives for S.H.P.S. equipment.

— Identification and diffusion of alternatives for the organization and financing of investment programs.

— Implementation of pilot projects, geared to perfecting adequate methodologies for the massive implementation of S.H.P.S.

GEOTHERMAL POTENTIAL IN LATIN AMERICA

1. A GEOTHERMAL ENERGY OVERVIEW

It is useful to diferentiate among geothermal resources according to their practical uses, in categories traditionally termed high, medium, and low enthalpy.

The resources in the first group can be used to generate electricity, while the others are economical for direct energy uses such as in heating, agro-industry, the public health sector, etc.

It is difficult to set precise temperature limits among the types of resources, given the fact that the enthalpy of a fluid also depends on the temperature of its physical-chemical factors.

In general, the range of 150-180°C is taken as the lower limit for high-enthalpy resources.

Considering the fact that the average value for the earth's geothermal gradient (temperature increase at depth) is on the order of 30°C/Km and that geothermal exploitation is economically feasible up to depths of approximately 3 Km., it is possible to establish the following:

a) The low-enthalpy resources ($\leq$100°C) are theoretically available wherever there are favorable hydrogeological conditions (aquifers with great potential and suitable depths).

b) The medium-enthalpy resources (100 - 150°C) and even more so the high-enthalpy ones (150°C) require special geological conditions, particularly the presence of an important positive thermal anomaly to determine two-to three-fold increase in the average geothermal gradient.

Geological Conditions for Developing High-Enthalpy Geothermal Resources

As has been mentioned, the first pre-requisite for the existence of high-enthalpy resources is the presence of an important thermal anomaly close to the surface. For this to occur, a sharp increase in the heat flow from within the Earth is needed, to cause the isotherms to approach the surface. This phenomenon can occur when heat is transported towards the surface by means of the displacement of high-temperature masses. In other words, it is necessary for important volumes of sub-surface magma, with temperatures on the order of 1200°C to move up to the surface, transferring heat to the surrounding rocks. Therefore, it can be affirmed that, in general, all of the regions affected by recent volcanic phenomena are considered potential geothermal zones.

The tectonic plates theory has permitted the formulation of a model which satisfactorilly explains the causes for contraction of volcanic activity in certain areas of the Earth. Volcanism as well as seismic activity entail the dissipation of the planet's internal energy along the border of contiguous plates.

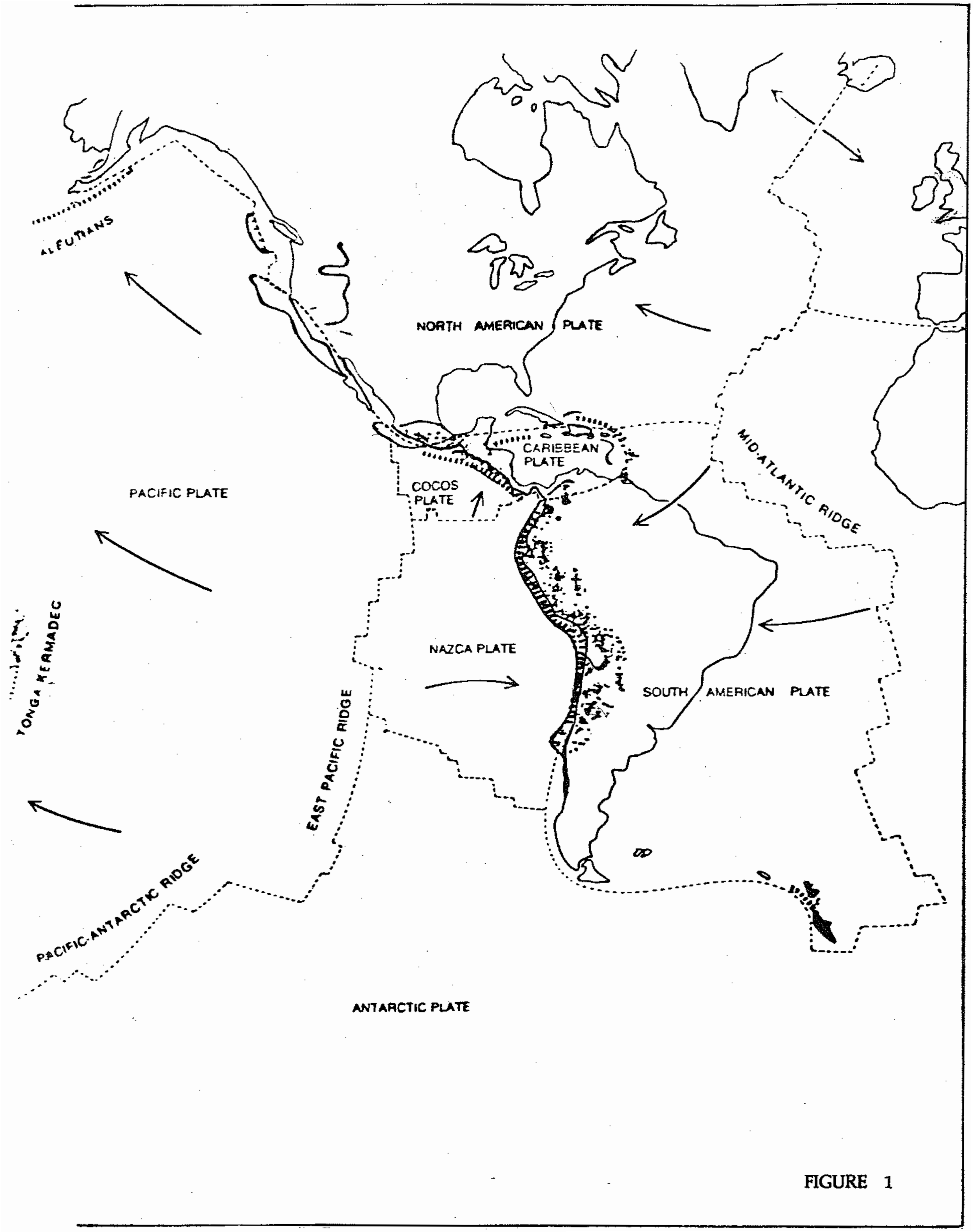

ALEUTIANS
NORTH AMERICAN PLATE
CARIBBEAN PLATE
COCOS PLATE
PACIFIC PLATE
MID-ATLANTIC RIDGE
TONGA KERMADEC
NAZCA PLATE
SOUTH AMERICAN PLATE
EAST PACIFIC RIDGE
PACIFIC-ANTARCTIC RIDGE
ANTARCTIC PLATE

FIGURE 1

According to the type of dynamic interaction among plates, two types of borders can be differentiated:

a) **Borders with diverging plates:**

This refers to the tectonic environment of the dorsal ocean plates, where new lithosphere is generated through continuous raises, with intrusions and effusions of basalt magma from the atmosphere. Continental rifts, such as those of the region of large lakes in Eastern Africa, represent embryonic phases of this type. Should their distension be continued, their evolution would continue until they become oceans.

b) **Border between converging plates:**

This refers to the tectonic environment of the cordilleras (active continental margins) and island chains. The Circumpacific Belt of Fire offers some of the most spectacular examples of this type of geodynamic situation.

The limits are characterized by subduction. One of the converging oceanic plates slides under the adjacent plate, which could be either oceanic or, more often than not, continental. In the contact zone, a compressive tectonic environment evolves, with the consequent formation of large blocks of crust isolated from its roots and displaced horizontally. At some distance from the point of contact —usually at least 100 Km.— an extensive front of active volcanism develops, where andesitic magma and its differentiated products prevail. Such magma is generated by physical - chemical interactions between the material of the plate and the overlaid stenosphere. In this case (as in that of the ocean dorsal plates, despite the fact that these are opposite tectonic environments characterized by quite different magmatic processes), the production, mobilization, and rise to the surface of enormous volumes of magma produce a regional thermal anomaly and an ideal setting for the development of high-enthalpy geothermal fields.

c) **Border between plates with lateral displacement**

It is in this environment that transforming faults connect the first two types of plate borders. The tectonics are controlled by horizontal displacement, with only a light distensive component. The volcanism is, therefore, generally less intense and; as a result, its geothermal prospects are less interesting.

While on the one hand it is true that volcanism is concentrated in these three environments, it should also be noted that there are some important exceptions. These are volcanic phenomena evolved inside the plates, whether these are founds in oceanic settings (Hawaii) or in continental ones (Tibesti mountains in Africa), far from the limits of the plates. These phenomena are generally attributed to the presence of "hot points" related to the rise conentrated at a point with hot material originating in the stenosphere. No matter what their origin, these zones offer great geothermal interest when the volcanism has developed with sufficient intensity in recent times.

The Geodynamic Situation and Geothermal Prospects in Latin America

The geodynamic situation of the Latin American countries is quite different from those of the Atlantic and Pacific.

The Pacific countries have the second type of tectonic environments described above, with converging plates (see Figure 1). The South American continent corresponds to one large geodynamic setting, characterized by conversions between the oceanic plate of Nazca, in subduction below the South American continental plate, resulting from this process, the formation of the Andean Cordillera, which extends for thousands of kilometers, from Argentina up to Colombian-Venezuelan border, passing through Chile, Bolivia and Ecuador. The complexity of the geodynamic processes currently gives rise to short discontinuities in volcanic activity along the Cordillera and also to a migration of the volcanic front with time. Nevertheless, the Andean countries offer great geothermal possibilities, precisely because of the presence of extensive volcanic phenomena occuring over many millions of years.

The geodynamic situation in Central America is much more complex, due to the existance of a triple function, in other words, contact among three plates: the Oceanic Cocos plate, and the continental North American and Caribbean ones. This situation produces an extremely complex tectonic environment, characterized by the subduction of the Cocos plate and the development of andesitic volcanism along the Pacific Strip of Mexico, Nicaragua, Costa Rica, Panama and Honduras, of much less interest. Along with this subduction phenomena transforming limits, such as those which characterize the septentrional and meridional border of the Caribbean plate, have evolved; these include Guatemala, part of the Northern Antilles, and the septentrional edge of the South American Continent (Colombia and Southern Venezuela), respectively.

Differential movements near these structures, give rise to force fields and the consequent formation of distensive depressions (grabens) with basic associated volcanism, frequently alkaline.

The areas of geothermal interest correspond, either to the Pacific strips of andesitic volcanism, or to intersecting zones between the active volcanic front and the transversal depreseions, and to a lesser degree, the distensive depresions themselves.

On the Atlatic side of the Caribbean plate, there is an area of recent subduction, caused by the convergence of the Caribbean plate and that of the Atlantic ocean. The result was the formation of an island chain, whose active volcanic front extends along the Lesser Antilles. Only those islands located along this active volcanic arch (St. Kitts to the North and Grenada to the South), offer a potentially favorable geological setting for the development of high-enthalpy geothermal resources.

Among the remaining Caribbean islands, Hispaniola is potentially interesting in terms of medium and high enthalpy, but only near the graben Cul-de-Sac, Enriquillo, at the transforming septentional limit of the Caribbean plate where very limited volcanic phenomena are present. The Atlantic countries of South America belong to the "passive" side of the continente, i.e., that without limits between adjacent plates. their geothermal possibilities are much slighter. In these countries, there is almost no chance that high-enthalpy geothermal resources exist; although there are some prospects for low-or possibly medium-enthalpy fluids wherever there are favorable tectonic and hydrogeological conditions (distensive zones permitting rapid rise of important volumes of hot water, along the fracture from deeper zones, and their infiltration into aquifers closer to the surface).

Latin American Geothermal Prospects

From the foregoing, it becomes evident that all the Latin American countries with a Pacific coast and the Lesser Antilles have good possibilities for high-enthalpy geothermal resources. Any attempt to quantify these in terms of their energy potential could be quite risky in this current stage of geothermal exploration. Actually, there are no methodologies for accurately evaluating geothermal resources quantitatively. The main difficulty consists of the practical impossibility of an **a priori** evaluation of the amout of heat present in a given set of rocks containing geothermal fluids before the filed has been explored and drilled. Neither can one know how much fluid is contained in rocks having a low or null permeability. With the technology currently available, fluids such as the latter cannot be exploited from the surface; and, therefore, the other constitute the only exploitable energy resource.

The methodologies used to estimate the exploitable portion indirectly (e. g., the methodologies developed by the United States Geological Service —U.S.G.S.— such as the volumes method, Maffler 1980) can provide fairly reliable results in those cases where one accurately knows about the permeability range of the formations within the thermal anomaly; this is usually only possible after an intense drilling program, a phenomenon still quite limited in the region.

The Latin American geothermoelectric capacity (installed or underway) is as follows:

Country	**Capacity**
Mexico	150 MW
El Salvador	95 MW
Nicaragua	30 MW (in progress)

However, it should be noted that most of the areas of interest are ina quite preliminary phase of exploration or have yet to be investigated. In recent years, OLADE —with the cartainty that geothermics represents one of Latin America's most important sources of energy— has dedicated major efforts to the assessment of such resources. After having established a suitable exploration methodology, OLADE has coordinated reconnaissance and prefeasibility studies in numerous Latin American countries; and the results obtained have been highly satisfactory. They can be summarized as follows:

Peru Reconnaissance study, 1979-80; identification of 9 areas of interest along the Inter-andean Depression, 3 of which have top priority.

Colombia: Reconnaissance study, 1981 (in progress); preliminary results indicate presence of areas of interest in the areas of Cauca and Nariño.

Dominican Republic: Reconnaissance study, 1979-80; one high-enthalpy area (Yayas) identified and as well as several of low-to-medium enthalpy.

Haiti: Reconnaissance study, 1979-80; definition of a low-to-medium enthalpy area in the Cul-de-Sac graben.

Guatemala: Reconnaissance study, 1980 (in progress); identification of 8 areas of interest along the active volcanic axis and related to the distensive depression related to the Mologua transforming fault. In the area of Xunil, several deep boreholes have been drilled by the Government.

Nicaragua: Reconnaissance and pre-feasibility study, 1980-81 (still in progress), in addition to confirming those areas of interest already known, 5 more were detected; parallelly, a pre-feasibility study carried out in the El Hoyo-San Jacinto area has located 3 sectors where deep exploratory wells will be drilled.

Grenada: Preliminary geovolcanological study, 1981 (in progress); definition of medium and possibly high-enthalpy interests in some parts of the island.

Jamaica: Reconnaissance study oriented to low - and medium-enthalpy, 1981 (in progress); evaluation of the possibilities for developing and applying the existing resources.

Panama: Geovolcanological study and evaluation of existing data on the western Chriqui, 1981; identification of one high-enthalpy area with good possibilities, quite different from that previously explored in the recent volcanic apparatus Baru-Colorado.

To these programs, one must also add the positive results achieved in other Latin American countries where exploration is underway:

Bolivia: Completed pre-feasibility studies, with quite favorable results, in the areas of Empexa and Laguna Colorada: identification of many other areas of interest.

Chile: Drilling program completed with positive results in the area of El Tatio and other areas of interest already identified.

Argentina: Reconnaissance studies in the province of Jujuy (completed), in the province of Mendoza (in progress); first phase of pre-feasibility completed in the area of the Tuzgle volcano, in the province of Jujuy; drilling of one well with positive results in the Copahue area, in the province of Neuquen.

Venezuela: Reconnaissance study in El Pilar-Casanay (completed).

Costa Rica: Drilling program with positive results in the volcanic area of Miravalles.

As a whole, the situation is very positive and this fact not only confirms the great importance of geothermal energy in the Latin American countries but also provides an incentive for intensifying studies to assess this invaluable energy resource in the region.

2. OLADE METHODOLOGY FOR GEOTHERMAL EXPLORATION

As a consecuenque of the high degree of geothermal potential described in Section 1, many countries have undertaken geothermal exploration programs. Nevertheless, there was no guide permitting the execution of the programs with a rational use of the resources and yeilding within suitable time limits. The wide variety of possible local condidtions require substantial changes in the sequence and/or modality of the use of existing techniques. Thus, it was considered necessary to elaborate a methodology allowing techniques to be selected and combined so as to aid in accomplishing the particular research objectives for the specific geological characteristics of each project.

Thus, as the result of 3 seminars between 1978-80, with broad regional participation, the different phases of a geothermal exploration and exploitation methodology was prepared. This methodology includes the general guidelines for a geothermal project, the exploratory methods to be used, the number of personnel and the magnitude of the investments required, etc., all this flexibly adaptable to the conditions and characteristics of each project and formulated on the basis of experience acquired in geothermal projects in Mexico, El Salvador, Italy, New Zealand, Iceland, and other Latin American countries, and in accordance with the latest scientific advances.

In general, a typical geothermal project is composed of two main parts: the first is high - risk, like the exploration of any mineral or form of energy; its purpose is to identify the reservoir (the geothermal field), including the study of its possible utilization. The second is of a mixed type (exploratory, technological, and energy risks), related to the development and exploitation of the reservoir. The first part entails notable levels of economic risk and requires progressively larger investments. On the other hand, the second part requires lower risks and investment of substantial sums.

The experience accumulated thus far has shown that the average dimensions of a productive area range between 10 and 100 Km^2. If the geothermal project is located in a region on the order of ...... 10,000-100,000 Km^2, the locating of the possible productive area will require intermediate investigation phases permitting: first, the definition of the area of interest (500-2000 km^2) on the basis of reconnaissance and, later, the singling out of one or more promising areas no larger than 100 Km^2, wherein sites will be determined for the deep exploratory wells to be drilled.

In accordance with the foregoing, a subsequent pre-feasibility study will locate the sites for deep drilling. The phase should be broken down into different stages to be accomplished within reasonable time periods, since investments are progressively larger as the project advances. Thus, it is imperative to initiate studies and investigations of a regional nature, which entail relatively low costs, while leaving the more in-depth prospecting and investigation for only those areas of major interest, usually 500-2000 Km^2.

This criteria permits the periodical, integrated interpretation of the investigation results; the elimination of less favorable zones; and the assessment of the merits of proceeding to the next stage of work.

Later, a feasibility study evaluates the potential of the area investigated and defines the preliminary design of the alternative utilization systems, thus permitting the programming of the operations to be undertaken during the subsequent phase of development.

From the practical point of view, it has been useful to formulate 5 different stages for a geothermal project. The first three are related to the exploratory part of the project: the reconnaissance, pre-feasibility, and feasibility studies. The other two phases, development and exploitation, are oriented to the systematic production of the endogenous fluid, to its industrial application, and to the problems proper to the field (Figure 2).

This structural design of the methodology permits the selection and combination of techniques easily adaptable to local conditions and characteristics, and effectively differentiates among the various phases of exploration and exploitation.

The validity of the OLADE methodology has been succesfully proven in the regional projects coordinated by this Organization.

3. TECHNICAL ASSITANCE

Within the program of technical assistance to foster the development of regional applications for geothermal energy, the following actions were considered:

- To establish a training infrastructure in this field, along with a systematic technical-scientific exchange;
- To advise in and coordinate the geothermal exploration projects in those countries which may so request;
- To support and encourage the development of geothermal projects already underway;
- To provide consulting services in specific areas and;
- To seek sources of financing to assure the development of the foregoing.

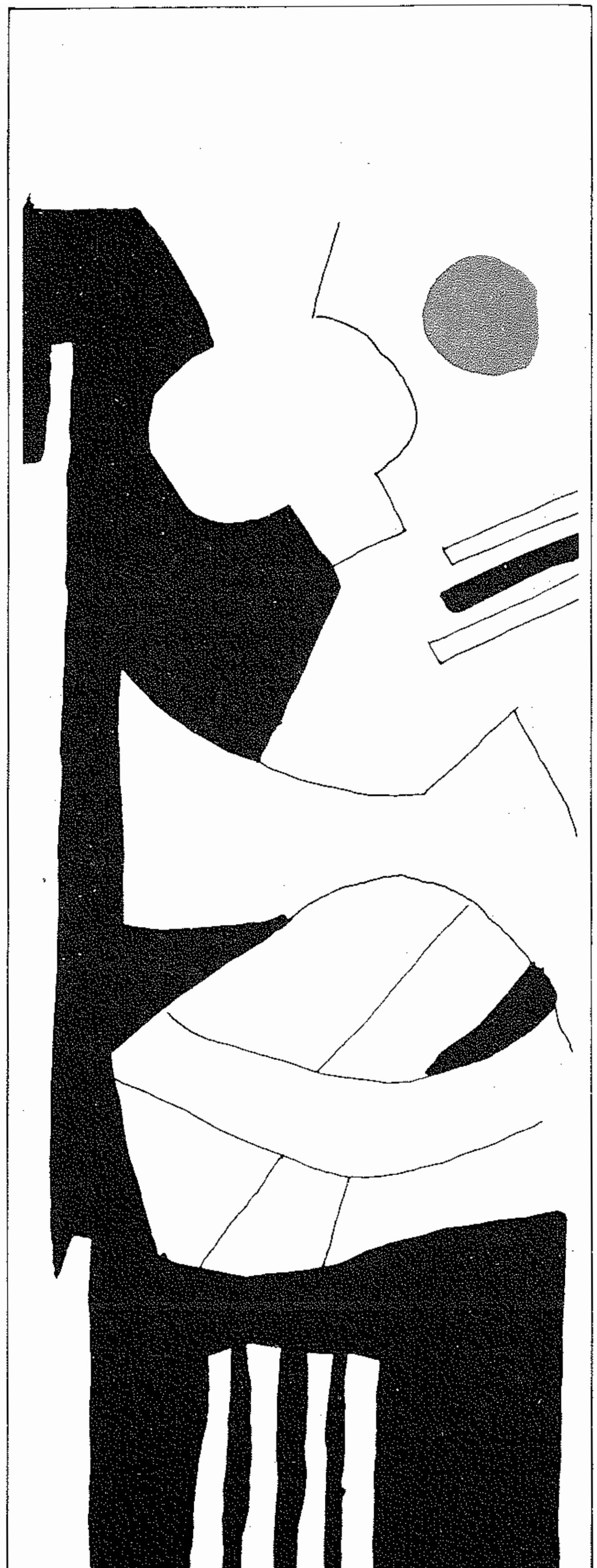
OLADE has provided assitance and coordination to the Latin American countries so as to increase the necessary exploratory activities in the search for low-, medium-, and high-enthalpy fluids for electricity generation and industrial applications. The assistance lent has included everything from simple consultations in the formulation of projects, to the directing of a complete exploration program. For this, the Geothermal Exploration Methodology has facilitated the control of activities in one or more countries by managing to "standardize" exploration criteria by simplifying their control and coordination.

Likewise, the coordination efforts have entailed assistance in the formation of national professional teams. In this regard, agreements have been established with regional entities, for the purpose of training technicians in different disciplines and for preparing practical training in those countries most advanced in geothermal activities. It has been thought to accomplish this through the institutionalization of six Latin American courses on topics related to geothermal energy; Geovolcanology, Geophysics, Geochemistry, Production Engineering, Drilling, and Reservoir Engineering. The courses have been structured to meet the basic needs of regional geothermal development; they will be offered on a yearly basis, in different countries, and will last approximately three months each. The latter two have already been given in Mexico, with the participation of 44 professionals from 10 countries.

OLADE anticipates geothermics to be integrated into the medium-term energy supply of most of the Latin American countries. It is thought that with the exploration already begun, the first geothermal units will be available during this decade, thus opening up possibilities for the intensive development of new areas which, with geothermoelectric generation, will be integrated into national productive activities. Within this operational framework, OLADE has carried out several programs, as indicated in the first part of this article.

Furthermore, by integrating the rural populations of Latin America, which account for more than half of the total, with transmission lines or conventional energy distribution grids, OLADE hopes to foster the exploitation of low- and medium-enthalpy geothermal resources in an attempt to increase productive and economic development in these areas with fewer resources.

note; The authors would like to gratefully acknowledge the valuable contributions made by Prof. Franco Barberi from the University of Pisa and by Dr. Andrea Merla from G. I. through conceptual discussions held during the preparation of this Article.



THE WIND AS AN ENERGY ALTERNATIVE FOR LATIN AMERICA

1. INTRODUCTION

Undoubtedlby, the wind is one of the most abundant natural resources in Latin America.

Although wind energy cannot compete on the same level as other sources of energy, it seems to constitute a quite attractive alternative for the region. Its characteristics allow it to be considered an important option for supplying energy to the rural areas of Latin America, to aid in their development.

The water used by regional agriculture for irrigation and for livestock or the electricity used in domestic and productive activities among the large rural populations of Latin America can be perfectly well obtained through wind energy conversion systems (WECS), also known as "wind machines."

These two applications of wind energy (pumping water and wind generation) are those with the longest history so far. For this reason, the Latin American Energy Organization (OLADE) has dedicated its efforts to the elaboration of a methodology for the development of wind energy in the region, especially contemplating the massive implementation of WECS in the rural areas.

However, it is first necessary to gain knowledge about the resource in each of the sites chosen to install à wind machine. The evaluation of wind energy potential has been undertaken by OLADE as part of its program in this field, with the aim of elaborating a Regional Wind Atlas which will allow the major areas of interest to be selected for supplying energy on the basis of this resource.

The human factor has not been neglected by OLADE's program. By means of courses and seminars, it has been sought to provide complementary technical training to the regional specialists in charge of the wind energy programs in their respective countries. This component of the Regional Wind Energy Program has generated three publications of real importance for any wind energy project:

— Prospects, Evaluation, and Characterization of Wind Energy
— Wind Generation
— Windmills for Pumping Water.

OLADE has also begun the preparation of an inventory of the technology available in Latin America for wind energy projects; because the Organization is of the opinion that the regional energy solutions can be found within the region itself.

The aim of the present article is to make its readers aware of some of the aspects of the use of wind as a source of energy, while providing an overview of the Regional Wind Energy Program of OLADE and inviting the countries of the region, once again, to participate in this program of Latin American integration.

2. PROSPECTING OF AREAS OF INTEREST

The exploration of the wind can be done at three levels: the regionalization of the wind; the prospecting of areas with good wind energy potential; and the locating of sites for optimal utilization.

For the regionalization of the wind, a country's meterological network and its historical information are unquestionably of vital importance.

In addition, it is necessary to develop a methodology for map analysis, permitting the localization of areas with winds, in order to determine a suitable correlation between the topographical and climatological factors associated with an area of relatively constant prevailing wind or winds of a well-defined periodicity.

At the level of site locating, sight inspections of the local topography, ecological evidence, and the placement of anemometers in different sites for simultaneous measurements will permit determining the most suitable sites.

These will vary according to the application which it is intended to give the wind energy -as a function of its magnitude and the requirements to be satisfied. It is not the same to locate a wind pump for an artesian well, where the well determines the point of application, as it is to place a 1-MW wind generator which will be connected to an electrical distribution network.

This is where questions arise as to the feasibility of development wind energy resources, e.g.:

a) In which places is there enough wind with sufficient intensity so as to be economically useful?
b) How much wind can be expected at a given site over the course of a year?
c) How is the distributed with time, during one day, one month, or one year, and even for longer periods?
d) What is the probable duration of the high-velocity winds or calm periods, and what is their frequency during a given time period?

To locate a good site for taking advantage of wind energy is equivalent to locating a vein of some mineral. A geological structure determines the possibilities that given minerals exist, while detailed prospecting locates the veins. In this comparison, the role of the geologist and of the meterologist are similar, as is the role of the specialists in wind energy and in mineral prospecting. Places with high wind energy potential, just as those with mineral deposits, correspond to quite specific site characteristics.

Then, what are the wind features and the topographical influences which make utilization of this resource interesting for energy purposes?

In terms of direction, the fact that the dominant winds usually prevail indicates the uniformity of the pressure gradients that give rise to them; constant changes of direction are indicative of local turbulence which is a drawback for energy development. As for wind velocity, it is necessary to know the statistical distribution of the same, for periods of one day, one month, or one year. The average annual velocity data are indicative of what can be expected of the winds at a specific site.

Some of the topographical characteristics which indicate a place with good wind energy potential have already been mentioned. The locating of these sites can be done on the basis of topographical and climatological maps, since strong imbalances and isobars close together are indicative of strong pressure gradients responsible for winds of a regional nature. In the specific site, the ecological evidence is important, since it is manifested as deformations in the trees that have been subject to continuos stress occasioned by the dominant winds; and the degree of their deformations is indicative of the average velocity.

Also, a good point for the development of wind energy has notable irregularities in its terrain or some other kind of obstacles: building, trees, or rocks. If the least possible turbulence is required, the site should be a minimum of 100 meters away from such interference.

In addition to the average velocities, it is necessary to know the instantaneous velocities of gusts, even though they do not contribute at all to the energy obtained, given the inertia of the conversion equipment. However, it is important to be aware of them, in light of the instantaneaous stress to which they subject such equipment. Since the wind machine can be placed at height 10 meters aboveground, the measurements can either be taken at the desired height, or a vertical pattern can be established for the velocity distribution at that point.

In view of the foregoing, it can be inferred that it is necessary to have a methodology for the prospecting of this important resource. For wind generation with WECS of medium-to-large capacities (100 KW) in installations of one unit or sets of units, the methodology for prospecting and evaluating sites covers the following six stages:

Stage 1: Gathering and Analysis of Data

A) Existing meteorological data*
1. Temperatures
2. Precipitation
3. Surface winds
4. Free atmosphere winds
5. Hourly wind recordings
   — Intensity
   — Duration

* By months, seasons and years

B) Topographical maps for the area under study

Stage 2: Field Investigations

This stage is oriented to compiling information on the following aspects of the region under consideration:

a) Potential use of the land
b) Land-holding modalities
c) Means of communication
d) Natural resources
e) Population distribution
f) Other aspects of interest.

Stage 3: Prospecting of Wind Energy Resources in a Given Area

An interesting region from the perspective of its wind energy potential can be physically limited to restricted areas, on the basis of the results from the preceding. Thus, the areas which are potentially exploitable can be studied in order to determine the spatial distribution of the wind; this can be done with a series of anemometers of relatively low cost.

Stage 4: Verification of the Area

After the areas of interest have been located, the winds therein must be characterized. This is done by using equipment of better quality and higher costs. While the first three stages were oriented to determining the intensity, duration, and variation of the wind from season to season in order to detect the sites of major interest from the energy perspective, in this stage, information is compiled on areas related to WECS once wind in the area has been characterized.

Stage 5: Specific Studies on the Sites for Large WECS Establishment

This meteorological analysis done in the specific site where it is intended to establish large WECS, requires measuring towers with velocity, temperature and pressure sensors at different levels, in order to characterize the behavoir of the lower atmospheric layer in terms of the vertical pattern conditions (velocities, turbulence, etc.) and the series of wind behavior parameters which affet the operation, cost, life, etc., of a large WECS.

Stage 6: Investigation on the Behavoir and Efficiency of WECS

This last stage is aimed at simulating the behavior of the WECS and the amount of electricity produced monthly, seasonally, and yearly. On this basis, it is possible to determine the total cost, per unit of energy produced with a WECS; and also, considering its integration with an electric system, it is possible to evaluate the savings which it would represent in terms of the fuel consumed by a thermoelectric plant or the water used in a hydro power station. This analysis will be what finally determines the techno-economic feasibility of developing the wind energy at this site.

Having mentioned the major features of the methodology for locatting sites of interest for the generation of electricity to be fed into an electric system, it is useful to insist on the fact that, depending on the magnitude of the application, it will be the quality of the process of site selection.

Broadly speaking, the localization techniques used to detect areas of interest, in terms of wind energy potential, can be divided into two groups: direct and indirect, as explained below.

Indirect prospecting:

Historical information on climatological parameters, provided by the National Meteorological Services.

— Climatological maps
— Toponyms and oral references

Direct prospect:
— Surveys
— Ecological evidence
— **In situ** measurements

2.1 Indirect prospect

2.1.1 National Meteorological Services

This historical information on the climatological parameters, which the meteorological services of each country have compiled over the course of many years, should undoubtedly serve as the starting point for the evaluation of this resource in each of the countries of the region. Nevertheless, experience has demonstrated that care must be taken in handling this information, first assuring its consistency and reliability before proceeding to its analysis.

The analysis of climatological maps is a preliminary step in direct prospecting, by which it is possible to define areas with good possibilities for developing wind energy.

This analysis is based on the areas of transition from one climate to another. The differences in topography, orography, precipitation, humidity, etc., determine a thermodynamic response different from that of the daily sunshine cycle and would give rise to local winds of an advective nature —similar to sea/land breezes— as a function of the difference in temperature in the lower layers of the atmosphere during the day. (Figure 1 illustrates this).

2.1.2 Climatological Maps

2.1.3 Toponyms and Oral References

An investigation of toponyms (names of sites) can serve as a helpful reference in detecting areas with strong winds; for when these constitute a significant phenomenon, it is usually somehow reflected in the name of the site. In Mexico, for example, the most important area of wind energy potential is located near a settlement known as "La Ventosa." (Windy Point").

Oral references are no more and no less than the fact that people comment that "That's a really windy place." However, for the staff of the governmental institutions or ministries doing work

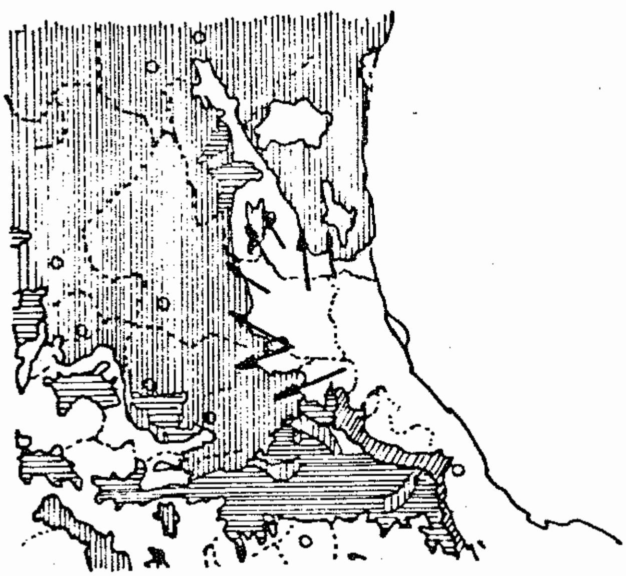


Figure 1 - Scheme of the Limits between one climate and another, indicating the probable direction of the advective wind.

in rural areas, this can be a valuable source of information.

2.2 Direct Prospect

2.2.1 Survey

A survey consists of the systematic search for oral references about places where the wind could be interesting from the energy point of view, within the region under study.

2.2.2 Ecological evidence

2.2.2.1 Introduction

Ecological evidence is basically the set of effects caused by the wind of the terrain and vegetation of a given site.

Within the investigation and selection of sites considered as having good possibilities for the development of wind energy, the observation of ecological evidence proves useful in obtaining information on the behavior of the wind.

The main objective of ecological inspections is that of obtaining a range of prevaling wind velocities and directions; and it provides savings in terms of research costs since no sort of instrument is used. This type of analysis involves a series of observations with respect to the terrain and vegetation affected by winds in a given range of velocities, bearing in mind that these effects can vary from place to place and that this inspection is only a preliminary step to more in-depth studies.

2.2.2.2 Clasification of Ecological Evidence

The ecological evidence can be classified as follows:

— Effects on terrain
— Effects on vegetation

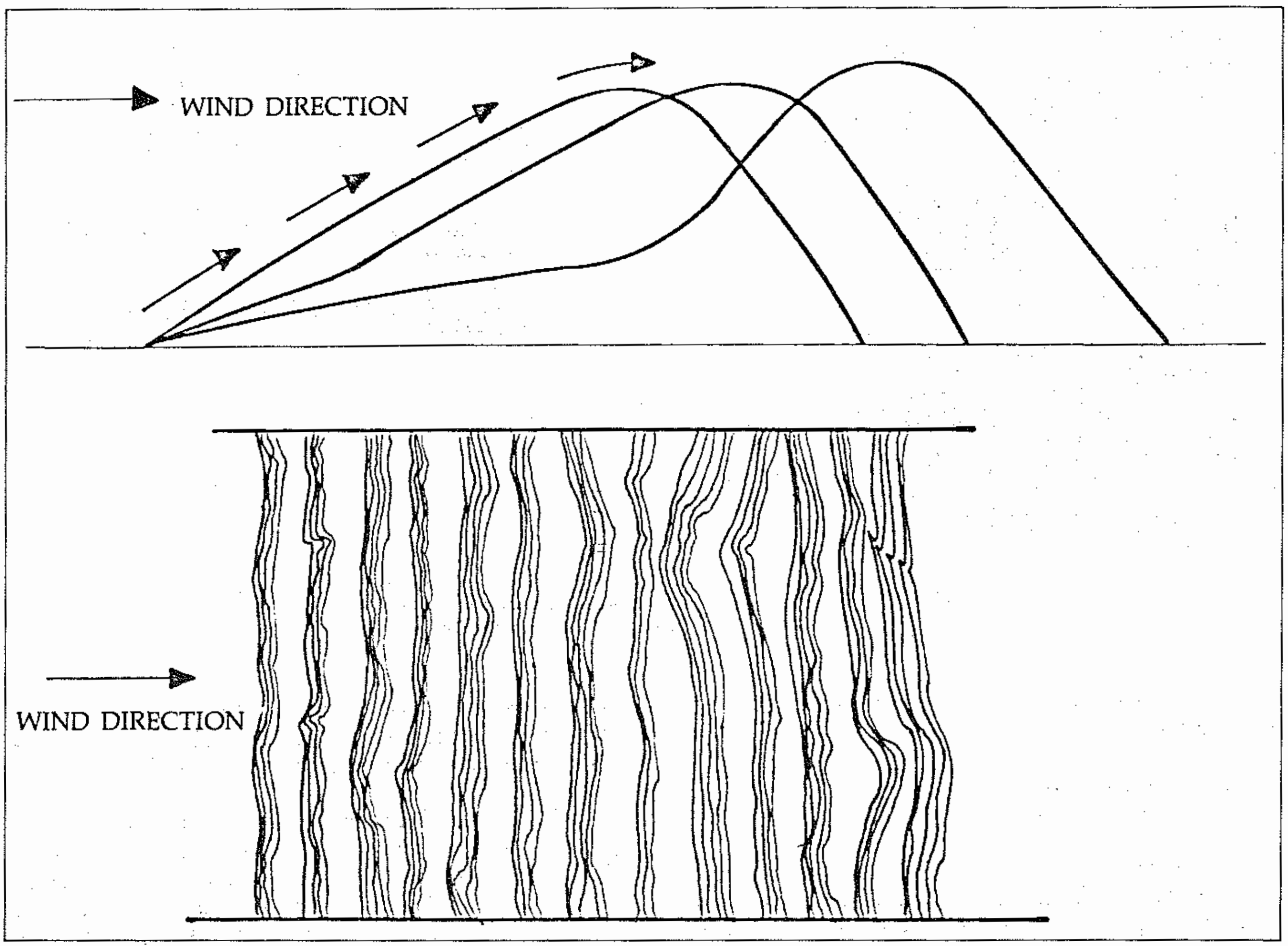


Figure 2 - Formation of Sand Dunes

Within the effects occasioned in the terrain due to its exposure to the wind, we can mention erosion and the formation of sand dunes in desert-like settings.

Erosion consists of the wear caused by the abrasion of the wind on the terrain, although the latter is not necessarily the only physical agent which causes erosion.

The formation of dunes is the accumulation of sand in small mounds, due to the effect of the wind in desert zones; these are distributed as large rows perpendicular to the direction of the wind. See Figure 2.

The effects caused on vegetation due to its exposure to the wind are as follows:

— Brushing
— Deformation
— Flattening

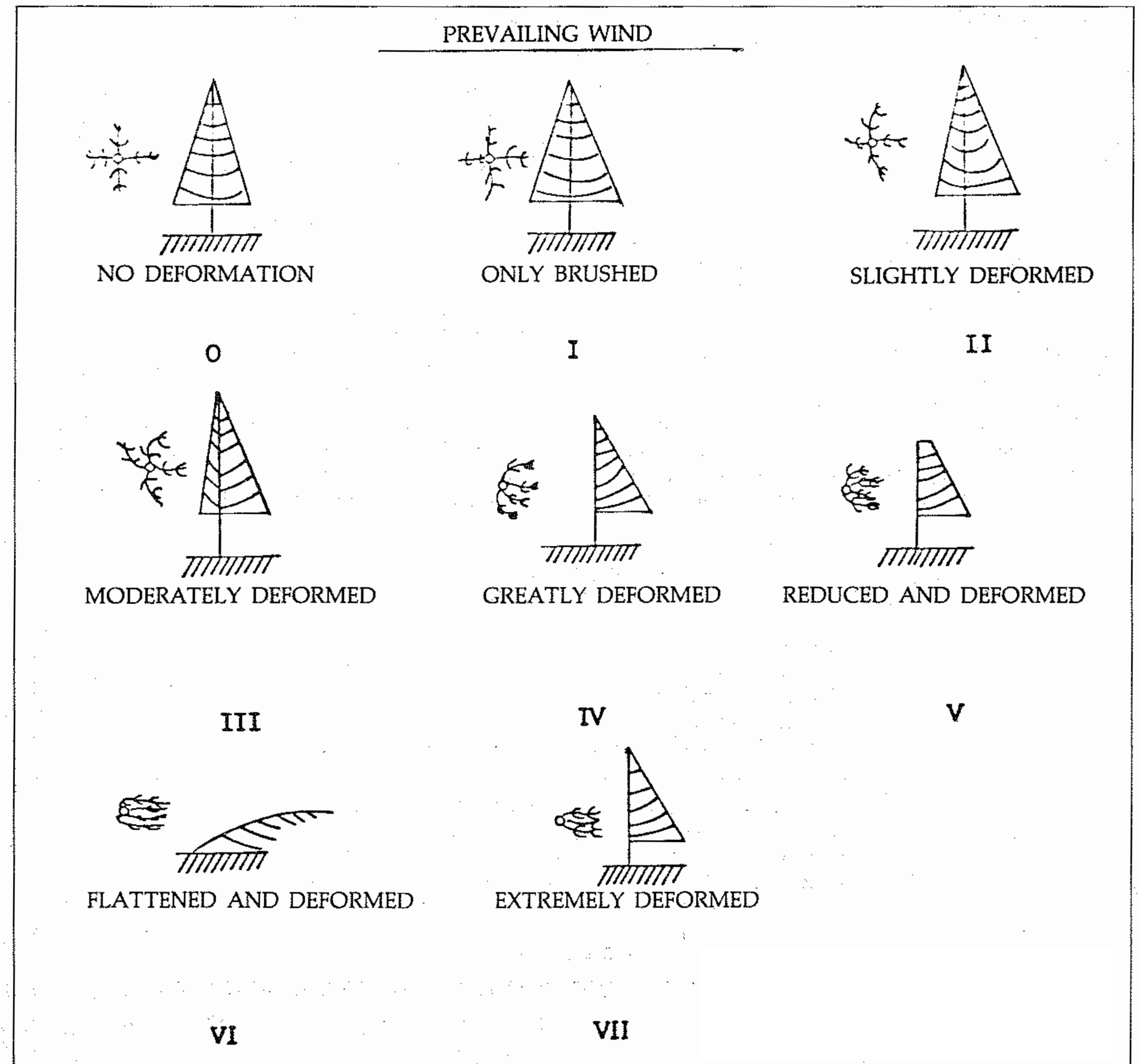


Figure 3 - Scheme according to the Wind Scale Based on Defoermation of Trees

The first effect consists of the simple brushing of the wind against the vegetation -winds with an average annual velocity of 2.7 and 4.5 m/s (6 and 10 mph). The second consists of deformation caused by prevailing winds between 3.6 and 8.5 m/s (8 and 10 mph). Finally, "flattening" is basically an extreme deformation close to the surface, at a speed of 9.83 m/s (22 mph).

One case which could be pointed out as an example is the low growth rate of vegetation on hills in Great Britain where the average annual wind velocity is 10.3 m/s (23 mph).

An interesting methodology for inspecting the ecological evidence consists of measuring the ecentricity of the rings of a tree trunk cross-section as wells the circular to elliptical deformations. This methodology can be applied without cutting down the trunk, by measuring the external dimensions of two octhogonal axes and taking a drill sample to locate the heart and calculate the eccentricity.

Finally, it is necessary to clarify that these techniques are of a generally qualitative nature, but not quantitative; since adaption to each specific habitat can give rise to different mechanical properties in the wood of one same variety of tree.

2.2.2.3 Velocity evaluation methods based on vegetation effects.

There are methods for carrying out velocity evaluations in a given place, on the basis of vegetation effects such as:

— Observations of tree deformations
— Calculations of the deformation ratio

The first method is simply the observation of the shape of the tree and its comparison with the schemes appearing in Figure 3, yielding the range of average annual velocities specified in Table 1.

TABLE 1

AVERAGE ANNUAL WIND VELOCITY ACCORDING TO TREE DEFORMATION

Deformation scheme	I	II	III	IV	V
Range of probably average annual deformation, mph	6-10	8-12	11-15	12-19	13-22

The second way is to calculate the deformation ratio on the basis of a photograph of a tree taken perpendicularly to the direction of the prevailing wind, according to Figure 4; from this value, the velocity range in Table 2 can be obtained.

TABLE 2

AVERAGE ANNUAL WIND VELOCITY ACCORDING TO THE DEFORMATION RATIO

Deformation Ratio	I	II	III	IV	V	VI	VII
Range of probable average annual velocity mph	4-8	7-10	10-12	12-15	14-18	15-21	16-24

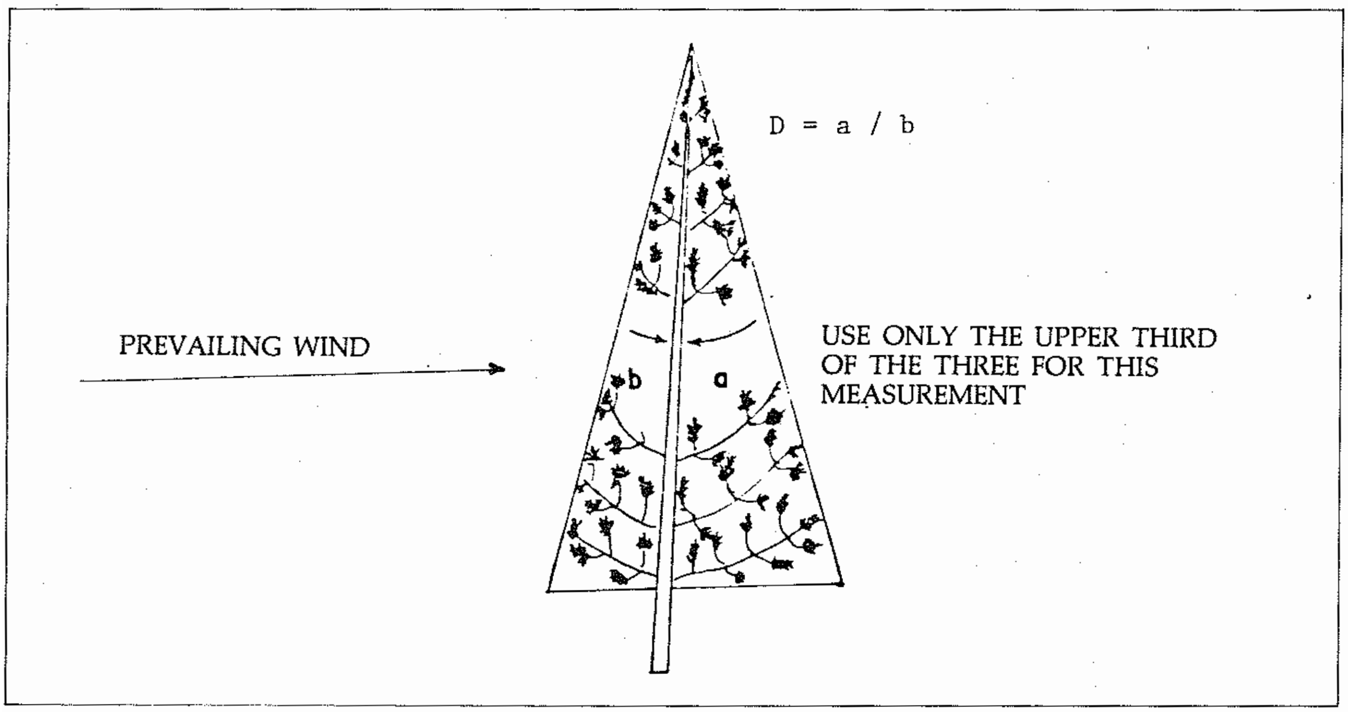


Figure 4 - Deformation Ratio

Caution should be taken when using this type of indicators, because the absence of deformation in a tree does not necessarily indicate that weak winds prevail since trees are not always susceptible to deformation or exposed to strong winds from all directions. The trees employed should be evergreen; the caducous varietes do not lend themselves to this type of analysis since they introduce greater uncertainty in wind evaluations.

2.2.3 **In Situ** Measurements

2.3.3.1 Site selection

Before beginning to measure the wind velocity, it is necessary to select the best site possible to install the anemometer. For this purpose, it will be useful to reiterate some basic concepts.

All of the winds are basically the result of atmospheric temperature differences and the influence of the planet's surface characteristics. The winds which are significant for energy purposes can be divided into two categories: the planetary winds and the local ones.

The planetary wind systems, usually known as prevailing winds, are those large movements which dominate entire areas and show constant directional characteristics, varying only with the movement of low-and high-pressure systems and with seasonal changes. In many places this kind of wind prevails and the good sites for wind energy development are those which maximize the merits of such prevailing winds, as in the case of exposed hills and coasts, an open plain or plateau, an open valley running parallelly to the prevailing winds or the individual side of a hill with gentle slopes.

On the other hand, local winds are caused by the temperature differences created by local topographical conditions.

The land/sea breezes, for instance, which blow from the sea to the land during the day and from the land to the sea at night, are simply due to the fact that the land temperatures are more susceptible to change than are those over the ocean. Valley and mountain breezes are caused by the same local effects and on a warm, sunny day, the winds can sharply displace themselves from the botton of the valley along the slopes of the adjacent hills.

It is clearly more difficult to select the best site in areas where the local winds predominate or where they are at least strong enough to modify the effect of the prevailing winds. Before making the final site selection, it may well be advisable to do frequent testing at several seemingly appropriate points.

Independently from the prevailing wind factor, care should be taken to see that the site selected has a minimum number of obstructions, thus allowing for the free flow of the wind. Large obstacles such as hills are propitious for creating a "wind screen" which reduces the total wind availibility. Small obstructions such as houses, trees, small hills or those with abrupt elevation behind the area of interest, can cause interference or turbulence, thereby wasting the flow of utilizable wind.

The anemometer should be installed in a site free of interferences in order to obtain representative area measurements, i.e., all obstacles (houses, trees, etc.) should be at a certain distance from the base of the instrument, at more than ten times the height of the obstacle.

2.2.3.2 Measuring height

After the measuring site has been decided, it will be necessary to establish the minimum measuring height. Conventionaly, this altitude will be 10 meters; however, if the areas of interest are for the wind generation, and if there are trees and other small obstacles, requiring a greater height for the wind generator, then the measurements may be taken at more than 10 meters. The turbulence produced by small obstacles not only reduces the availibility of wind energy but is also damaging for wind energy conversion systems, because it gives rise to differences in pressure and stress not uniformly distributed among the blades of the rotor.

A simple method for detecting turbulence in the area of interest is first to place one or two 1.5-meter listers in the point of the mast of the anemometer. With a good breeze, if the listers float straight and steady, the wind flow is uniform; but if they move a great deal, there is turbulence and the measurements will have to be taken in another place or at a greater height.

2.2.3.3 Measurements

The first energy evaluations can rely on continuous logging of the velocity in order to obtain velocity distribution graphs, the use of electronic recorders to obtain a histogram the velocities and energy during the period, or the use of summing anemometers (anemometer-odometer) to obtain the average velocity for the period.

Once the anemometer is functioning, it is useful to compare this information with that from the nearest meteorological observatory and to establish some form of comparison in order to verify any existing correlation. If it is possible to derive a correlation factor from month to month it will be feasible to establish annual behavior rapidly. Otherwise, it will be necessary to prolong the observations long enough to permit the evaluation of seasonal variations.

3. WIND GENERATION

These are different kinds of wind energy conversion systems, but all of these must operate under the theoretical and practical restrictions on

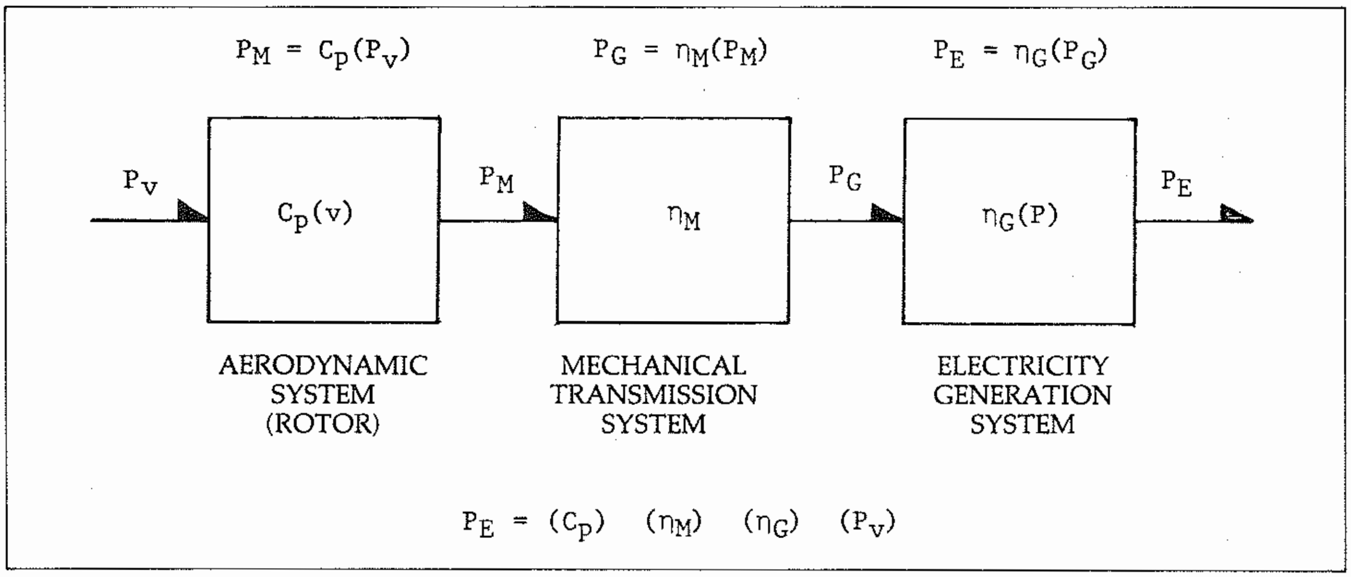


Figure 5 - Block Diagram of a WECS

the amount of wind energy that it is possible to capture.

Figure 5 illustrates the general scheme of a wind generator (WECS) used to produce electricity.

3.1 Schemes for Generating Electricity on the basis of a WECS

It is actually the rotor which obtains part of the energy that it receives and this is delivered to the transmission system (59.3% in optimum operating conditons $\doteq$ Betz coefficient).

Given the behavior of the rotors -in terms of their rpm versus the wind velocity during operation- they can be classified into two groups:

a) Those with variable rpm, as a direct function of the wind velocity (variable velocity VV).
b) Those with constant rpm, due to the effect of the action of a governor (constant velocity CV).

Due to the different types of electric machines, electricity be this direct current (DC) or alternating current (AC), can be generated at constant or variable angular speed, which can be termed constant and variable frequency (CF and VF), respectively.

There are four possible combinations, although only three are logical, as illustrated in the following chart:

Generators

Rotors		VF	CF
	VV	VVVF	VVCF
	CV		CVCF

The **logical combinations are:**
a) Variable Velocity, Variable Frequency (VVVF)
b) Variable Velocity, Constant Frequency (VVCF)
c) Constant Velocity, Constant Frequency (CVCF)

These three basic configurations permit a great variety of technological solutions, considering among other things:

— Desired cost per kWh
— Cost per kW installed
— Range (or goal) for nominal kW with the WECS
— AC or DC generation
— Utilization of the WECS by itself or coupled to another autonomous source of electricity or electrical distribution network.
— Use or not of some kind of energy/storage system.
— Type of applications for energy produced.

These three schemes for electricity generation can take the following forms:

I) Variable Velocity, Variable Frequency
   a. AC generator - rectification
   b. AC generator - resistive heating charge

II) Variable Velocity, Constant Frequency
   a. AC generator with commutator
   b. Generator with regulated field
   c. Double-outlet induction generator
   d. AC generator - rectifier - battery bank - convertor - charge
   e. AC generator - rectifier - synchronous converter - electric grid

III) Constant Velocity, Constant Frequency
   a. Synchronous generator
   b. Induction generator

3.1.1 Systems with Variable Velocity and Variable Frequency

This kind of system is used to charge batteries and it is the most commonly used small-capacity WECS (less than 10 kW). In this system, an AC generator with DC excitation is attached to an aerodynamic rotor with a variable velocity; and the generator outlet with variable frequency is rectified to obtain DC. The energy is later store in Batteries.

Another of the applications of this system is electricity generation for heating purposes, where the current generated circulates by means of heat-producing resistance. In this application, the amount of utilized energy is the important factor, rather than the quality of the electric current, in terms of the stability of the voltage and frequency.

In refering to the characteristics of the coupling, another of the possible applications for this scheme should be analyzed in detail: the direct utilization of electricity in an universal engine for the purpose of pumping water, where the energy conditioning is kept to a minimum so that the cost of this application will be economically competitive.

3.1.2 Systems with Variable Velocity and Constant Frequency

These are the generating systems where there is no control for the angle of attack of the rotor blades, which are left to rotate freely with the wind. The rotor's angular speed, however, is determined by the load-velocity characteristics of both the rotor and the generator.

The rotor's efficiency in converting wind energy into mechanical energy (the C_p - power coefficient) is optimum at only one value for the angular speed of the rotor/wind velocity ratio. This ratio is usually expressed as the tip speed/wind velocity (λ o). Thus, it is possible in a system of this kind to permit the rotor to revolve at a speed proportional to he wind velocity, with the electric charge for the generator programmed according to the former. This would lead to an optimal solution to the problem of total conversion efficiency in the transformation of wind energy into mechanical energy.

A system variable velocity and an optimal maximum power coefficient is more complicated than a constant velocity scheme.

The electricity in the variable frequency should be converted at constant frequency for its utilization in conventional electrical devices and equipment.

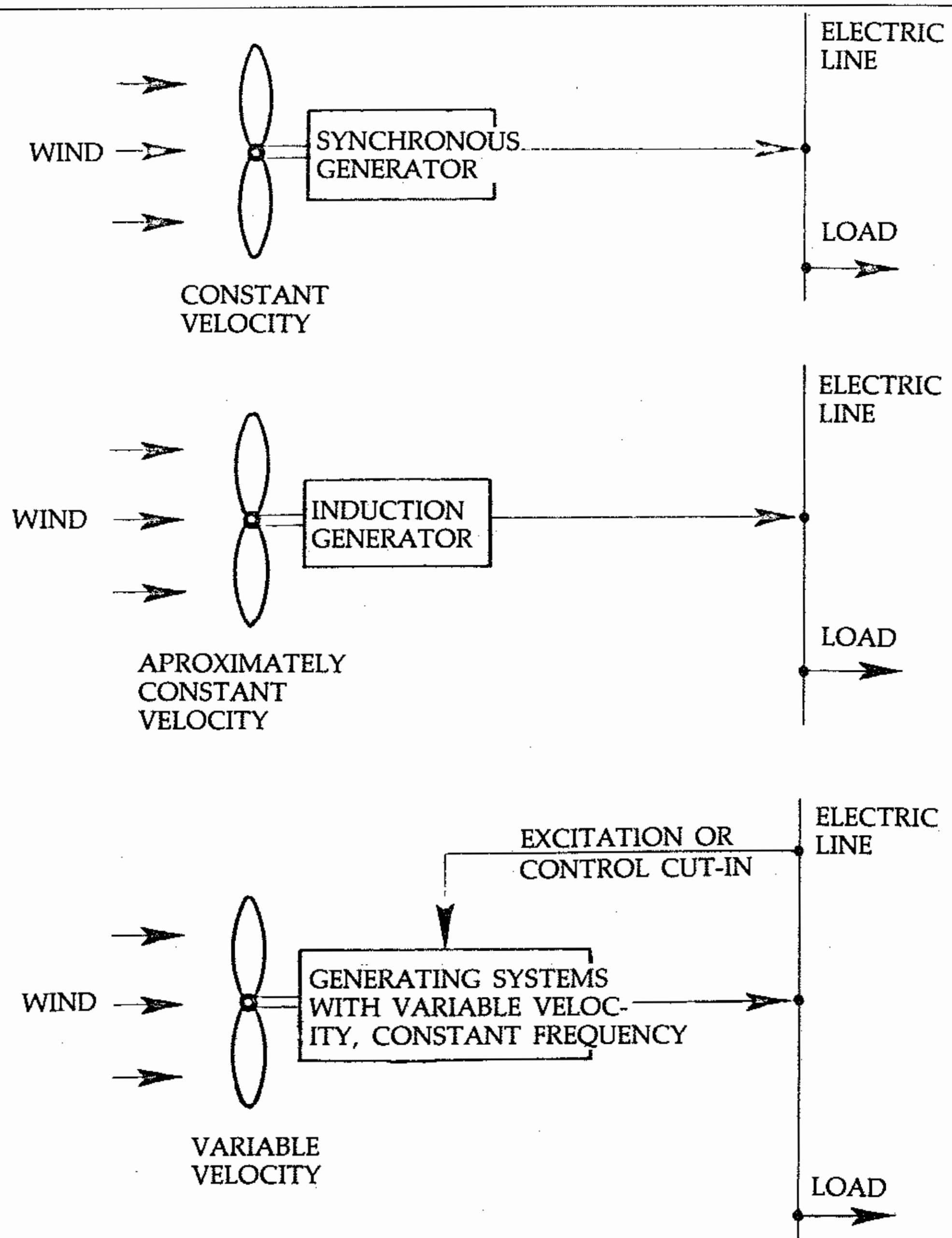


Figure 6 - Schemes for Generating AC at Constant Frequency, On the Basis of Wind Energy

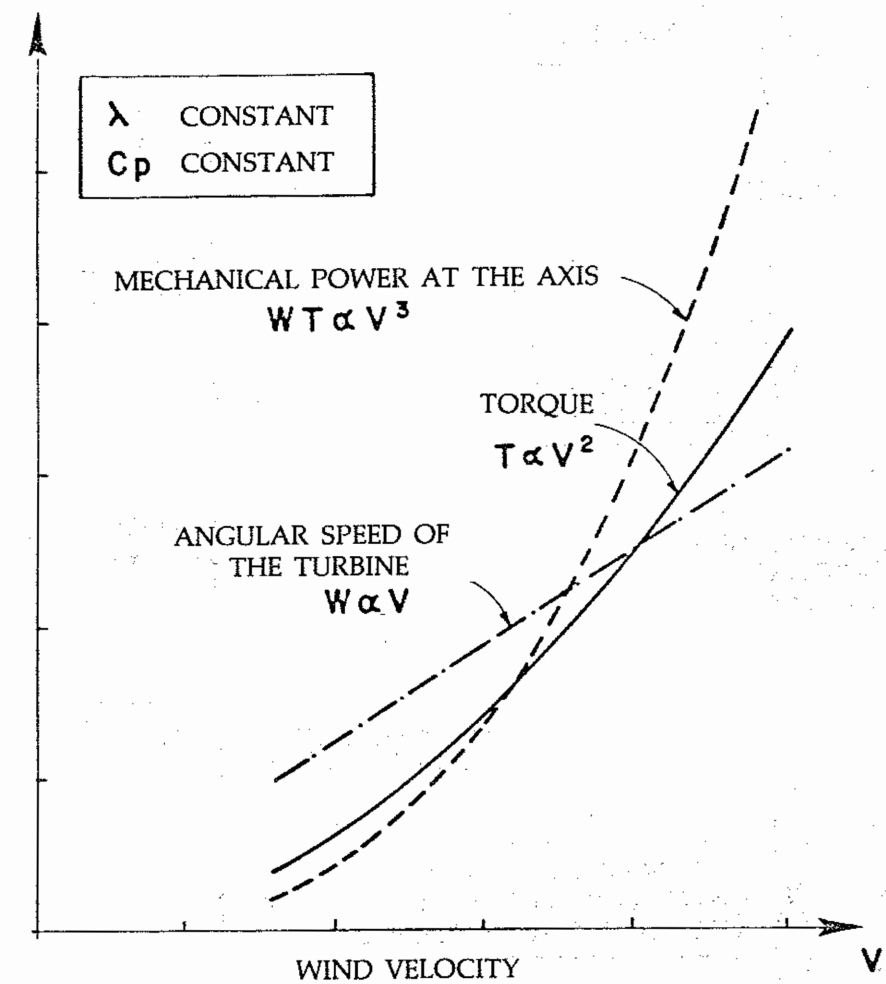
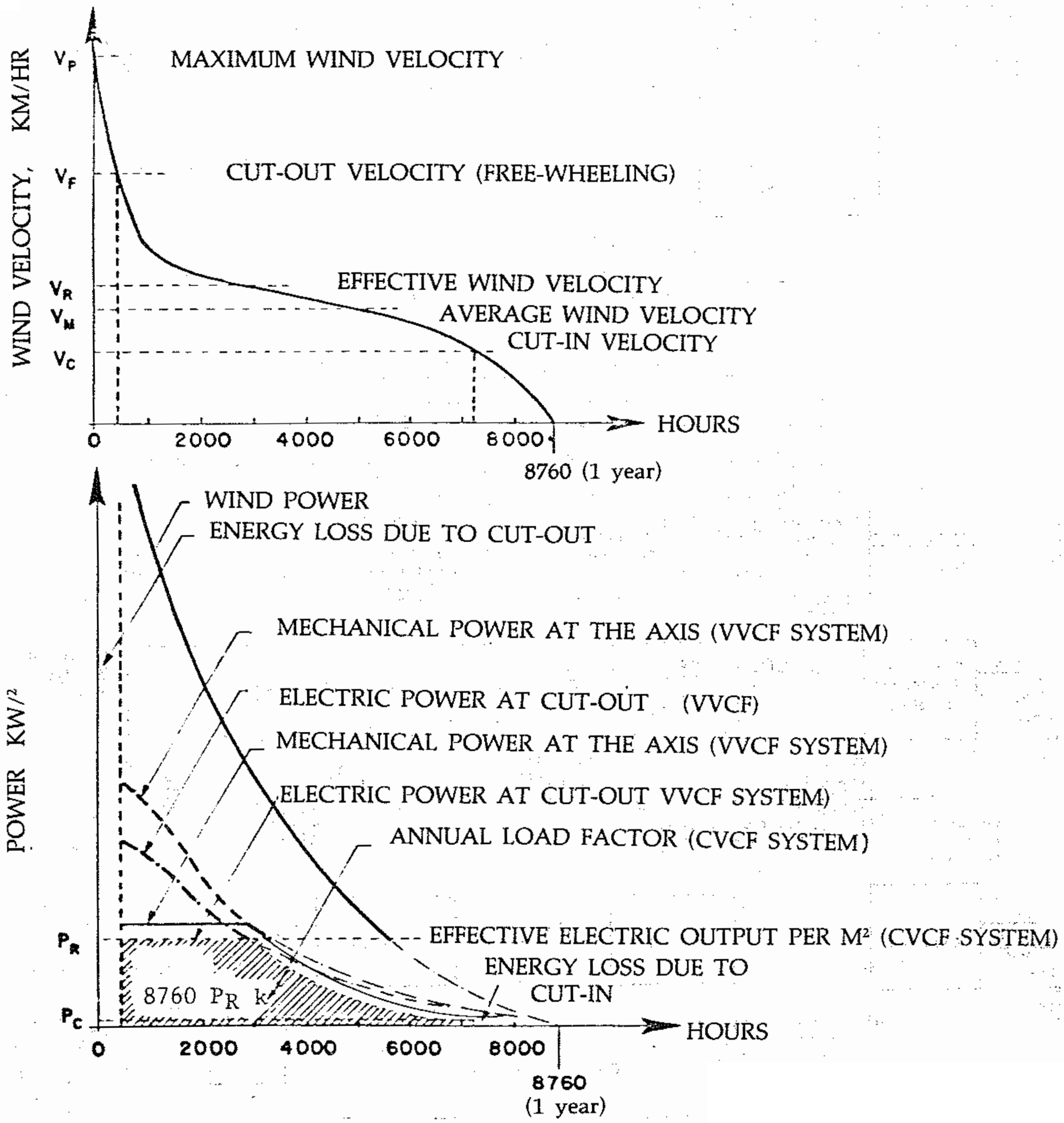


Figure 7 - Ideal Operating Conditions for VVCF Systems



Energy ouptput (KWh/ /m²) = 8760 P_R k

Figure 8 - Comparison of VVCF and CVCF Schemes

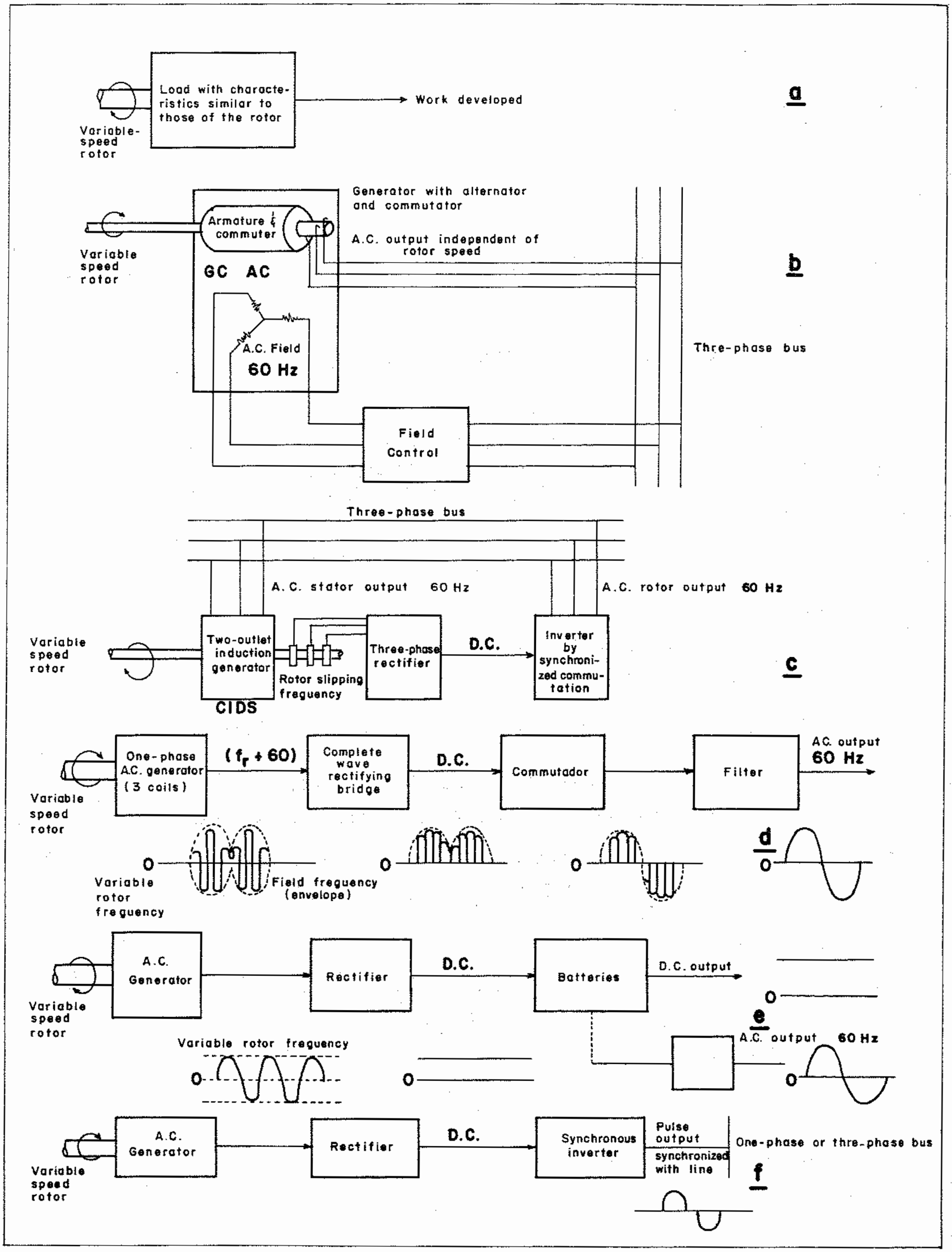


Figure 9 - Schemes for VVCF and CVCF Electricity Generation Systems and Their Operating Characteristics.

3.1.3 Systems with Constant Velocity and Constant Frequency

For an electricity generation system based on wind energy and connected to an electric grid, the problem of variable availabilities of wind energy can be suitable resolved with CVCF systems, due to the fact that the voltage and frequency are kept constant.

A synchronous generator attached to a wind machine rotor and connected to an electrical network can only rotate at one speed: the synchronous velocity.

An induction generator in the electrical system revolves at a speed above the synchronous one but not very different. Normally, the tripping slipping speed is from 1 to 5% of the synchronous velocity, which is a slight difference when compared to the variations in wind velocity. Therefore, these two systems which have to maintain a constant velocity, due to restrictions of an electrical nature imposed by the grid -no matter what the wind velocity- can be classified as CVCF and thus they require mechanical governor systems in the rotor.

Figures 6, 7, 8, and 9 indicate the constant frequency schemes and operating characteristics for constant and variable velocities.

4. THE USE OF WINDMILLS FOR PUMPING WATER

The most transcendental application of wind energy is, no doubt, the use of windmills to pump water.

The pumping systems based on wind energy can be classified according to the following criteria:

— Their pumping capacity, expressed as ranges of available power and water levels.
— Wind energy conversion processes.
— Processes for converting wind energy into another form, in accordance with the type of pump used.
— Degree of technological sophistication in the design, manufacturing processes and operational requirements.

For practical purposes the classification according to capacity is the most meaningful since it determines the type of applications. This classification is composed of two large groups:

I. Equipment with power capacities on the order of 0.5 to 3 HP, the majority of which are indigenous designs, hand-made, using low-speed rotary or reciprocal pumps oriented to the satisfaction of limited needs and certain points for water pumping. This equipment should be utilized for irrigation purposes when the conditions of the site allow for a massive installation.

Within this group of aeropumps is included the North American type with multiple blades, which constitutes the only model of proven reliability whose industrial manufacture has already been implemented.

II. Equipment in the conceptual or experimental stages, in the range of 10 to 100 kW, based on highly efficient aeromotors with an energy pump (electric, mechanical, or pneumatic).

The following conversion processes are possible, according to the type of pump used:

a. Reciprocal
   — Simple piston, metallic, industrially manufactured
   — Wooden piston, hand-made
   — Double-action piston, industrial
   — Inertia, hand-made or industrial.

b. Low-speed, rotary

   — Chain, square blades, hand-made
   — Low-speed centrifugal, hand-made
   — Centrifugal, aspersion, hand-made
   — Arquimedes screw.

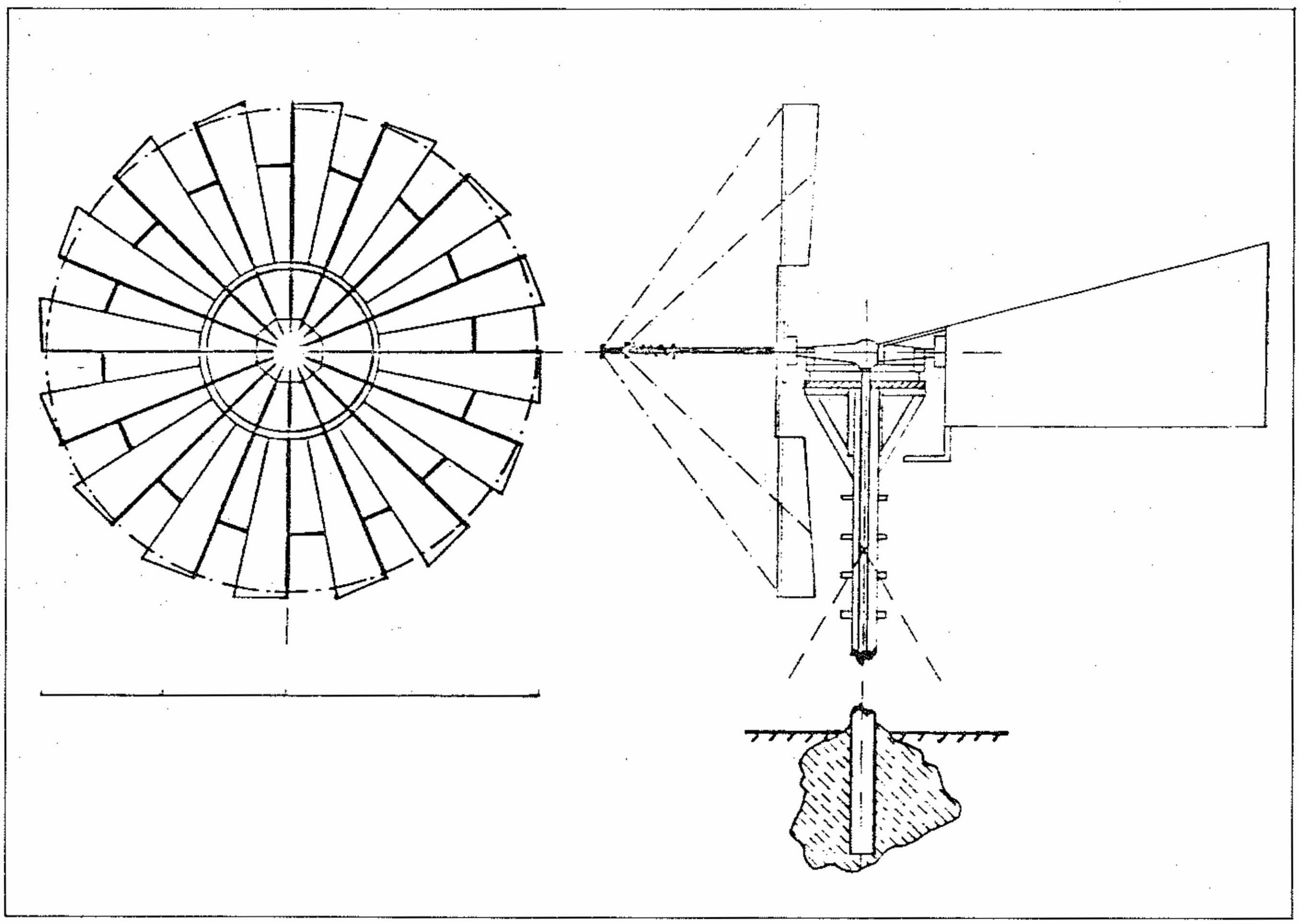


Figure 10 - North American Type of Wind pump

— Rotary cylinder, hand-made
— Helicoidal rotor, industrial
— Rolled tube, hand-made.

— Peristaltic pump, hand-made

c. High-speed rotary
   — Vertical pump with cups
   — Submerged electric
   — Rotary, with positive displacement

d. Pneumatic pump
   — Compressed air
   — Hydraulic piston.

From the perspective of the technological sophistication of the design and manufacturing processes for the small units in use, only the North American wind pump represents the development of engineering involving manufacturing processes such as molding, melting, casting, and galvanization by immersion (cold-forming) and thus requiring appropriate industrial facilities.

4.1 Technical and Economic Considerations for Wind pumps

The North American windmill illustrated in Figure 10 was the only model to survive the advent of the steam engine, the internal combustion engine, and the rural electrification.

This type of wind pump -whose rotor diameter varies between 6 and 16 nominal feet (1.8 m to 5.0 m)- is suitable for small applications such as supplying water for a family (household), their garden and livestock, and for waterholes in pastures.

This pump is being manufactured in the United States, Europe, Australia, Argentina, Brazil, Chile, and Mexico, among others, under licences or with modifications, given the expiration of its patents. Nevertheless, its utilization in the developing countries has not been as extensive as it might have been, due to a lack of adequate dissemination and the fact that many of its economic advantages are lost because it is manufactured abroad and must consequently be imported.

In general, for the inter-tropical countries that do not produce such equipment, the following problems have been presented for its broad diffusion:

A. The imported windpumps represent a large capital investment when compared to a diesel pump of similar capacity. Due to its longer life and low operating costs, the former's cost per unit of pumped volume is more inexpensive in the long run. However, lack of capital or financing can mean that the smaller original investment required by the diesel plant will prove more attractive.

B. The large volume and weight of these windpumps, designed in an era in which sturdiness meant reliability, considerably increase transportation costs and are almost always greater than those for a pump driven by an internal combustion engine.

The international transportation cost of one of these windpumps comes to represent up to 100% of the factory price.

C. The lack of technical information on this kind of equipment gives rise to problems for the user, ranging from an incorrect selection of the size of the rotor and pump, to a lack of spare parts. This lack of information creates a vicious circle whose result is a lower volume of sales, where the distributor seeks a higher margin of profit than that earned on products which "move" more quickly.

D. Due to the fact that the windpumps models existing on the market were mostly designed several decades ago, they prove to be too material-intensive and, therefore, too expansive for the present-day markets. Nevertheless, the manufacturers of this equipment have been reluctant to invest in the creation of new designs or the re-equipping of plants in order to produce more economical equipment, since the disadvantage mentioned under item B is only manifested bacause of the reduced export market.

E. Local manufacturing of these aeropumps under licenses has the limitation of large investments in the tools and equipment necessary to carry out the processes involved in their manufacture.

F. Most of the countries accruing large benefits with the use of windpumps are found in tropical latitudes with moderate winds. This means that the largest of these windpumps do not deliver sufficient water even for the very applications for which they were designed in their countries of origin, all of which have significantly greater wind regimens.

The general features of the North American type of windpump are as follows:

- High capital cost.
- Long lifetime, typically 30 years, although it is common to find units which have been working longer.
- Low maintenance.
- Pumping depths of up to 300 m.
- Manufacturing requiring mature industrial processes in steel technology.
- Very evolved design engineering.
- Availability on international export market.

Figure 11 indicates the cost per kW equivalent for water pumping, as a function of rotor diameter and the average annual wind velocity for a specific site.

5. THE REGIONAL WIND ENERGY PROGRAM OF OLADE

Recognizing the importance of wind energy as an alternative source to those currently in use, OLADE is proposing a methodology for the development of this resource in Latin America and the Caribbean, with the structure indicated in the following diagram:

Base Actions

I. Evaluation of the Regional Wind Energy Resource

On the basis of the meteorological information available in the different countries of the region, OLADE is elaborating a Wind Atlas for Latin America and the Caribbean, which will provide a good idea of the region's wind energy potential.

With this, an important analytical instrument will be made available to define the most promising areas for the implementation of programs using wind energy conversion systems.

The areas chosen by the program will be the object of a more exhaustive study of the wind resource and the development of pilot projects for the purposes of demostration and additional evaluation of the wind in diverse areas.

II. Inventory of the Technology Available in the Region

OLADE is attempting to discen and inventory the technology available in Latin America and the Caribbean in the area of wind energy, both in terms of the research undertaken by the various specialized regional organizations as well as in terms of the equipment production capacity available to satisfy the potential demand of the areas chosen for the Program.

The storehouse of experience already acquired by the region in the fields of research, development, and demostration for systems geared to exploiting the wind energy potential will serve as a starting point for establishing optimal projects to attend the specific needs of each area.

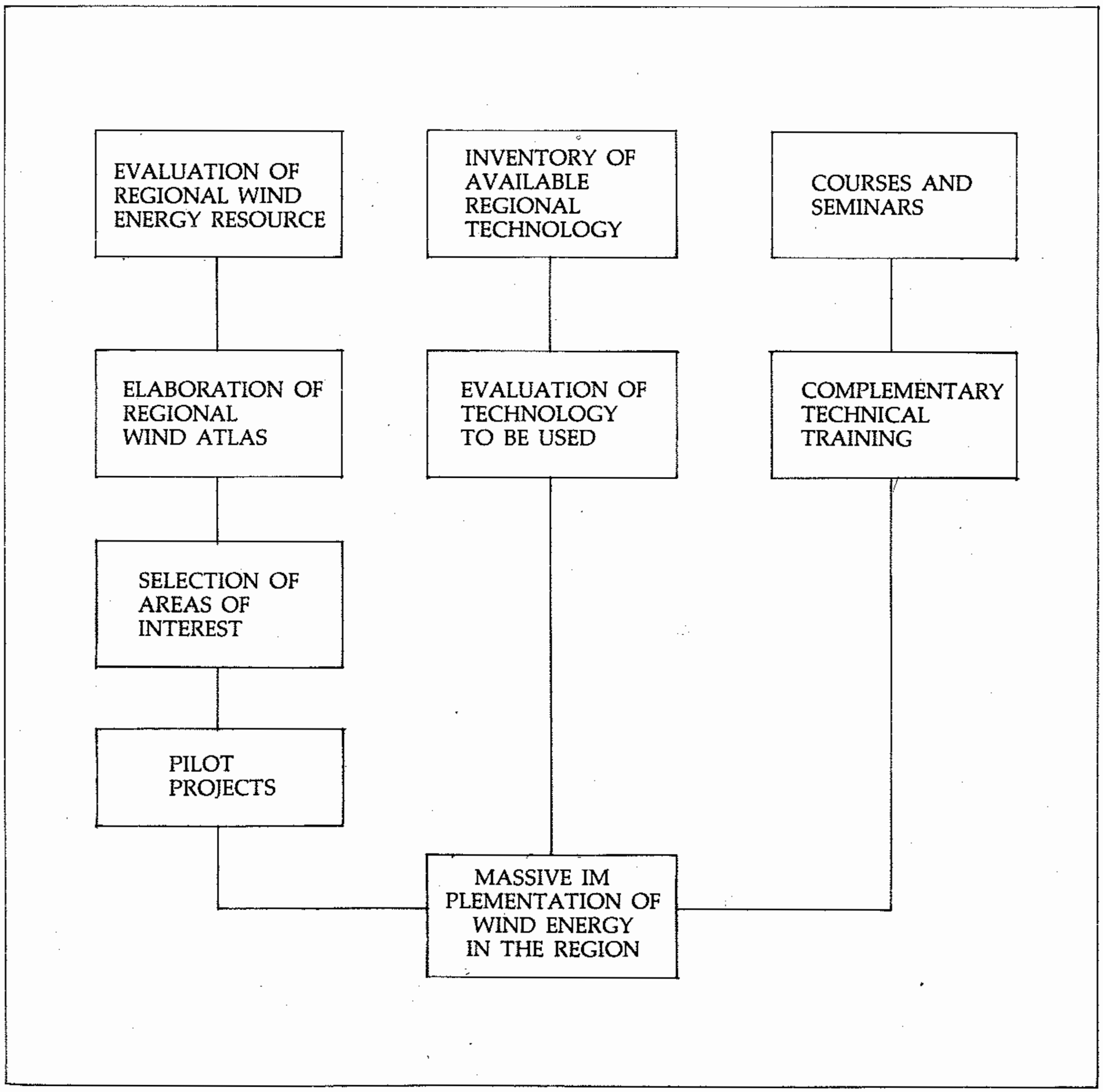
The inventory will reflect the advantages and disadvantages of each technology and, as a result, the most suitable solutions using the possible combinations of conventional and non-conventional technologies.

III. Courses-Seminars

This component of the Program is of fundamental importance and seeks to disseminate complementary technical training among the regional experts in charge of the projects utilizing wind energy.

To this end, OLADE has organized the following events:

- Latin American Seminar-Course on the Prospects, Evaluation, and Characterization of Wind Energy. Cuernavaca, Mexico, May 26-30, 1980.


EVALUATION OF REGIONAL WIND ENERGY RESOURCE
INVENTORY OF AVAILABLE REGIONAL TECHNOLOGY
COURSES AND SEMINARS
ELABORATION OF REGIONAL WIND ATLAS
EVALUATION OF TECHNOLOGY TO BE USED
COMPLEMENTARY TECHNICAL TRAINING
SELECTION OF AREAS OF INTEREST
PILOT PROJECTS
MASSIVE IM PLEMENTATION OF WIND ENERGY IN THE REGION

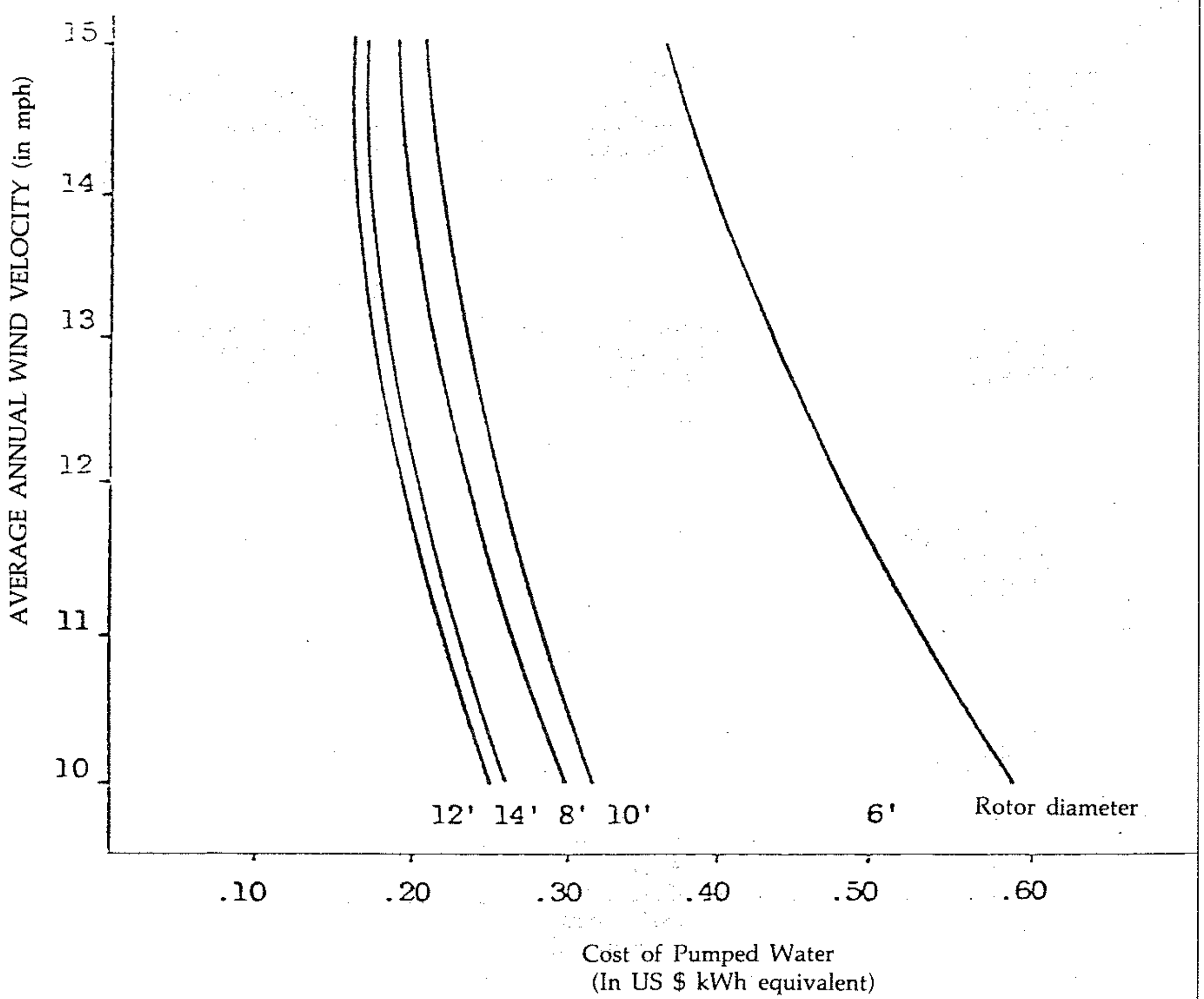


Figure 11 - Costs for Pumping Water Using the North American Type of Windpump (Data for the United States, 1978)

— Latin American Seminar-Course on Wind Generation. Rio de Janeiro, Brazil, september 1%5, 1980.

— Sub-regional Seminar-Course on Wind Energy for the English-speaking Member Countries of OLADE. Barbados, The Caribbean, January 26-29, 1981.

— Latin American Seminar-Course on Windmills for Pumping Water. Lima, Peru, August 3-7, 1981.

The aformementioned events generated three technical documents which can serve as a basic guide for any energy project.

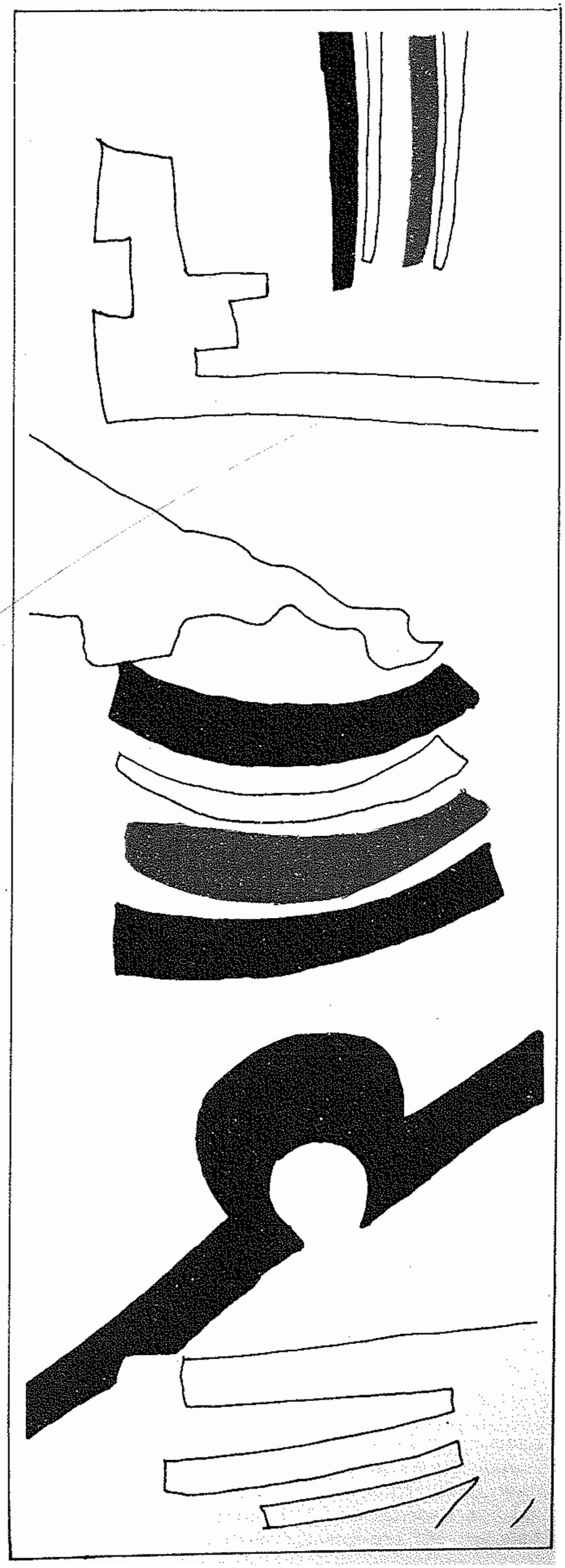
IV. Massive implementation of wind energy in Latin America

This constitutes the final objective of the Regional Wind Energy Program of OLADE.

As can be inferred, one of the premises of the Program forms part of the assumption that one way to keep the rural population in its setting is implicit in the decision to make that population a beneficiary of technical developments, thus making it possible for them to gain access to a higher astandard of living than their current one.

The conventional energy supply to disperse populations or those concentrated in small settlements has proven difficult thus far —when not imposible— due to the economic feasibility criteria for such service.

In this context, wind energy presents itself as a viable energy alternative for the region, ready to fight for a place in Latin America future energy picture.



BIOGAS AND DEVELOPMENT IN LATIN AMERICA
(A FIRST REGIONAL EXPERIENCE)

1. Biogas as a resource

It is widely recognized today that the non-conventional energy sources contribute to a great extent in the energy supply of Latin America and, new efforts are made day by day to increase the contribution and reduce the high dependency on the traditional sources such as petroleum and its derivatives.

One of the sources that has been taking a position of high priority, given the magnitude of its participation and its rate of use is Biogas. This is not only because of its great development potential but also because of its feasibility of self-promotion in the rural areas, especially the most isolated ones, where it could have a great impact. Of course, it will require time to gain an entrance, absorption and acceptance in the market.

The concept of biogas and biogas technology should be amplified in order to understand its real advantages; for it should not be seen as just an energy source (as important as that is) since it has a direct role in the prevention of deforestation and, therefore, protects the ecosystem. Also it serves as a partial solution to the health problems of environmental pollution by using and recycling organic wastes (animal, plant, agro-industrial and human).

From the process of decomposition and digestion to generate biogas a by-product is obtained which can be either liquid or solid, with a high nitrogen content, and which is considered a high-grade fertilizer, competitive with chemical ones.

These by-products, which behave similarly to peat moss, lead to improvements in the quality of the agricultural soil, and this is directly related to an increase in food production and indirectly to an improvement in the quality of life for the rural inhabitants. The latter could aid in the reduction of the now high rate of migration to the cities.

It should be noted that another of its interesting characteristics which could facilitate both its exploitation and diffusion, is that the fertilizer produced requires no transportation. In the majority of the rural communities, transport systems are practically non-existent for taking commercial fertilizers from the place of production to the place of application.

Biogas constitutes a resource around which small rural communities can develop through the production of energy and organic nutrients, bringing tangible benefits such as the reduction in health and environmental problems (the latter at medium and long-term).

Based on experience, and considering the costs involved in selection, construction, maintenance, interests, depreciation, etc., for a biogas plant with a capacity no larger than 20 m^3 (small-scale and for families of no more than 8 members) the installed cost per kilowatt hour is US$ 0.40 which is competitive with other energy sources.

Also, according to studies by UNDP-OLADE, the optimistic estimates for possible biogas production volumes, expressed in tons of oil equivalent (TOE) and considering ideal conditions forecasted for 1985, the contribution of biogas would be 45.50 TOE and for 1995 69.85 TOE, which corresponds to US$ 10.682 million and US$ 16.404 million respectively for the years cited, (using a price of US$ 32.00 per barrel or US$ 235.00 per metric ton). In addition, in this superficial analysis, the value of the organic fertilizer produced is not considered. The volume of this would be between 12 and 16 metric tons per year, per plant.

Is summary, it can be said biogas deserves to belong to the group of "alternative agro-organic technologies in the agricultural world", that is to say, it aidsn the natural processes of energy and food production and health, but in a decentralized way.

More important still, biogas is not only a technology; it also implies the introduction of new and different concepts in the rural area that are traditionally resistant to change. As with any change it implies introducing risk, disorder, new customs, to seeing things in another way and this causes many create negatively, and create barriers or mental blocks to protect themselves.

Thus, the energy alternatives (in this case biogas) do not only base their future on the use of equipment or tools but also on the generation of new ways of thinking to organize the action or actions that are attempted.

Within this same vein, it should be considered that the prevailing technologies form the character of the economic systems, since they are not neutral elements in the determination of what resource is utilized, who works and where, how much they earn and what level of academic preparation is needed.

Within this context, the OLADE Regional Biogas Program developed a Pilot Project for Training and for the Construction, and Demonstration of Biogas Plants in Rural Areas of Six Latin American Countries whose relevant aspects are detailed herein.

2. Pilot Project for Training and for the Construction and Demonstration of Biogas Plants in Rural Areas of Six Latin American Countries

2.1 Background

The definition of "Development of Technical Projects and Transfer of Technology" that OLADE follows, with the governmental support of the member countries, allowed a group of the principal Latin American biogas experts to meet in Quito, Ecuador in February, 1980, to discuss the document - proposal that OLADE presented at that time. The result of the meeting was the approval of the document, and this became the basis of the Pilot Project.

2.2 Objectives

The basic objectives are detailed below:

2.2.1 To transfer biogas technology through the training of local technical support.

2.2.2 To demonstrate the viability of biogas on a small scale in the rural area.

- Fuel production (biogas)
- Organic nutrient production (bio-fertilizer)
- Improvement of the ecological and sanitary conditions of the rural area.

2.2.3 To promote, coordinate and direct the development of biogas in the OLADE member countries.

To accomplish the proposed objectives, a direct mechanism was established: the construction of 60 digesters distributed in six countries* of the region, using the systems whose ease of transfer had been effectively demonstrated.

a. Discontinuous (OLADE - GUATEMALA)
b. Semi-continuous, horizontal displacement (XOCHICALLI)
c. Semi-continuous, horizontal displacement (IIE - MEXICO)
d. Semi-continuous with dome (CHINESE).

It was hoped that once the proposed objectives had been accomplished, the governments involved would develop their own Biogas programs, not only on a small scale but also medium and large ones, according to their needs and accomodating their application to other areas such as the agricultural/livestock industry, treatment of garbage and waste waters.

2.3 Implementation

The process of sensitizing the members of OLADE was done to determine which countries were interested in the adoption of biogas technology, not as an energy substitute but as an attractive and renewable source, as well as an experience in the process of the transfer of technology. Within this context, members of the Regional Program Staff visited the participating countries Bolivia, Guyana, Haiti, Honduras, Jamaica and Nicaragua) between October 1979 and January, 1980.

The initial contacts were made with the Ministers or Directors of the energy sector, and these designated the institutions that would work with OLADE in the execution of the program.

According to the adopted strategy, OLADE developed the following activities in order to train the government technicians from the participating countries and others who have shown interest:

a. Four (4) practical courses on biogas plant construction in Ecuador, Guatemala, the Dominican Republic, and Grenada.

b. Two (2) meetings of the advisory group in Ecuador and Jamaica.

c. A practical-technical course on biogas in Guatemala.

d. A meeting of coordinators in Ecuador.

e. A seminar on biogas in the Dominican Republic.

f. An evaluation meeting in Ecuador.

g. Two (2) seminars on Bio-energy in Atlanta, Georgia, USA, and in Brazil.

These activities were attended by a total of 381 participants from 26 countries.

Within the implementation, the most relevant problems were centered in construction and other types of problems that are inherent to innovative development projects. The majority of the problems were solved. Some of these were resolved objectively, accomplishing the development of indigenous techniques and motivating the creativity of responsible counterparts. Among these can be cited: the ferrocement technique, the assuring of access to the plants, and inmediate availability of construction materials.

In addition, the economic crisis in the countries involved in the project resulted in delays that have not permitted the star-up of all the plants.

The following table shows the current status of all the plants built:

* Bolivia, Guyana, Haiti, Honduras, Jamaica and Nicaragua.

SUMMARY TABLE

Type of Plant	In Operation	Ready to Operate	Not in Operation*	TOTAL
Chinese	16	2	—	18
Xochicalli	3	5	1	9
IIE-Mexico	—	8	—	8
OLADE - Guatemala	4	11	—	15
TOTAL	**23**	**26**	**1**	**50**

2.4 Conclusions

The conclusions considered most relevant by OLADE are presented herein with:

1. A prudential time period should be granted in order to determine the operational efficiency of ALL the plants.

2. The majority of the plants show costs which surpass the budgeted ones, but this is due to the form in which labor was hired. Nevertheless, it is considered feasible to reduce the costs by even even 50% if more appropriate mechanisms are established.

3. The objectives related to the transfer of technology were achieved. (Ferrocement technique, small-scale operational procedures and construction aspects).

4. The experience attained should permit the governments in question to plan their own biogas programs.

5. OLADE will need complete statistics on the operation, maintenance and follow-up of the plants, with the purpose of offering a more useful and objective technical support; and it should be stressed that without this basic information, OLADE will not be able to generate strategies and policies which are technically and economically feasible.

* One plant is not in operation due to soil collapse and 10 more plants were constructed at the same time that practical courses were carried out.

2.5 Benefits attained

No doubt it is hard to observe or confirm if the immediate benefits were total or partial when the project has just recently been completed; this could only be appreciated with time and will depend on the way in which the countries utilize the obtained resource. However, the most outstanding benefits are described below:

a) The technical feasibility of biogas as an alternative energy source is being studied. In Bolivia, especially, it is planned to install 40 more digesters and in Jamaica funds have been requested from the European Development Fund to construct 2,500 digesters in five years.

b) The concept has been introduced that biogas technology not only constitutes an energy source but that it could also contribute to the improvement of soil quality, through the bio-fertilizer produced.

c) The generation of local technology for construction has been motivated as difficulties in handling the ferrocement technique have been overcome; and the lack of availability of construction materials has promoted the search for alternatives.

d) The joint utilization of other energy sources has been encouraged.

e) It permits the governments to be aware of, to evaluate, and to demonstrate a locally known technology, which could improve their capacity for self-sufficiency.

f) Biogas has been strengthened as an integrating element in the countries' energy policy.

g) It has contributed to rural development through the generation of interest among users.

2.6 Future outlook

The strategy on which OLADE has been based consists of giving priority to the development of efficient demonstration projects, so that these can provide the national teams with the basis and support for an eventual diffusion and acceptance of this technology among the corresponding sectors and authorities.

With this strategy, OLADE has been able to successfully transfer technology. Now, it is a task of the national entities to disseminate and promote the results attained in this stage, to create public awareness, and to generate interest in this program, which is an innovation in every respect.

ANNEX 1

This section describes the raw material and operation of the diverse types of digesters utilized, as well as some construction details (these are not complete sets of designs).

Additional information could be requested to:
REGIONAL BIOGAS PROGRAM
P.O. Box 6413 C.C.I.; Telex 2728
QUITO, ECUADOR

A. OLADE-GUATEMALA DIGESTER

RAW MATERIAL FOR THE DIGESTER PROCESS

The materials used in this technology of low dilution (40 to 60% solids in solution, depending on the density of the material) vary greatly. With this system it is possible to digest methanogenically with some variation —materials not easily digested with techniques of high dilution and continuous or semi-continuous load. Preferably, animal waste is mixed with waste to obtain an appropriate ratio of carbon/nitrogen, in order to achieve a bio-fertilizer of superior organic characteristics.

A digester has been operated efficiently with the use of residue from grain crops (corn, rice and wheat); sugar cane bagasse; pulp or husks from coffee, aquatic plants; waste from bananas, tobacco, and beans; animal manure in general; and composed organic waste.

The animal manure should not be less than 1/3 of the volume, which can be augmented with plants having a low content of organic matter and high levels of cellulose. It is also useful to consider the addition of mineral nitrogen, urea, to aid in providing the nitrogen required by the bacteria in order to function in this environment.

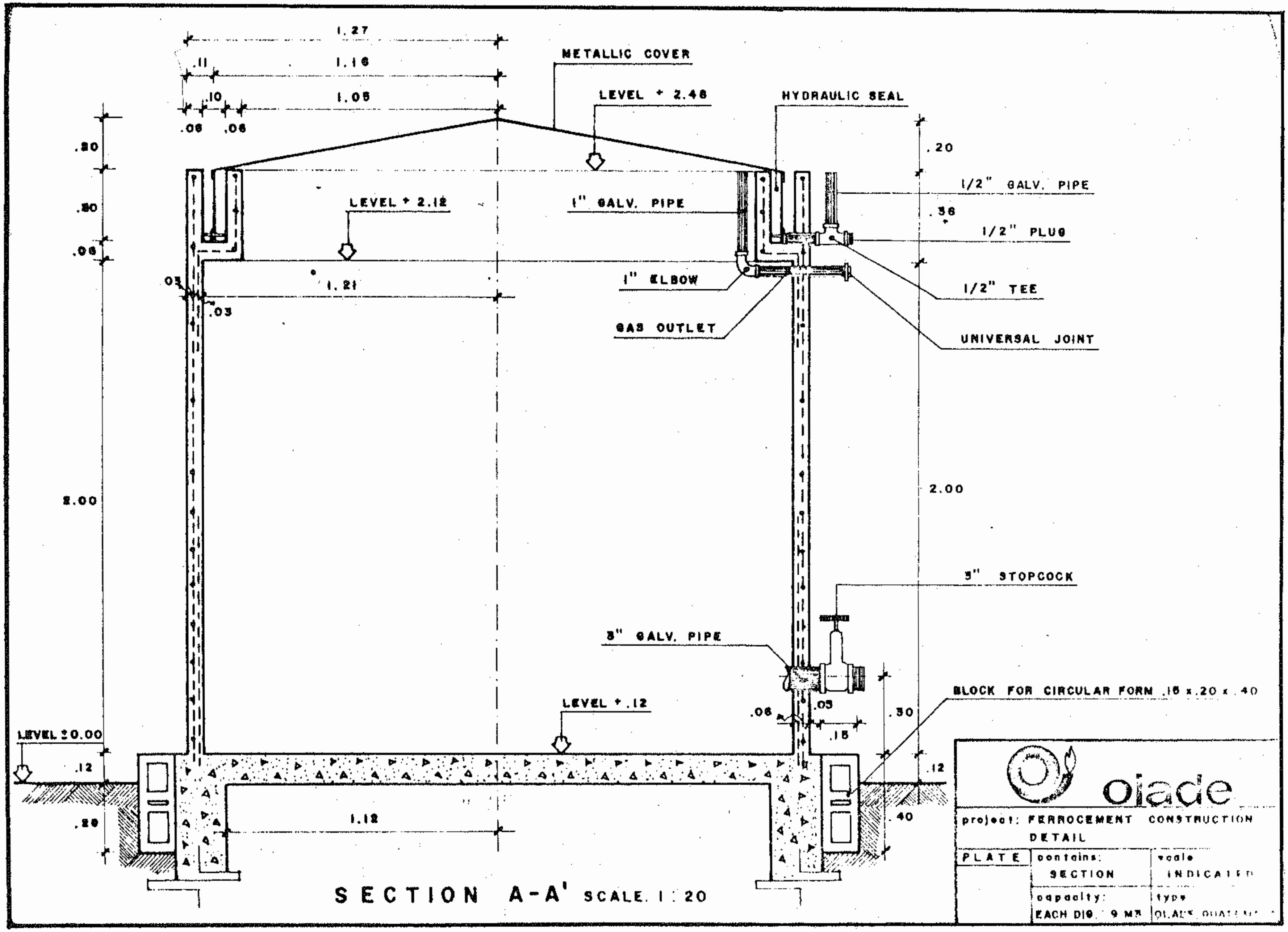
OPERATION OF THE DIGESTER

The loading of the digester begins this phase. The material to be used should have been previously composted in the open air for ten or fifteen days, of the volume, which can be augmented with plants ning to the digestion process, reduces the humidity contained in the fresh material. This action is necessary (although not essential) to facilitate the compaction of the material inside the digester before it is completely filled.

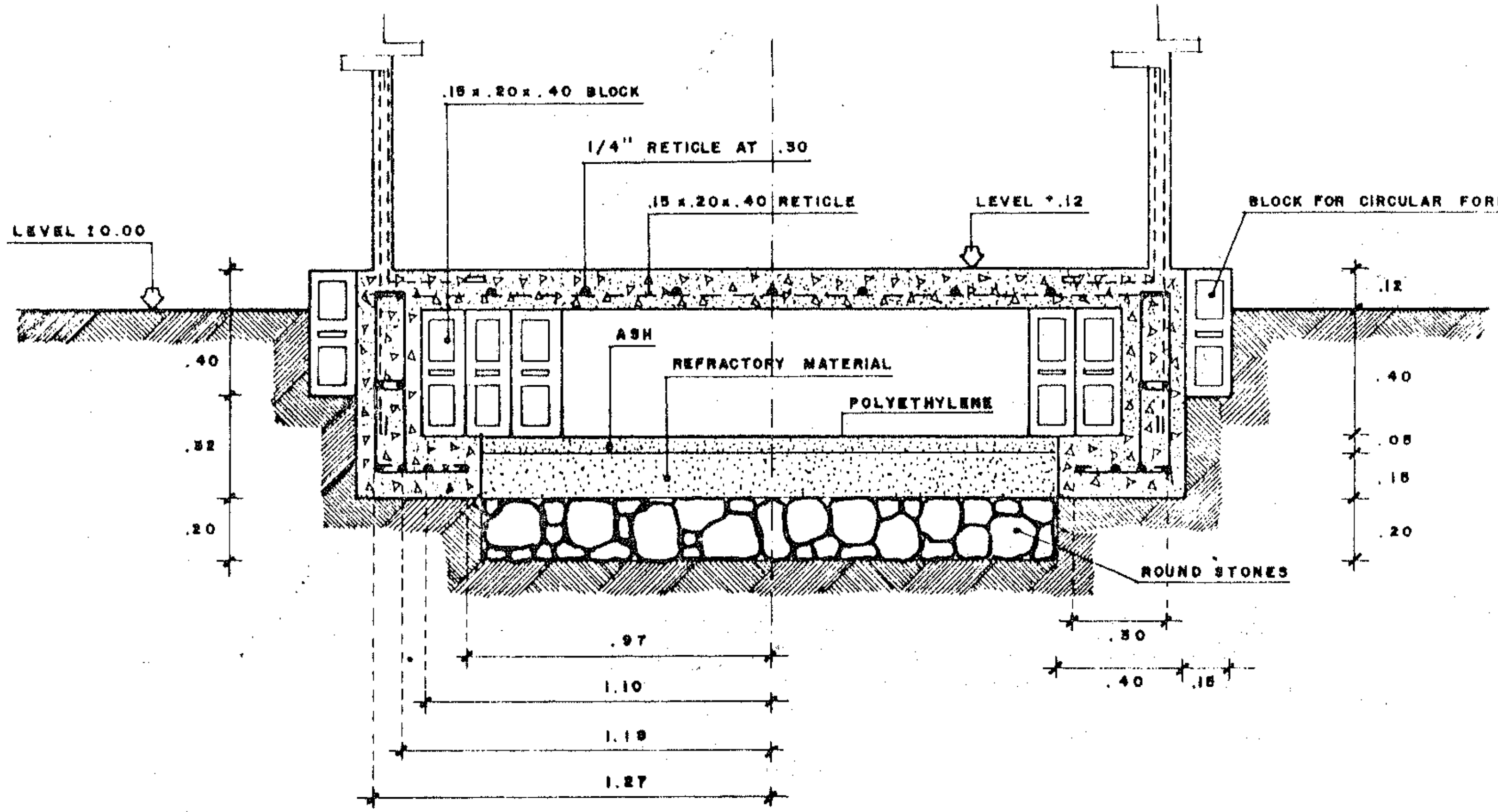
When the digester is to be loaded with only one kind of material, the operation should be done in layers 30 cm. thick, successively compacted, the load is comprised by a mixture of materials to be deposited.

The required compaction permits the elimination of air bubbles that may remain inside and at the same time increases the digester's capacity for receiving solids.

Once filled, the digester is saturated with water (or preferably, with residual liquid from previous loads) to a level some 10 cm. above the level of solids.



1.27
.11
1.16
.10
1.05
.06
.06
METALLIC COVER
LEVEL + 2.48
HYDRAULIC SEAL
.20
1/2" GALV. PIPE
.36
1/2" PLUG
1/2" TEE
UNIVERSAL JOINT
LEVEL + 2.12
1" GALV. PIPE
1" ELBOW
GAS OUTLET
.03
.03
1.21
2.00
3" STOPCOCK
3" GALV. PIPE
BLOCK FOR CIRCULAR FORM .15 x .20 x .40
LEVEL + .12
LEVEL ± 0.00
.06
.05
.15
.30
.12
.40
1.12
SECTION A-A' SCALE 1 : 20
olade
project: FERROCEMENT CONSTRUCTION DETAIL
PLATE
contains: SECTION
scale INDICATED
capacity: EACH DIG. 9 M3
type OLADE QUATEMALA



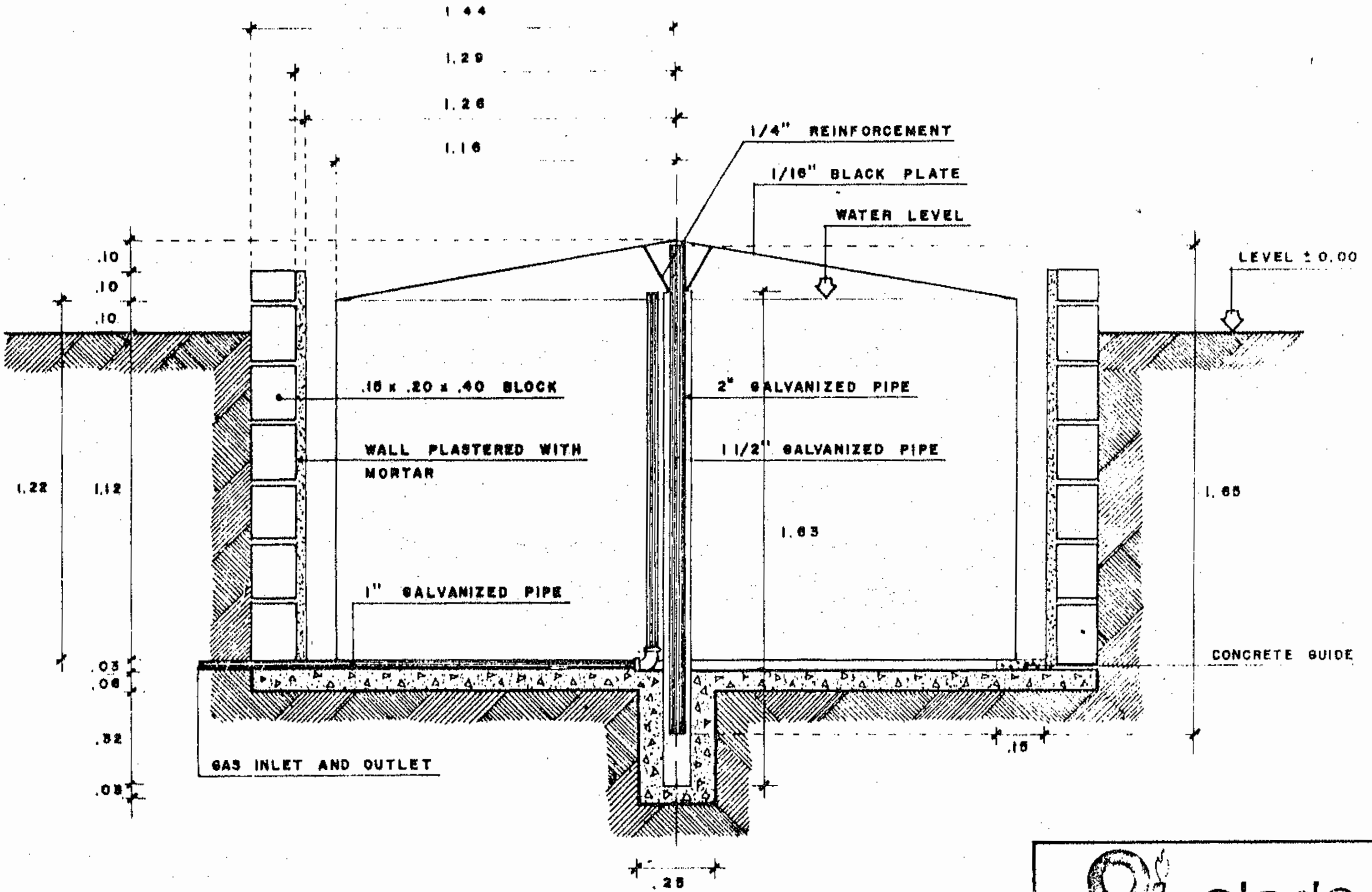
SECTION A-A' SCALE. 1:20

(CONTINUATION)

olade

project: FERROCEMENT CONSTRUCTION DETAIL

PLATE	contains: SECTION	scale: INDICATED
	capacity: EACH DIG. 9 M3	type: OLADE-PHAT...



SECTION B-B' SCALE. 1: 20

olade

project: FERROCEMENT CONSTRUCTION DETAIL

PLATE	contains: SECTION	scale: INDICATED
	capacity: 5 M3 GASOMETER	type: OLADE-GUATEMALA

62

It is also important to mention that before sealing the digester, one should wait for the water to seep into the material, in order to avoid unexpected drops in the level of water situation which is quite undesirable.

After this, the digester is closed and hermetically sealed, with water added to the respective seal. The digestion process now begins.

Under favorable environmental conditions, the production of gas fuel is noted between 4—1 days after the sealing of the digester.

The period of digestion, given adequate mixtures and suitable climatic conditions, can take approximately 35—45 days, with useful outputs of gas.

On observing a decrease in gas production (when this reaches levels which are not very useful), it is time to begin the discharge process.

The gas outlet valve on this digester should be closed, and the water seal should be emptied. After this, the digester should be uncovered and the drain —pipe opened to allow the liquid bio-fertilizer to scape, leaving it to drain completely; this process takes approximately 48 hours. At the end of this process the solid fertilizer is extracted and the digester is cleaned, so as to be ready to be loaded once again.

B. SEMI-CONTINUOUS CHINESE DIGESTER WITH A DOME

RAW MATERIALS FOR DIGESTERS

The Chinese-type digester uses all types of agricultural waste, including human excretion, while it is always recommended that a mixture of materials be used. The Chinese operation techniques permit the digestion of cellulose material, e.g., grain residues, grass, leaves, etc., as long as the digester is loaded with material that has been aerobically pre-composted. The techniques of pre-compost is described in a subsequent diagram. It is important to emphasize that a large degree of the success of the Chinese biogas technology depends on pre-compost, and the following advantage are to be derived:

a. Adequate temperature for the multiplication of aerobic and anaerobic bacteria.

b. Generation of heat (60—70°C) that removes the waxy coating of the straw and permits partial cellulose and lignine brakdown until their homogeneous disintegration in the digesting liquid, avoiding the formation of foamy scum.

c. Heat that is responsible for destroying the majority of parasites which are initially present.

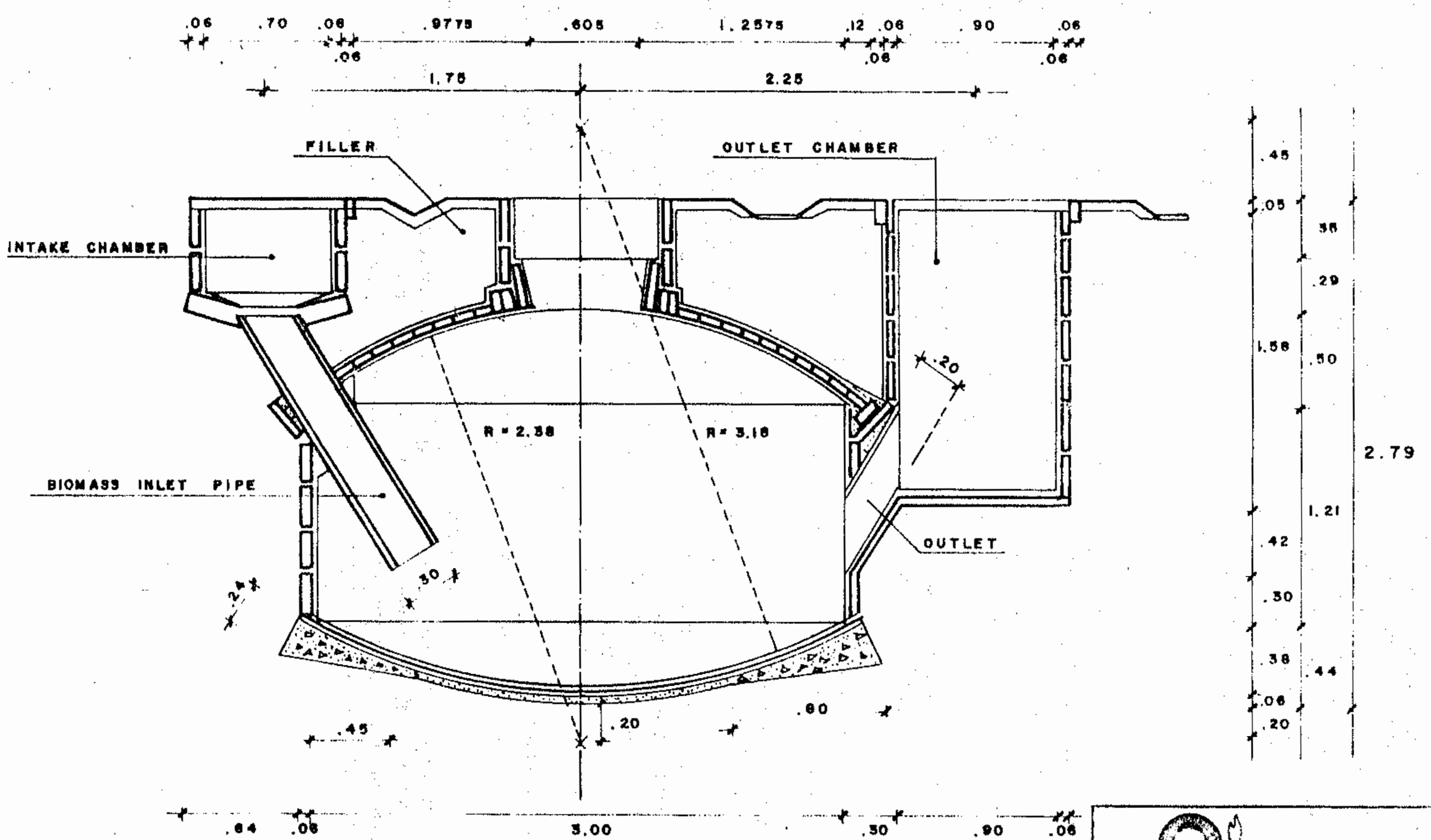
d. Heat that raises the temperature of the initial solution of the loads.

e. Partial degrading of the initial raw material which accelerates the production of Biogas fuel.

f. Obtaining of more homogenous and accessible effluents and sludge. Moreover, it is very important to add different types of inoculores in the initial load, up to a volume of 10% of the total volume of liquid.

DIGESTER OPERATION

The Chinese-type digester functions on a semi-continuous basis. It is initially loaded with pre-composted material at a concentration level of 7—15- of the total of solids in suspension and, then it is reloaded periodically (daily, every other day, or weekly) with raw materials, preferably precomposted, in a quantity equivalent to the gas produced. It is recommended that the liquid effluent be recirculated frequently.

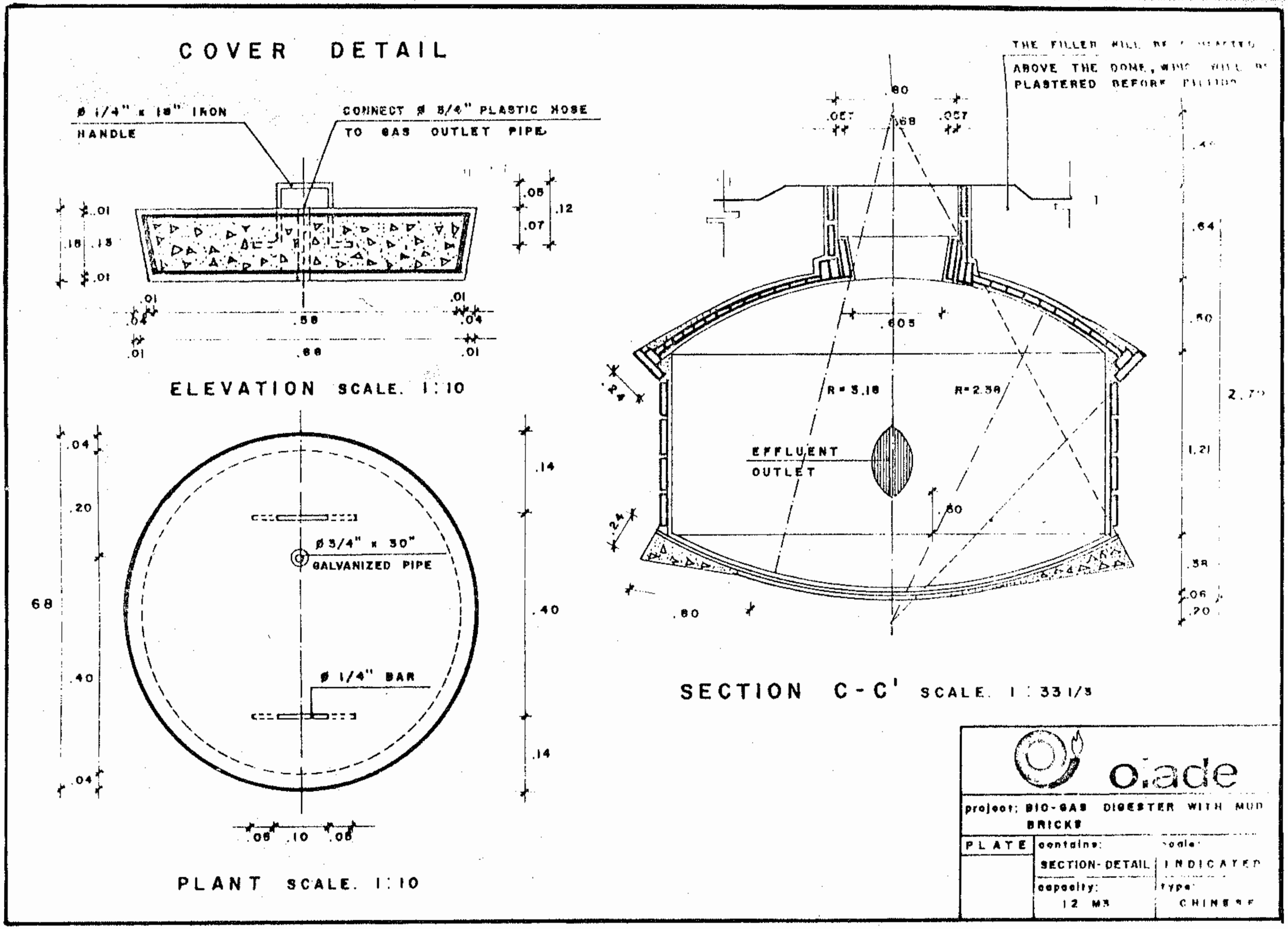


SECTION A-A' SCALE. 1: 33 1/3

olade

project: BIO-GAS DIGESTER IN MUD BRICKS		
PLATE	contains: SECTION	scale: INDICATED
	capacity: 12 M3	type: CHINESE

64



COVER DETAIL
ø 1/4" x 10" IRON HANDLE
CONNECT ø 3/4" PLASTIC HOSE TO GAS OUTLET PIPE
ELEVATION SCALE. 1:10
PLANT SCALE. 1:10
ø 3/4" x 30" GALVANIZED PIPE
ø 1/4" BAR
SECTION C-C' SCALE. 1:33 1/3
EFFLUENT OUTLET
R=3.18
R=2.38
ABOVE THE DOME, WHICH WILL BE PLASTERED BEFORE
o.lade
project: BIO-GAS DIGESTER WITH MUD BRICKS
PLATE
contains: SECTION-DETAIL
scale: INDICATED
capacity: 12 M3
type: CHINESE

C. SEMI-CONTINUOUS
XOCHICALLI-DIGESTER

RAW MATERIAL FOR DIGESTER

For this type of digesters, organic waste, sewage, manure, organic industrial wastes, crop residues, etc., may be used as raw material. To the mixture of solids introduced into the digester liquid (water and/or innoculators) must be added until there is an approximately 90% dilution.

OPERATION OF THE DIGESTER

It is similar to that described for the Chinese system; in other words, its load is semi-continuous or continuous; the initial load is preferably made with pre-composted material. The addition of the initial liquid is preferably a mixture, with 10% of the residual liquid from another digester or from a septic tank.

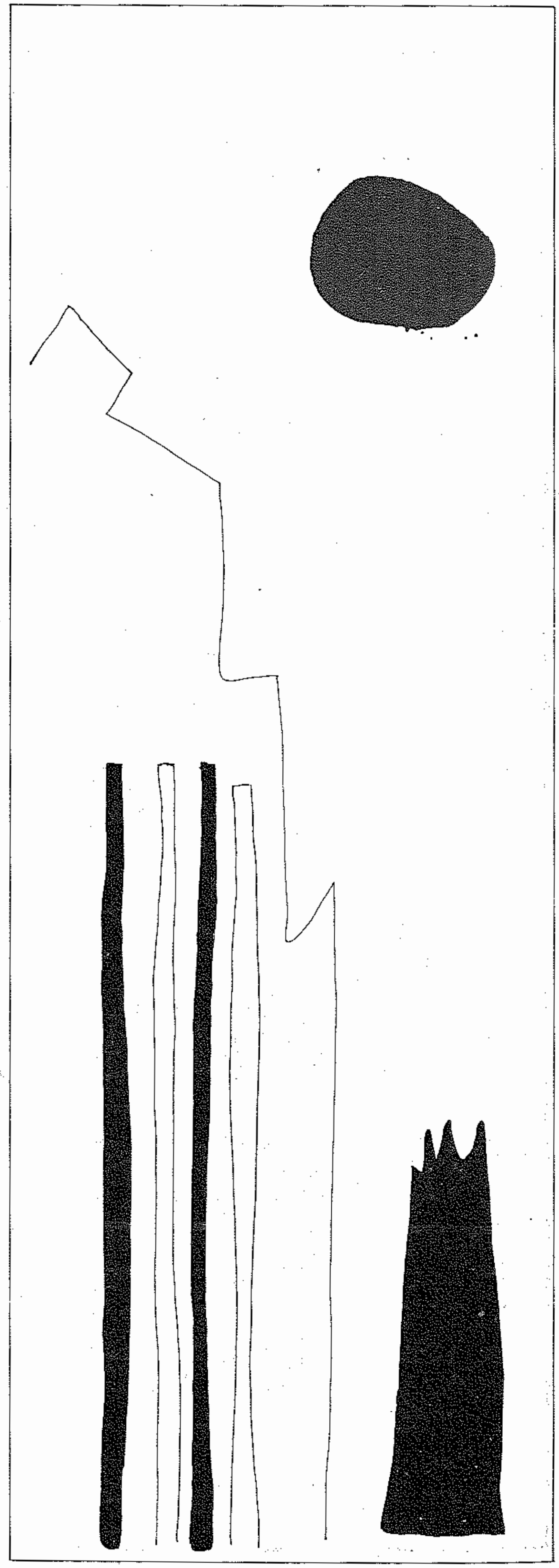
The digester should be loaded until the liquid covers the mouth of the inlet pipe. The skimming process takes place 2 or 3 times a year, keeping in mind that the first scum forms, 15 days after the initial loading, so that it becomes necessary to drain liquid as far as the lower level of the scum removal outlet and to extract the scum with a device designed for that purpose, by dragging.

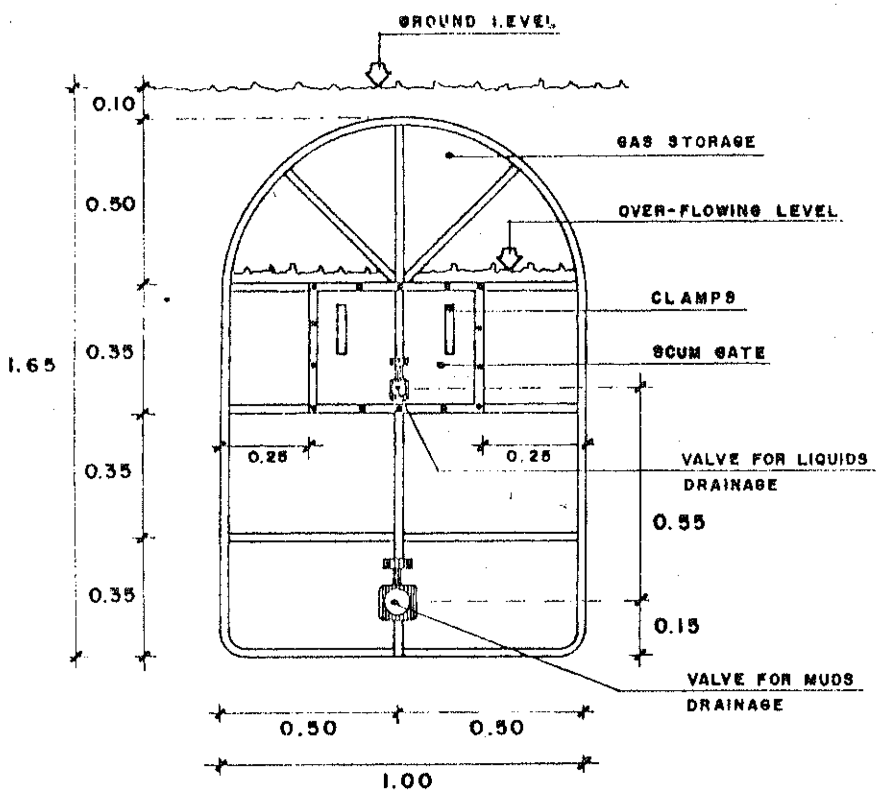
It is necessary to ensure that there is no leakage, particularly through the screws of the scum removal outlet.

Unloading the Digester

This ought to be done in such a way that the level does not fall below 50 cm. from the bottom, so as not to stop the process. The unloading can be done daily, every two weeks, monthy, etc. Two-thirds of the daily load can be unloaded as liquid, and a quarter as sludge.

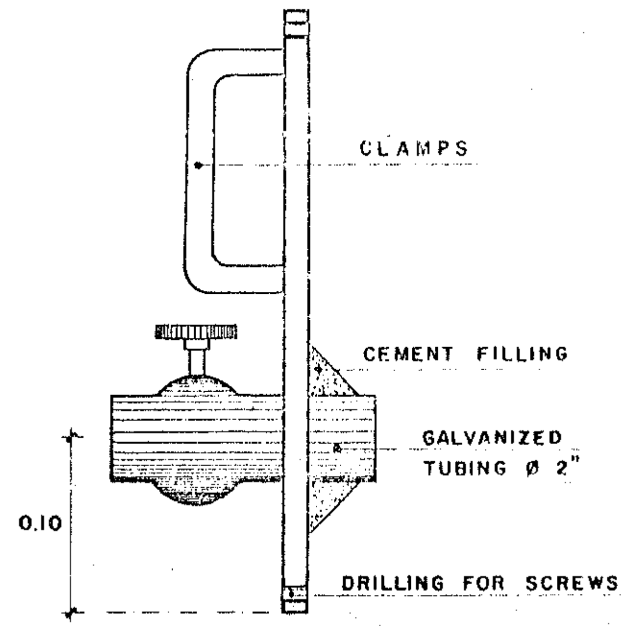
The water that is collected can be recirculated for the sake of economy.





FRONT ELEVATION

SCALE. 1:20



SIDE VIEW

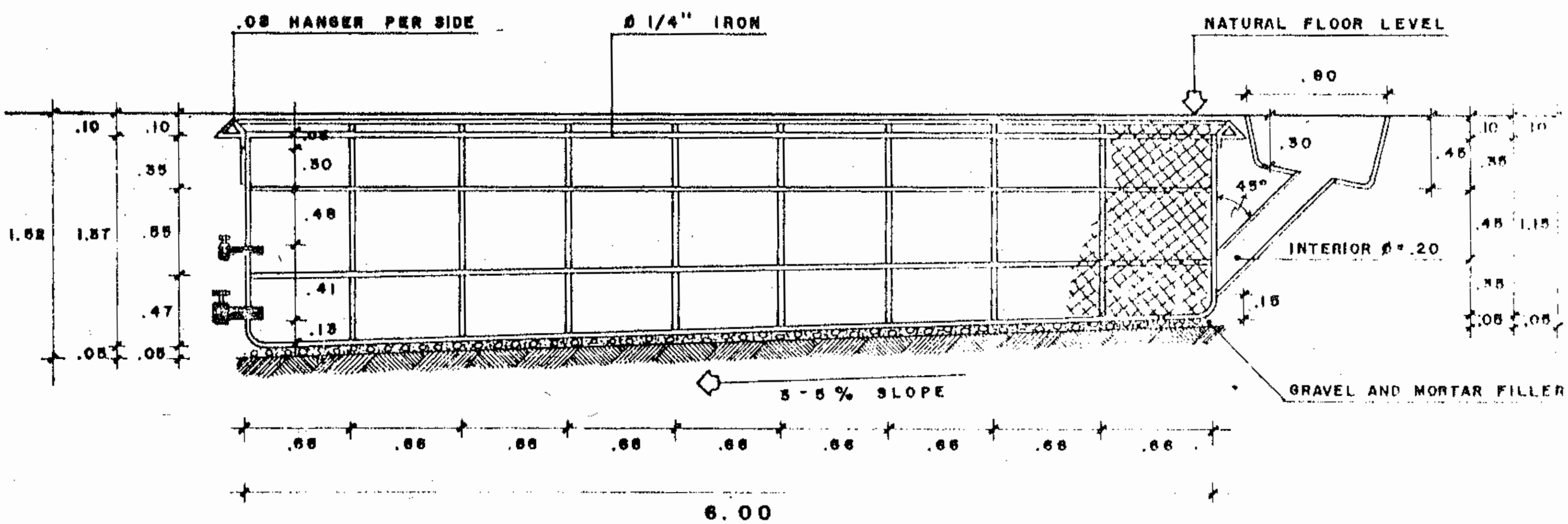
FLOOD GATE AND
VALVE FOR LIQUIDS DRAINAGE

SCALE. 1:4

olade

project: DETAIL OF MODIFICATIONS IN SEALING AND FLOOD GATE

ANNEX	contains: ELEVATION F.	scale: INDICATED
	capacity: 6 M³	type: XOCHICALLI

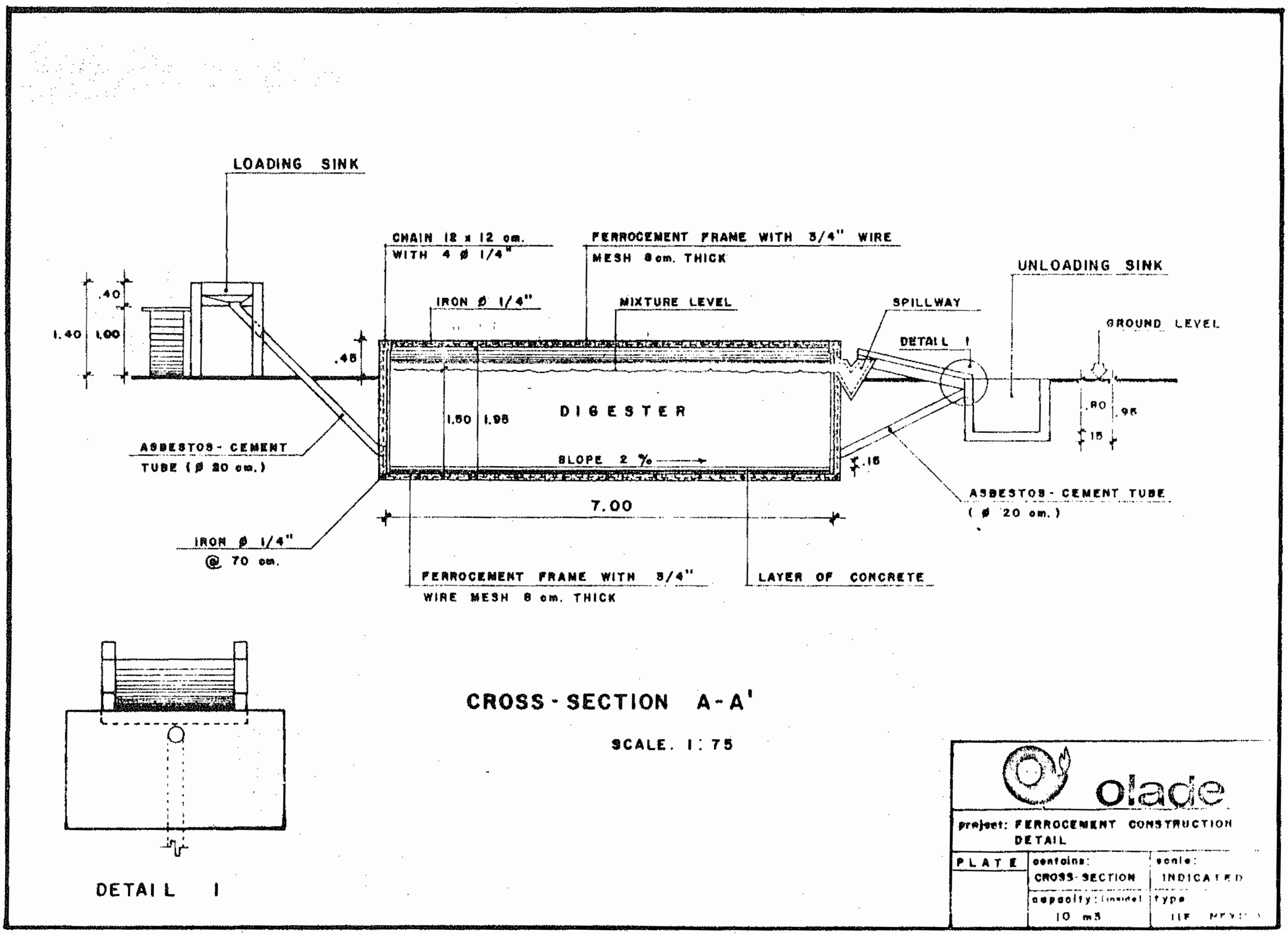


IRON REINFORCEMENT (LATERAL ELEVATION) SCALE. 1:40

olade

project: FERROCEMENT CONSTRUCTION DETAIL

PLATE	contains: L. ELEVATION	scale: INDICATED
	capacity: (inside) 5 M3	type: XOCHICALLI-MEXICO


LOADING SINK
CHAIN 12 x 12 cm.
WITH 4 ø 1/4"
FERROCEMENT FRAME WITH 3/4" WIRE
MESH 8 cm. THICK
UNLOADING SINK
IRON ø 1/4"
MIXTURE LEVEL
SPILLWAY
GROUND LEVEL
DETAIL I
.40
1.40
1.00
.45
DIGESTER
1.60
1.95
SLOPE 2 %
.80
.95
.15
.15
ASBESTOS - CEMENT
TUBE (ø 20 cm.)
7.00
ASBESTOS - CEMENT TUBE
(ø 20 cm.)
IRON ø 1/4"
@ 70 cm.
FERROCEMENT FRAME WITH 3/4"
WIRE MESH 8 cm. THICK
LAYER OF CONCRETE
CROSS - SECTION A - A'
SCALE. 1 : 75
DETAIL I
olade
project: FERROCEMENT CONSTRUCTION
DETAIL
PLATE
contains:
CROSS - SECTION
scale:
INDICATED
capacity: (inside)
10 m3
type

D. SEMI - CONTINUOUS
IIE - MEXICO DIGESTER

RAW MATERIAL FOR DIGESTERS

This digester utilized a technology of high dilution, and due to this the raw material fed, has around 8% of total solid materials in dilution (water and /or inoculous material). It is fed with manure from 8 to 10 semi-stable cows or the equivalent in other animals; this could be mixed with wastes from harvests and a compound can be prepared in such a way that it will disgregate the organic material.

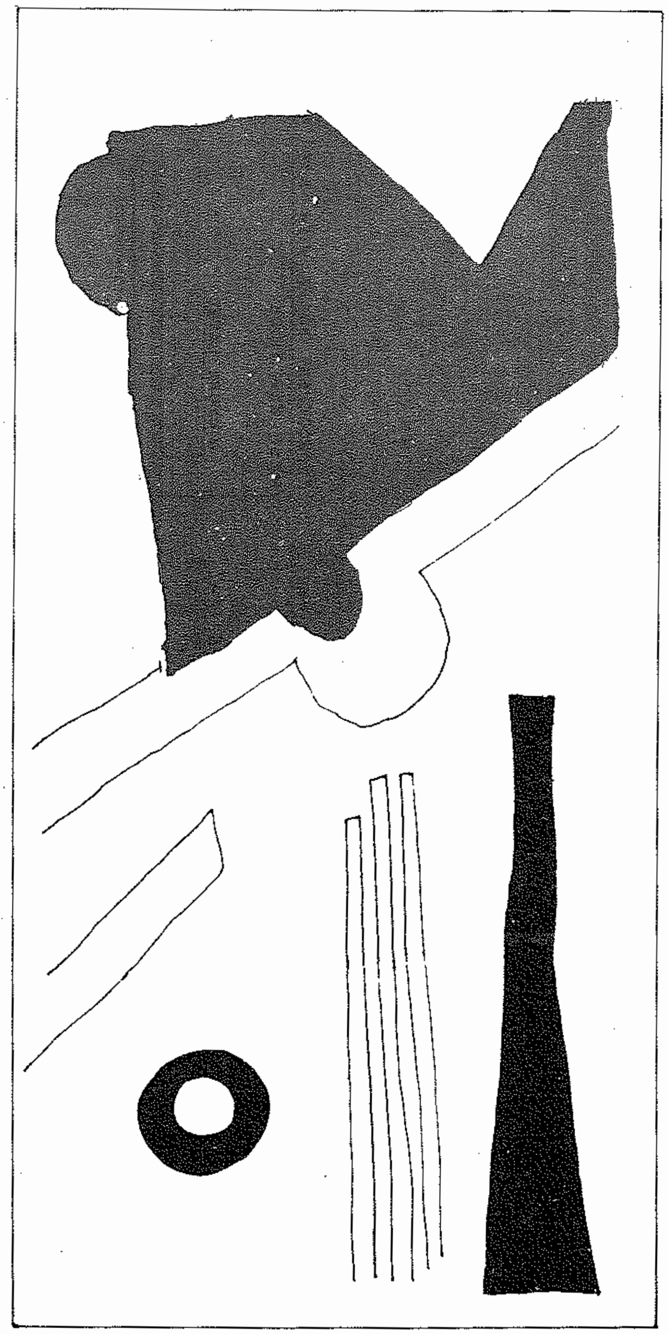
OPERATION OF THE DIGESTER

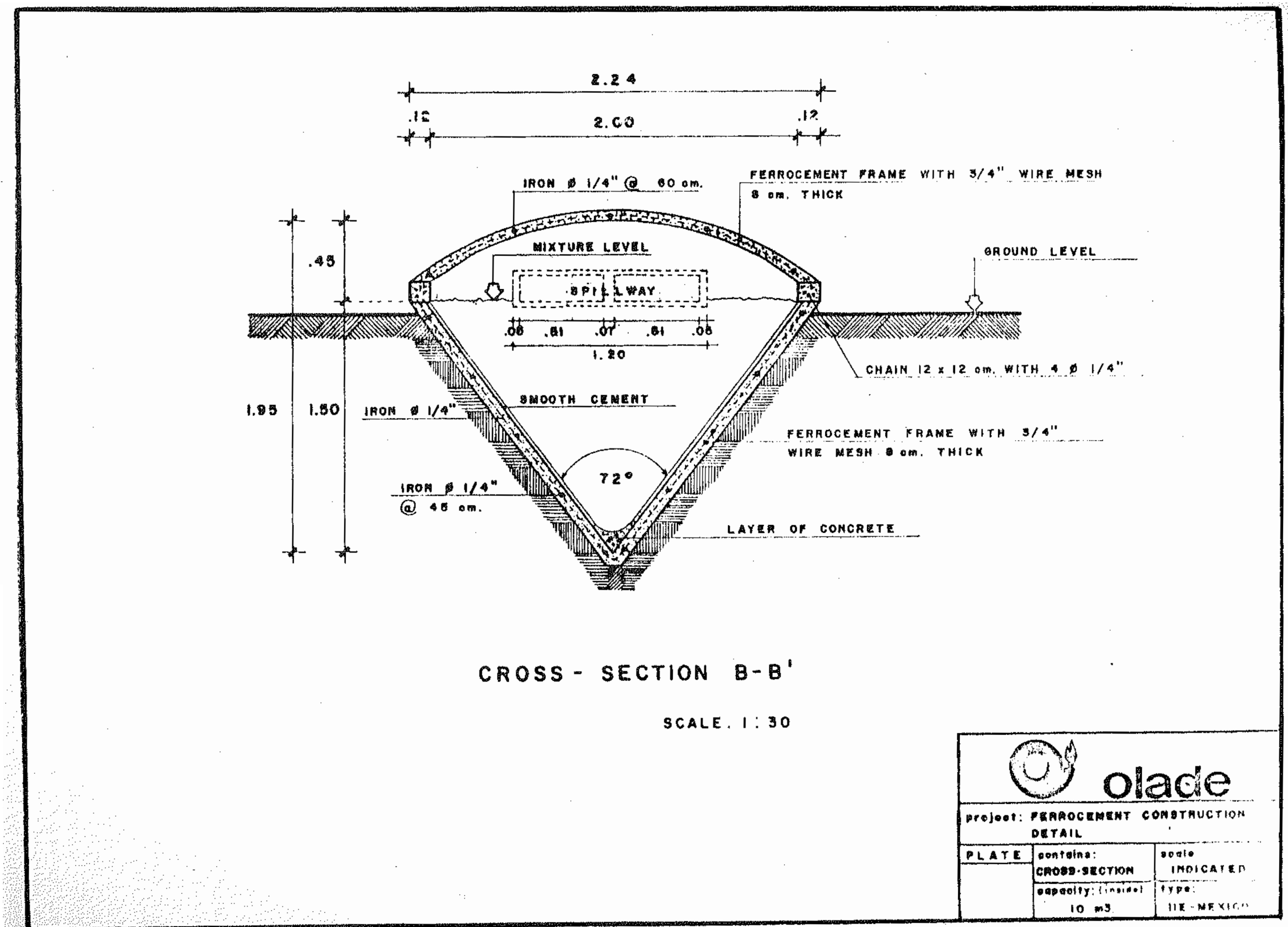
Loading is done in a continuous or semi-continuous form, through an entry chamber, feeding it the first load with pre-compound material preferably.

During the first load it is necessary to introduce the inoculous material, with the purpose of accelerating de-composition of the organic material, and therefore the gas production.

The digester is loaded every day with a mixture volume determined previously and the same volume is extracted by communicating receptacles towards the unloading sink, avoiding utilization of pumps.

The overflowing device, besides being an unloading alternative, is also a water seal that works as a relief valve in case the internal pressure will surpass the maximum permissible pressure.





2.24
.12
2.00
.12
IRON ø 1/4" @ 60 cm.
FERROCEMENT FRAME WITH 3/4" WIRE MESH
8 cm. THICK
MIXTURE LEVEL
GROUND LEVEL
.45
SPILLWAY
.08 .51 .07 .51 .08
1.20
CHAIN 12 x 12 cm. WITH 4 ø 1/4"
SMOOTH CEMENT
1.95
1.50
IRON ø 1/4"
FERROCEMENT FRAME WITH 3/4"
WIRE MESH 8 cm. THICK
72°
IRON ø 1/4"
@ 45 cm.
LAYER OF CONCRETE
CROSS - SECTION B-B'
SCALE. 1 : 30
olade
project: FERROCEMENT CONSTRUCTION DETAIL
PLATE
contains: CROSS-SECTION
scale INDICATED
capacity: (inside) 10 m3
type: IIE-MEXICO