Mini Hydro Power Stations (A Manual for Decision Makers)

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MINI HYDRO POWER STATIONS

(A Manual for Decision Makers)*

PREPARED JOINTLY BY

THE UNIDO TECHNOLOGY PROGRAMME
AND
THE LATIN AMERICAN ENERGY ORGANIZATION (OLADE)

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Preface

The development of new and renewable sources of energy has become a matter of priority in many countries all over the world. In particular, increased attention has been paid to the development of micro, mini and small-scale hydro power generation units which could under certain circumstances appropriately contribute to industrial and economic development of rural and remote areas.

In places where limited hydro power is available, mini hydro power generation units (MHG) constitute a readily accessible source of renewable energy. They use proven technologies that in many cases need only adaptation, require limited investment and obviate excessive transmission costs.

As part of its programme of Action in Appropriate Industrial Technology, UNIDO has been actively involved in promotion of MHG development and application in developing countries. It has organized three projects related to this subject:

1. Group Study Tour to the People's Republic of China in the Field of Medium and Small-Scale Hydro-Power Plants, 14 May - 2 June 1979,
2. Seminar-Workshop on the Exchange of Experiences and Technology Transfer on Mini Hydro Electric Generation Units, Kathmandu, Nepal, 10-14 September 1979, and
3. Second Seminar-Workshop/Study Tour in the Development and Application of Technology for Mini Hydro-Power Generation, 17 October - 2 November at Hangzhou, P.R. China, and 3-7 November 1980 at Manila, Rep. Philippines.

The Seminar-Workshop in Nepal, recommended that UNIDO encourage the preparation of manuals providing guidelines for the development of mini hydro-power generation units in developing countries.

As a first step, it was considered useful to prepare a manual on MHG for the guidance of decision-makers in this field, at central or regional government level or at the planning and project implementation levels. The manual is intended as a working tool to help decision-making on the establishment of small and mini hydro power stations and the formulation of comprehensive and coherent policies and programme for this purpose.

The preparation of this Manual was made possible by the financial support of the Swedish International Development Agency (SIDA).

The Manual was prepared by OLADE, under the general leadership of Mr. G. Rodriguez Elizarraras, Executive Secretary of OLADE, through a group of its experts, Mr. C.A. Hernandez, Mr. L.E. Machado and Mr. L.A. Suarez with Mr. Enrique Indacochea, Head, Regional Programme on Small Hydro Power Stations, as the technical co-ordinator. The Manual also benefited from inputs provided by Mr. Guo Ruizhang, Chief Engineer, Bureau of Water Conservancy, Shanghai, and Mr. Thovild Persson, VAST, Sweden.

It is hoped that the Manual will serve as a practical and useful reference for those involved in working in the Mini Hydro Generation Power Field. It should, however, be considered as a first volume to be updated and expanded in the future to enhance its usefulness. Any constructive suggestions or proposals in this regard are welcome.

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I. INTRODUCTION

It is intended that this manual will be a working tool for decision makers at different levels. Since the potential main users of the manual will not necessarily have a specialized engineering background, the technical elements have been restricted to descriptive aspects and elementary concepts, with more emphasis being given to questions of mini-hydro power generation (MHG) development, policy, planning and programming than to the engineering and technological requirements and potentialities, instructional organization and training.

It should be also mentioned that in this manual, specific approaches and, in some cases, alternative solutions are proposed. However, the optimum solutions may vary for every aspect of MHG development considerably from country to country as a result of differences in socio-economic systems, political organization, level of development, history and culture. The specific conditions of each country or region must therefore be taken into account when the recommendations contained in the manual are being applied.

The manual comprises eight chapters. The first four chapters contain general information including definition and classification of MHG units, advantages and limitation of MHG in solving energy and industrial development problems in rural and remote areas and at the country level, and a comparison of MHG with other alternative energy systems.

As regards the classification of MHG, it should be noted that at the time of writing there is no united and generally accepted classification of MHG units. Different organizations and countries have different approaches. For this reason, some systems of MHG classifications are presented in Chapter 2, including the system proposed at the UNIDO Seminar-Workshop on the Exchange of Experiences and Technology Transfer on Mini-Hydro Electric Generation Units, 10-14 September 1979, Kathmandu, Nepal.

Chapter 5 presents an analysis and methodology of MHG development, starting from the assessment of possible applications in a certain area and the evaluation of resources and demand to providing decision-makers with useful information on the operation and maintenance of MHG units.

Chapter 5 and chapter 6 constitute the core of the manual and suggest a methodology for considering the possibilities of MHG development in a certain area and identify a number of aspects which should be taken into consideration before a final decision is made.

Chapter 7 is addressed to those persons who are responsible for organizing and supervising projects and discusses the development of specific MHG projects.

Annex A contains bibliographical references of use to those who wish to go into the subject more thoroughly, particularly its technical aspects.

Annex B contains basic MHG calculations which may be of interest to those who have a basic engineering training.

Although the approach to the problem and the recommendations contained in the manual are mainly applicable to MHG of less than 1,000 kW, they can also be used for the higher power ranges provided that the limited application of some concepts, particularly technology questions, are clearly borne in mind.

The manual will have achieved one of its objectives if it has succeeded in making it clear that a mini hydro power station is more than just a small-scale model of a large hydro-electric plant.

2. DEFINITION AND CLASSIFICATION

A Mini Hydro Power Station (MHG) is an installation where hydraulic power is used to generate small quantities of electricity by means of one or more turbine-generator units or groups.

MAIN COMPONENTS OF MHG	
CHECK LIST	DESCRIPTION
DAM	A structure built across the main watercourse in order to store and/or raise the level of the water. In MHG it is usually used to raise the water level and is of simple construction. MATERIALS: concrete, earth, rock, wood, plastic materials (or combinations).
INTAKE WORKS	A structure to facilitate the entry of water to the conduit system. May or may not be submerged. For MHG it may be of permanent or artisan construction. MATERIALS: concrete, masonry, rubble (artisan construction).
CONDUIT CONDUCTION SYSTEM	The water is taken from the intake to the forebay by means of a canal or tunnel. For MHG, irrigation canals may be used. CONSTRUCTION: lined or unlined.
FOREBAY	Structure which facilitates the entry of the water to the penstock. MATERIALS: concrete, lean-mix (?) concrete, asbestos-cement, ferro-cement.
SILT BASIN	A system for preventing solid particles from entering the penstock (to protect the turbine). May be installed as part of the intake works or the forebay (depending on flow, terrain, material of which channel is constructed).
SPEED REGULATOR	A servo-mechanism which keeps the turbine revolving at a constant speed and consequently maintains the electrical energy generated at a constant frequency. TYPES: MECHANICAL: almost never used. OIL MECHANICAL: the standard one. Electro-Electronic with flow regulation. Electro-Electronic with energy dispersion. Alternative: Manual control.
GENERATOR	An electrical machine that converts the mechanical energy into electrical energy; TYPES: ALTERNATOR: (synchronous generator) - the most frequently used in MHG. ASYNCHRONOUS GENERATOR: (induction motor).

TRANSFORMER

Electrical equipment varying the voltage which enables energy to be transported over distances economically.

ELECTRO-MECHANICAL ACCESSORIES

Main valve (gate or butterfly). Turbine-generator transmission by direct coupling or by transmission systems (V-belt, chain or gears). Hydraulic instrumentation (manometers). Lighting conductors.

TRANSMISSION LINE

In MHG low and medium voltages are used to transmit the electrical energy from the plant to the point of consumption.

CIVIL ENGINEERING ACCESSORIES

Screens (for controlling solids), gates, spillways, etc.

SURGE TANK

A structure for compensating overpressure. Not often used in MHG, depending on the head, length of penstock, velocity of water in the penstock, materials of which penstock is made and time needed to close the main valve. May form part of the forebay.

PENSTOCK

Pressure pipe for conveying the water from the forebay to the turbine.

POWER HOUSE

Structure in which the generators and other electro-mechanical equipment are housed.

TAIL RACE

Structure which returns the water from the power house either to downstream of the river from which it was taken or to a neighbouring basin.

TURBINE

A hydraulic motor that converts the energy of the water (head, or drop, and flow) into mechanical energy. TYPES:

PELTON: a free-jet impulse turbine used for high heads; low cost.

MICHELL-BANKI: cross-flow impulse turbine used for medium heads; low cost, low efficiency.

FRANCIS: reaction turbine (operates filled with water) used for medium heads; high cost, high efficiency.

AXIAL: Reaction turbine (variants: Kaplan with adjustable blades, fixed blade propeller-type, tubular-type, bulb-type, etc.) used for low heads.

Alternative:

WATER WHEEL: not a turbine. Low cost, low efficiency. Artisan construction possible. Slow, operates with small heads.

The amount of power that can be generated (measured in kilowatts) is equal to that available in the water after allowing for the losses of efficiency in each successive component of the MHG, and is proportional to the product of the net head and the flow.

GROSS HEAD:	Difference in level from the upper surface of the water at the highest usable point to the lower level of its use by the turbine. MEASUREMENT: METRES.
NET HEAD:	Equivalent to the gross head less the hydraulic losses in the different elements conveying the water to the turbine. MEASUREMENT: METRES.
FLOW:	Quantity of water (volume) per unit of time. UNITS: CUBIC METRES PER SECOND.

MHG can be classified according to various criteria and it is considered advisable not to propose any one system, not only because of the arbitrary elements that enter into every classification but also because the specific characteristics and degree of development of each country may better be served by different classifications.

The systems given below are in the nature of guidelines that could be taken into account in defining criteria for specific countries or regions.

a) According to power and head.

We propose two schemes:

Country or Organization		Micro HG (kW)	Mini HG (kW)	SHG (kW)
UNIDO	Kathmandu Seminar	up to 100	100-1,000	
	Hangzhou-Manila Seminar	up to 100	101-2,000	2,001-10,000
China	by the unit			up to 6,000
	by the installed capacity			up to 12,000
Philippines				up to 5,000
Peru		5-50	51-500	500-5,000
Romania				5-5,000
Thailand*			up to 1,000	
Turkey*		0-100	101-1,000	1,001-5,000
USA				up to 20,000
Sweden				100-1,500
Preparatory committee for the UN Conference on New and Renewable Sources of Energy (Panel on Hydropower)		up to 1,000		1,001-10,000

*) Classified not so clear.

SYSTEM PROPOSED BY OLADE FOR THE LATIN AMERICAN REGION AND THE CARIBBEAN

	POWER RANGE (kW)	HEAD (metres)		
		LOW	MEDIUM	HIGH
Micro hydro-power stations	up to 50	less than 15	15-50	more than 50
Mini hydro power	50 - 500	less than 20	20-100	more than 100
Small hydro power	500-5,000	less than 25		more than 130

NOTES:

- The low, medium and high heads correspond approximately to the employment of Axial, Francis or Michell-Banki, and Pelton turbines, respectively.
- "Small hydro electric power stations" also covers all plants with outputs of less than 5,000 kW.

The upper and lower head and output limits adopted for any classification are indicative only and should not be rigidly applied.

For very small outputs, generally less than 5 kW., and where the water resources and characteristics of the country justify it, the use of water wheels, particularly for direct mechanical power, is also possible.

b) According to intake
   - run of river (lateral intake from a main watercourse);
   - with reservoir or dam.

c) According to its regulation
   - adjustable flow (control of the flow at the turbine intake) - this may be either manual or automatic;
   - constant load, whether because of the actual nature of the load or through dissipation of the excess energy.

d) According to its links to the grid
   - isolated plants;

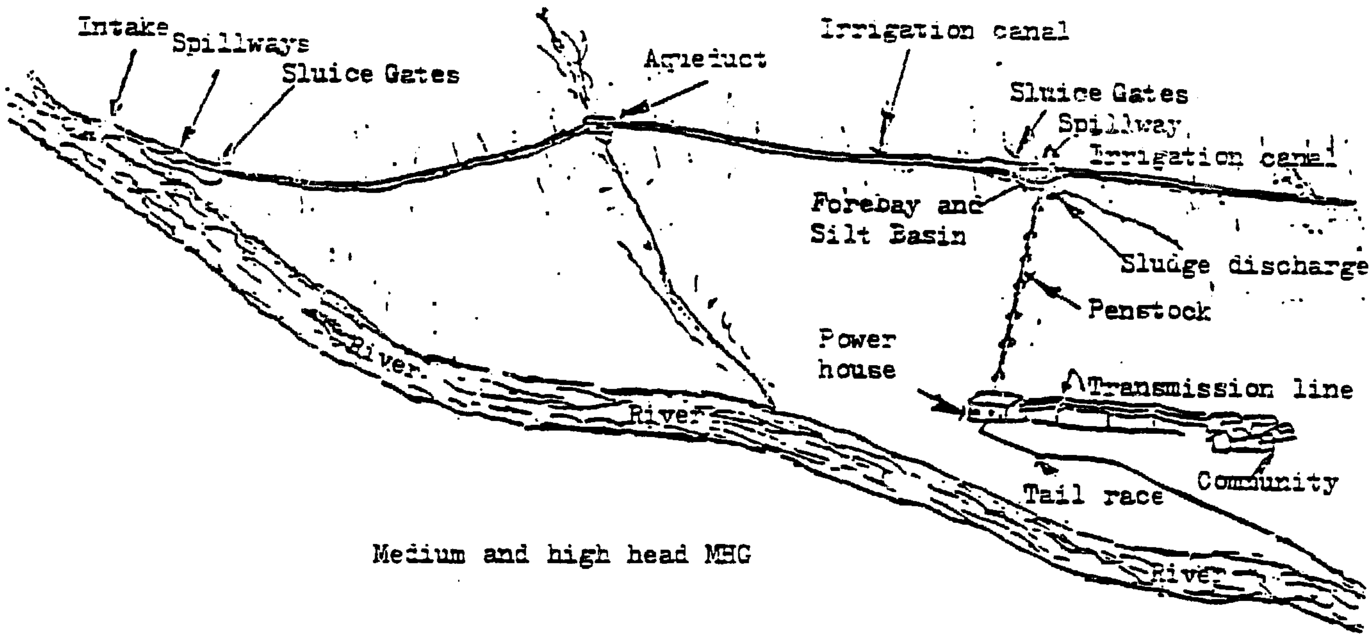
- plants conncected to small electrical grids;
- plants connected to major zonal or national networks.

e) According to technological conception

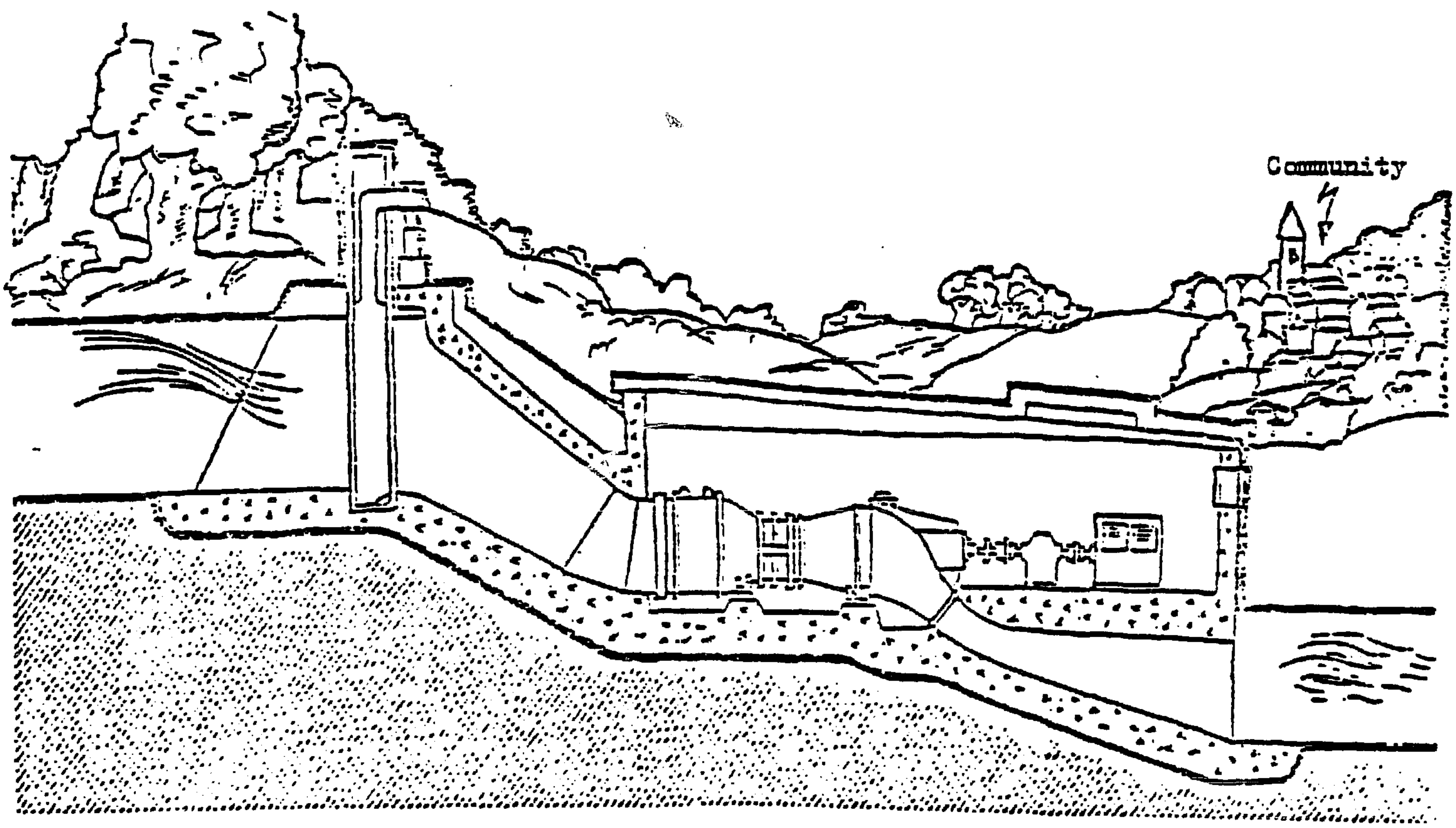
This is an indicative classification based on the nature of the main technological components of the plant.

- plants with conventional technology. This means quality civil engineering works for the intake, canal and forebays; silt basin at the intake, steel piping, expensive electro-mechanical equipment constructed to strict material and manufacturing criteria, fully instrumented switchboards.
- plants using non-conventional technology. Often use intakes from existing irrigation canals which are improved, the forebay installed in line on the canal and incorporating the silt basin, electro-mechanical equipment designed and constructed with technologies appropriate to the country's level of industrial development and the availability of local materials, standardized equipment, modular switchboards with minimum instrumentation.

FIGURE 1 SCHEMATIC DIAGRAMS OF MINI HYDRO POWER STATIONS (MHG)



Medium and high head MHG



Low head MHG

FIGURE 2 DAMS

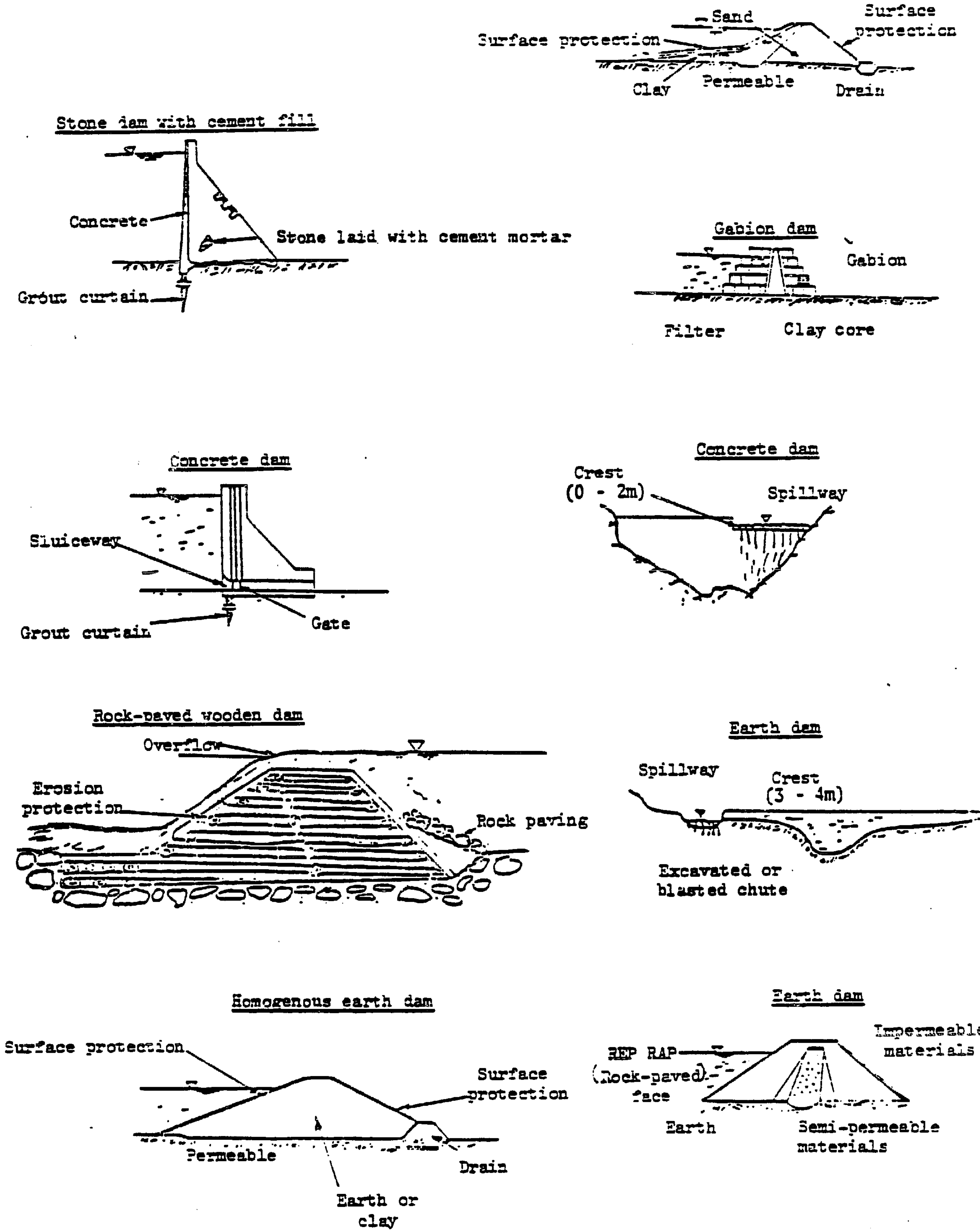
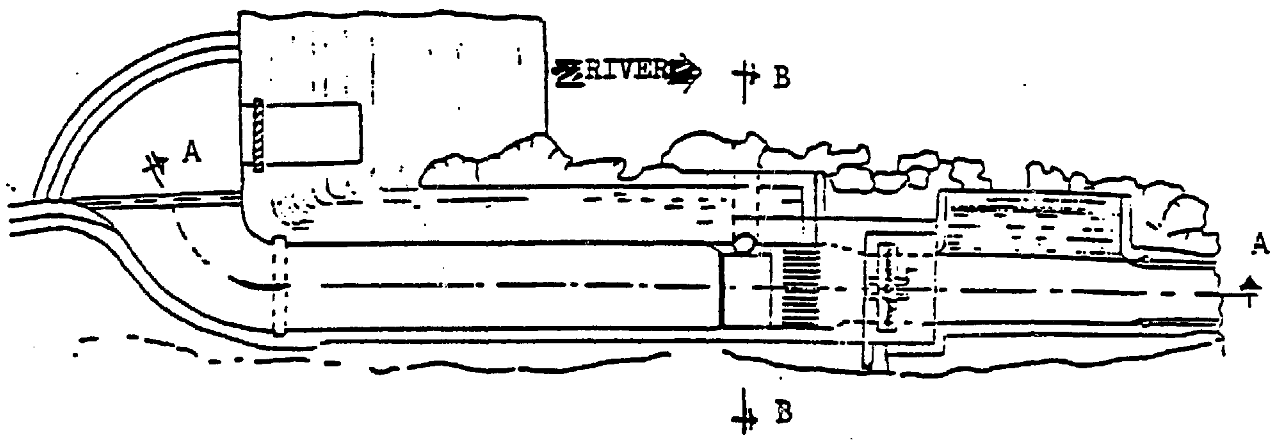
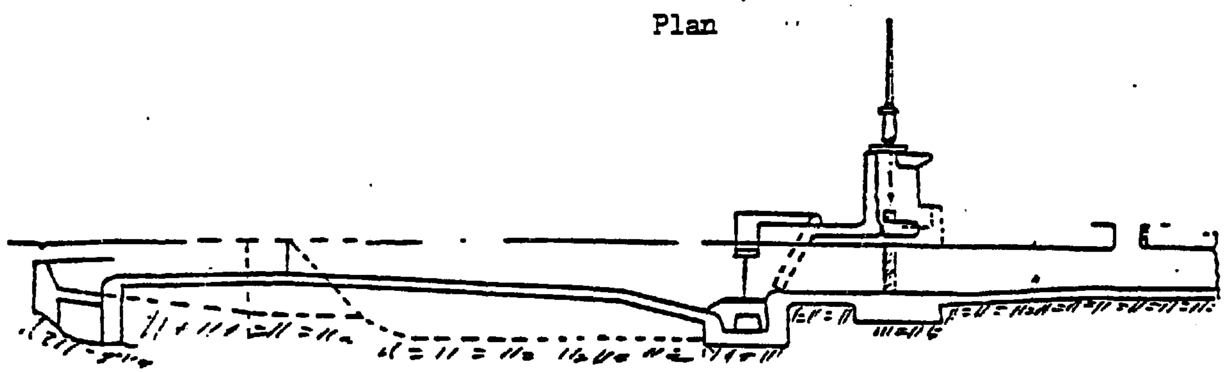


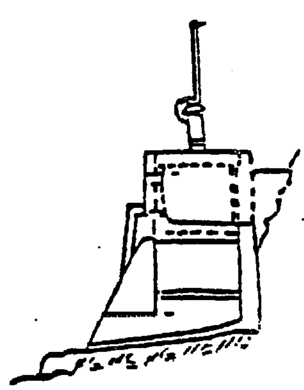
FIGURE 3 GENERAL DIAGRAM OF INTAKE



Plan

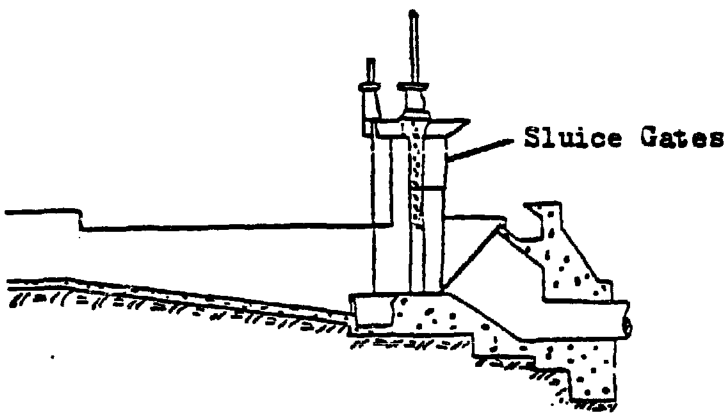


Cross section (A-A)

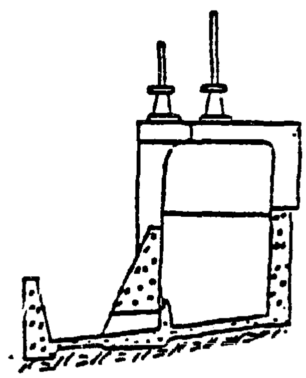


Cross section (B-B)

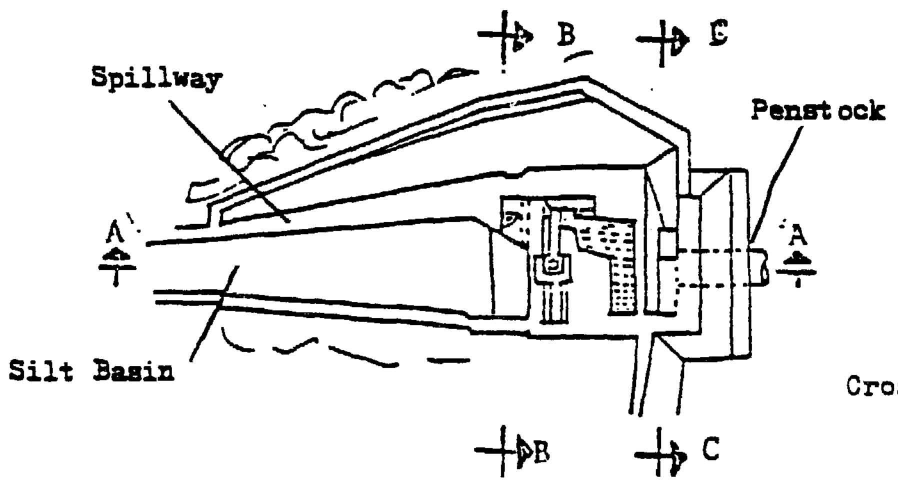
FIGURE 4 GENERAL DIAGRAM OF A TYPICAL FOREBAY

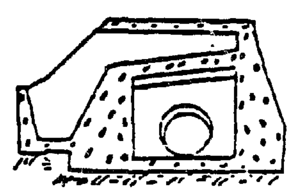


Cross section (A-A)



Cross section (B-B)

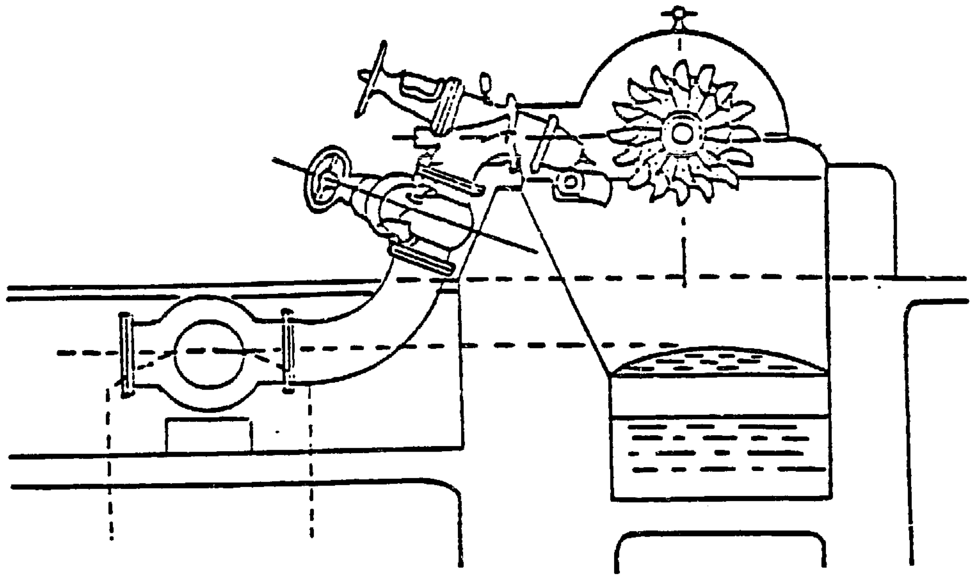




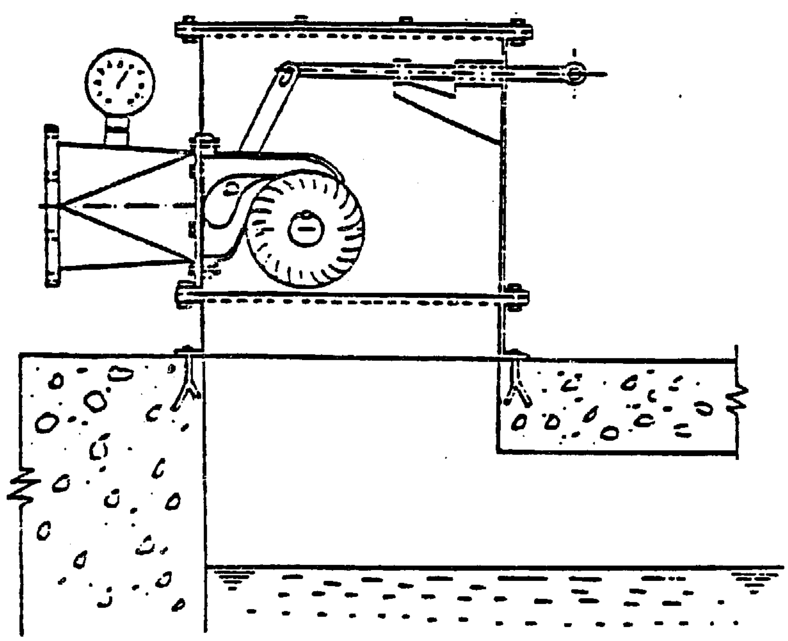
Cross section (C-C)

Plan

FIGURE 5 IMPULSE TURBINES

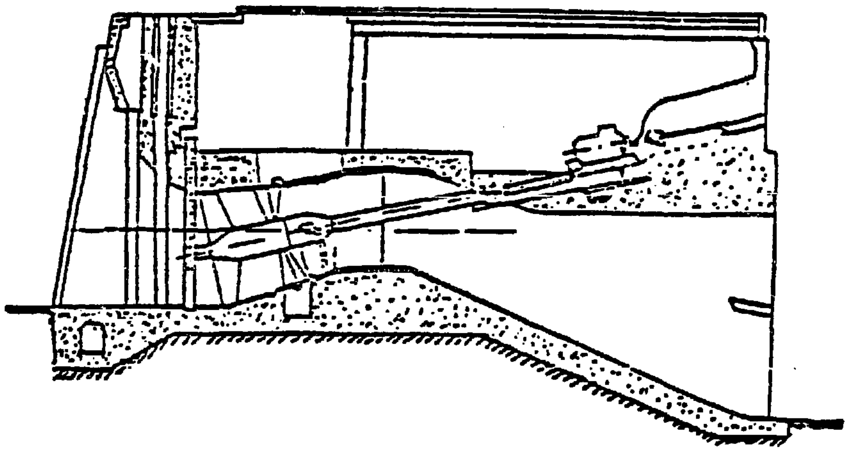


PELTON TURBINE

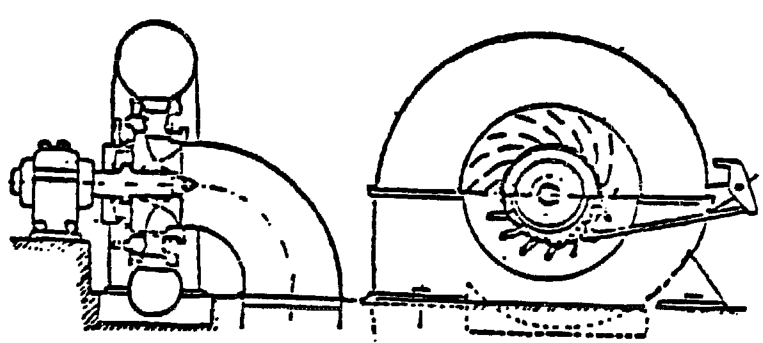


MICHELL BANKI TURBINES

FIGURE 6 REACTION TURBINES

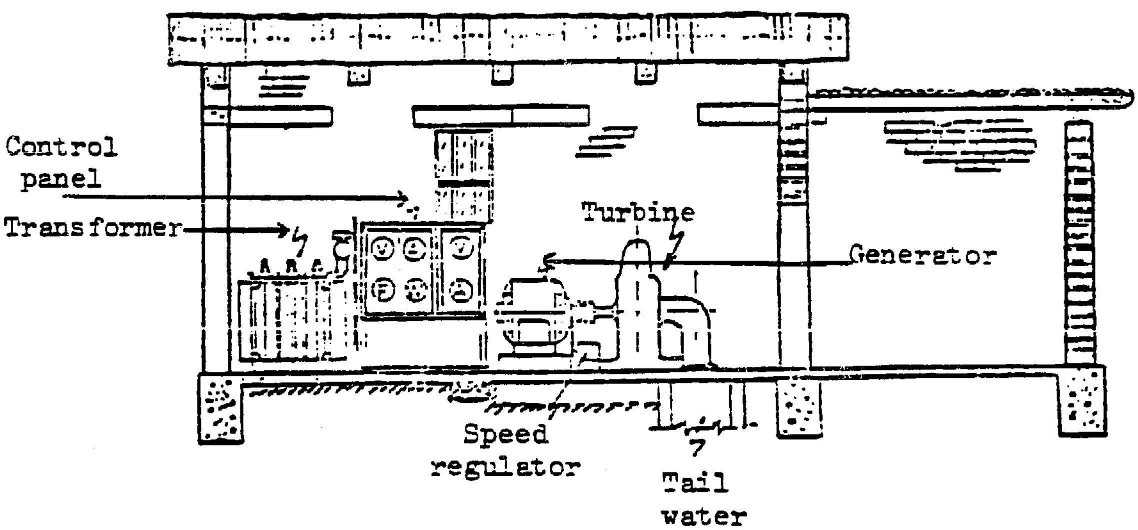


KAPLAN TURBINE

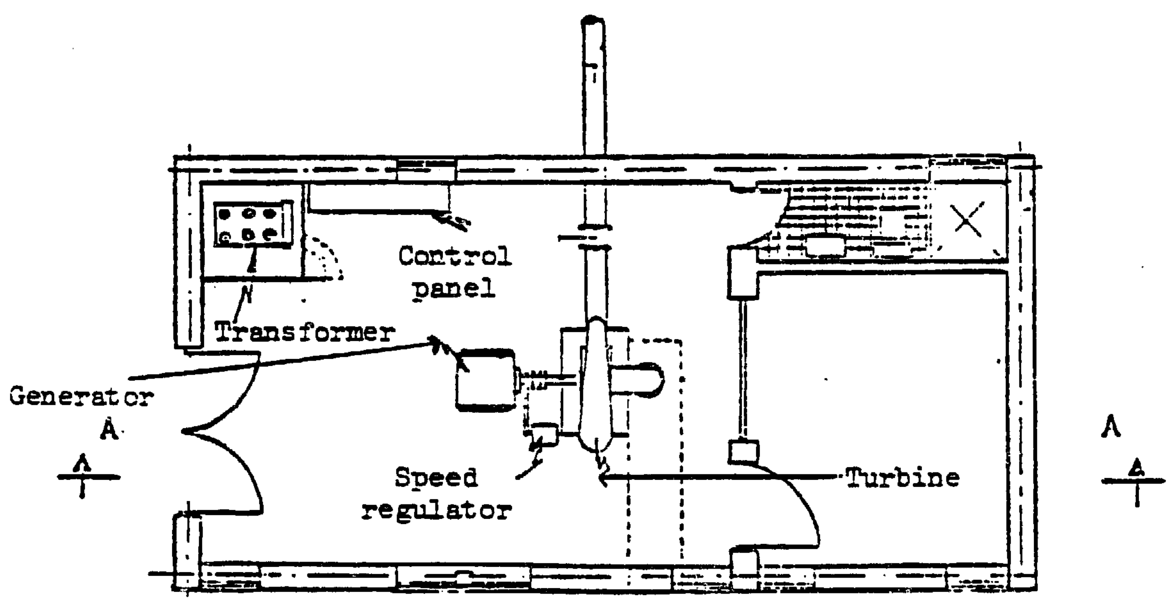


FRANCIS TURBINE

FIGURE 7 TYPICAL POWER HOUSE



Cross section (A-A)



Plan

3. ADVANTAGES AND LIMITATIONS OF MHG

One of the main elements in any policy for developing MHG as sources of energy is how to make the most of their specific advantages and overcome their limitations. Below are given some of the outstanding characteristics in this respect, although they should not be taken as absolute.

ADVANTAGES	LIMITATIONS
- Solution to problems of growing and difficulties in the supply of fuel, particularly in rural and isolated areas. - Helps to promote socio-economic and cultural development in the rural environment. - Technologies available that only require adaptation to specific conditions and in order to reduce costs. - Low operating costs. - Cheap and simple maintenance. - Long service life. - Little or no environmental impact; better control of the hydraulic system. - Can be compatible with the use of the water for other purposes (irrigation, drinking water, etc.) thereby improving investment.	- High unit investment cost per installed kW. - High cost of studies in relation to overall investments. - Utilization dependent upon the availability of hydraulic resources near the points of demand. - It is necessary to solve possible contradictions in the priorities of use of water, particularly for irrigation. - Power production may be affected by meteorological and seasonal conditions. - Continuity of operation depends on the technological characteristics of the installations, an an adequate economic productive basis for the use of the power generated and on adequate institutional arrangements for administration, operation and maintenance.

The specific advantages of MHG open up enormous possibilities of application. Their disadvantages may be grouped under two fundamental problems: the investment required per installed kW and the prospects for the continued operation of the plants installed. Figure No. 8 shows in schematic form the causes of these problems and outlines some of the solutions which can be considered when drawing up development policies.

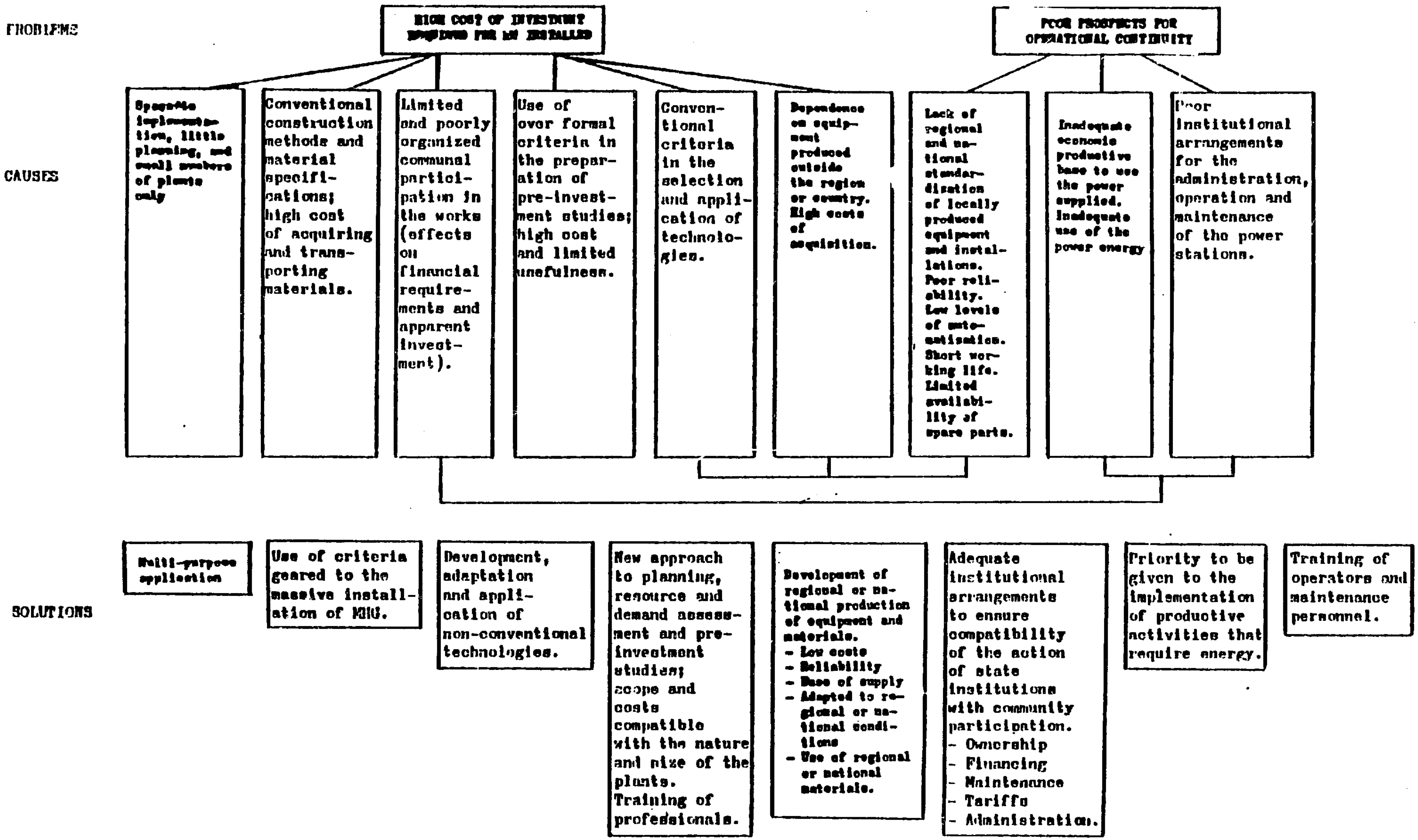


Figure 8 Problems and Solutions for the Development of MHG

4. COMPARISON WITH ALTERNATIVE SYSTEMS

It is not proposed in this chapter to determine the absolute advantages of one or other power system, but rather to establish in qualitative form, without proposing methodologies for quantitative analysis, the main elements and criteria for comparing the alternatives.

Often when making comparative analyses of MHG and other alternative systems certain disadvantages, real or supposed, of the MHG are assumed a priori and the economic evaluations of alternatives are frequently distorted by over-conservative indices.

It is not claimed that MHG are the "best" solution, only that there are appropriate solutions for each case, which are determined by making a comparative analysis of the various alternatives.

4.1. EXTENSION OF AN EXISTING GRID

The question of whether to install an MHG or extend an existing grid (EEG) is mainly one of economic comparison, particularly as regards the investment required. The following are some of the elements which must be taken into consideration in such a comparative analysis:

M.H.G.	E.E.G.
CIVIL WORKS (intake, conduction system, forebay, penstock, power house, accessories, etc.) ELECTRO-MECHANICAL EQUIPMENT (Turbine, regulator, generator, switchboard, etc.) TRANSFORMING To medium tension; not always necessary (Transformer) TRANSMISSION AND DISTRIBUTION LINE From the machine room to the point of consumption; small distance (low or medium tension, voltage reduction for distribution and consumption)	CIVIL WORKS (Sub-station, switching area) TRANSFORMING From high to medium tension (transformers, switchboard, etc.) TRANSMISSION AND DISTRIBUTION LINE Medium tension from the sub-station to the point of consumption, voltage reduction for distribution and consumption

The advantages of one or other alternative are given by the characteristics of the application, i.e. the greater or lesser importance or magnitude of a given parameter determines the comparative advantages of installing MHG or extending an existing network EEG.

PARAMETER	COMPARATIVE ADVANTAGE	
	GREATER IMPORTANCE OR MAGNITUDE OF PARAMETER	LESSER IMPORTANCE OR MAGNITUDE OF PARAMETER
- Distance from point of consumption to existing network	MHG	EEG
- Distance from point of consumption to site of water offtake)power-related factor)	EEG	MHG
- Quantity of energy to be provided	EEG	MHG
- Load factor	MHG	EEG
- Importance of reliability of supply	EEG	MHG
- Uneven terrain	MHG	EEG
- Availability of small-scale economically harnessable hydro-power resources	MHG	EEG
- Availability of energy	EEG	MHG
- Prospects of community participation	MHG	EEG

COMBINING MHG AND EEG

It is possible to combine MHG and EEG in situations such as:

- In countries with abundant small-scale hydraulic resources, densely populated and highly electrified.
- Possibility of using irrigation and water control dams for power purposes in placed near the grid where demand for electricity in the proximity of the dam is only small.
- Countries over-dependent on imported fossil fuels for generating electricity and with abundant small-scale hydro power resources available.
- Progressive development of electrification in several rural localities, beginning with the installation of an MHG and later supplemented by EEG when justified by the growth in demand.

4.2. THERMAL UNITS

Diesel engines - or for smaller needs, gasoline engines (OTTO cycle) - are usually used for generating electricity.

These were traditionally the main alternative to MHG and their very widespread use was due to:

- Low cost of fuel and lubricants
- Low cost of acquisition
- Ease of installation
- Simplicity of operation

With the ending of power systems based on the low cost of hydrocarbons, these units in many cases cease to be a valid alternative way of providing power in rural areas. Also small scale steam power stations operating ranking cycle can be employed to generate electricity, frequently utilizing waste combustable materials or even coal when it is easily available and cheap, such as in coal mines.

ADVANTAGES AND DISADVANTAGES OF THERMAL UNITS AS COMPARED WITH MHG

ADVANTAGES	DISADVANTAGES
- Smaller investments - Ease of installation - Simplicity of operation - Fewer studies needed for their installation	- High and increasing cost of fuels and lubricants. - Expensive to maintain and repair. - Need more highly skilled maintenance and repair staff. - Require imported and difficult to obtain spare parts. - Little prospect of developing local production of motors. - Short service life (5-8 years) - Contribute to environmental pollution. - Help to increase demand for oil.

Economic comparisons of the two alternatives - Thermal Units or MHG - are frequently distorted by the fact that in some countries the prices of oil and its derivatives are subsidized. In such cases the micro-economic analysis must be corrected by macro-economic factors derived from the true cost of the fuels.

At the present time the main cases in which the employment of small thermal units is appropriate are as follows:

- As emergency or reserve units.
- In isolated areas where there are no easily harnessable hydraulical resources and the extension of transmission lines is not justified.

4.3 OTHER RENEWABLE SOURCES OF ENERGY

The various renewable sources of energy offer valid alternative power supplies for rural development. However, in most cases they are not substitutes for MHG, either because of the terminal form of the energy supplied (direct mechanical energy or source of heat) or, even if they can produce electric power, their uses can usually be justified economically only for very small power loads.

The advantages of MHG over other renewable sources of energy may be summarized as follows:

- Easy adaptation for producing electric power.
- Lower unit costs of investment per unit of useful energy.
- Mature and proven technology.

As regards the specific characteristics of the main alternative sources of energy, the following may be said:

a) Direct solar energy

Its main field of application in the countries of the third world is for heating and drying needs.

As regards its passive use, its role is particularly important in environmental heating through appropriate architectural designs.

Solar energy can be harnessed for the direct production of electricity through the use of thermal units operating with the Rankine steam cycle, which involve very high initial investment costs and very low efficiency. Photovoltaic cells are also used for the direct conversion of solar radiation into electrical energy, but in the third world their utilization is only justified for the production of energy needed in small quantities and for highly specialized applications as they do not yet constitute a cheap source of energy.

b) Wind power

Although wind power is mainly used for pumping water from the subsoil, it has many other applications as well and there is even a commercial production of windmills for the generation of electricity.

In general they provide an alternative to MHG for the under 10 kW power range.

c) Bioenergy

Biogas production has great advantages, not only as a source of energy but also in regard to its capacity for the production of fertilizers and its positive impact on health and the environment.

Its main uses as a source of power are in the form of heat for lighting, cooking and the like. It can also be used to fuel properly - adapted combustion engines, a use for which it is also competitive with MHG in the lower power ranges.

Also pyrolisis processes and alcohol can be interesting sources of bioenergy to operate small thermal units.

d) Geothermal energy

Where the resource is available geothermal energy can also be employed to generate electricity, however, this is most frequently applied in medium or large power stations, even though it is also possible to utilize geothermal energy for small units.

5. DEVELOPMENT OF MHG

5.1. POSSIBILITIES OF APPLICATION

Before carrying out specific projects to promote the development of MHG in a given country, it is necessary to determine, at least qualitatively or with a few quantitative elements, the nature and magnitude of the problems to be solved by using MHG, to ascertain, tentatively, the existence of small-scale hydraulic resources and to have an over-all assessment of national capacities in order to initiate their development.

PROBLEMS TO BE SOLVED WITH MHG

PROBLEM OR NEED	ELEMENTS FOR ANALYSIS
TO PROVIDE ENERGY FOR THE RURAL ENVIRONMENT, INCLUDING SMALL INDUSTRIES DEVELOPMENT	Situation: orders of magnitude of the problem Alternatives For what purpose? - To improve living conditions - To develop farm industry - To develop small industries (fertilisers, sawmills, etc.) - For mining development - To develop handicrafts - For irrigation and drainage by pumping - Education and culture - Health
REPLACING HYDROCARBONS	Situation with regard to the use of thermal groups for generating power, use of petroleum derivatives for cooking, lighting or heating. The country's situation with regard to the production and importation of hydrocarbons; orders of magnitude, prospects and limitations in replacing them.
PROBLEM OR NEED	ELEMENTS FOR ANALYSIS
	Transporting hydrocarbons to rural areas. Implications of using thermal equipment (cost, useful life, supplying fuel, maintenance and repairs, etc.). Erosion of soil. Hydraulic control. Deforestation. Pollution.

ASCERTAINING THE EXISTENCE OF SMALL-SCALE HYDRO POWER POTENTIAL WHICH CAN BE USED FOR MHG

POTENTIAL	ELEMENTS FOR ANALYSIS
AVAILABILITY OF HYDRO POWER RESOURCES	Qualitative assessment of: a) Precipitations and hydrology (flow) b) Terrain (heads) c) Geological and qualitative geo-morphological characteristics of the territory. Estimate (if possible) of the order of magnitude of the potential. Analysis by areas or regions.
LOCATION OF HYDRO RESOURCES IN RELATION TO DEMAND	It should be borne in mind that for isolated MHG or those which are a part of small grids, use of hydro power should be close to the location of demand. Potential should be estimated in areas which are close to the demand, except for MHG which are interconnected with larger grids.
ACCESSIBILITY OF AVAILABLE RESOURCES	- Communication - Geographic accidents - Climate - Healthiness
POSSIBILITIES OF MULTIPLE USE	- Irrigations, use of existing waterways. - Use of existing dams. - Multiple projects (irrigation and energy).

MAXIMUM UTILIZATION OF NATIONAL CAPACITIES FOR DEVELOPING MHG

CAPACITIES	ELEMENTS FOR ANALYSIS
PLANNING	Organization, experience
OVER-ALL EVALUATION OF RESOURCES AND DEMAND	Institutions, studies which have been carried out, organization.
PREPARATION OF PRE-INVESTMENT STUDIES	Institutions, advisers able to prepare projects and develop engineering; experience.
FINANCING	Availability, financial institutions, external sources.
INSTITUTIONAL ORGANIZATION	Electrical enterprises and their activities in rural areas. Municipal and co-operative enterprises. Private producers, communal participation; traditions and experience.
CONSTRUCTION	Experience, small contractors, contracting firms, enterprises; materials.
OPERATION AND MAINTENANCE	Organization of operation and maintenance.
HUMAN RESOURCES	Availability at all levels.
TECHNOLOGY	Availability, capacities for development and adaptation, information. Experience in acquiring technologies.
SUPPLYING EQUIPMENT	Existing or potential production, imports, information.

After analysing energy needs, the availability of hydro power resources and the national capacities, a policy decision must be taken as to whether the implementation of MHG should be encouraged or not, in which connexion the following should be borne in mind:

- It should rely on such information as is available and not wait for the preparation of ad hoc studies; consequently, the decision will be based on fundamentally qualitative elements and on very approximate quantitative elements. Together with the process of planning the development of MHG, studies must be carried out to define the scope of a development programme, as well as any possible corrections of the policy which has been adopted.

- It should be borne in mind that there may be territorial distinctions within a country concerning the development of MHG, depending on the availability of hydraulic resources and the energy needs which have to be met.

- The policy decision should be taken with due regard for the time and context of development priorities in relation to other energy sources.

- A policy for the development of MHG is absolutely dependent on such factors as the availability of hydraulic resources and energy needs. National capacities are factors which can facilitate or impede the development of MHG in a country, but they are not absolute factors, since they can be changed.

- The development of MHG calls for integrated actions on various fronts, as is pointed out in the table of national capacities and summarized in Figure 9.

- The policy decision to develop MHG should be the basis for the formulation of a strategy of development and specific policies, the elements of which are analysed in the following section of this chapter.

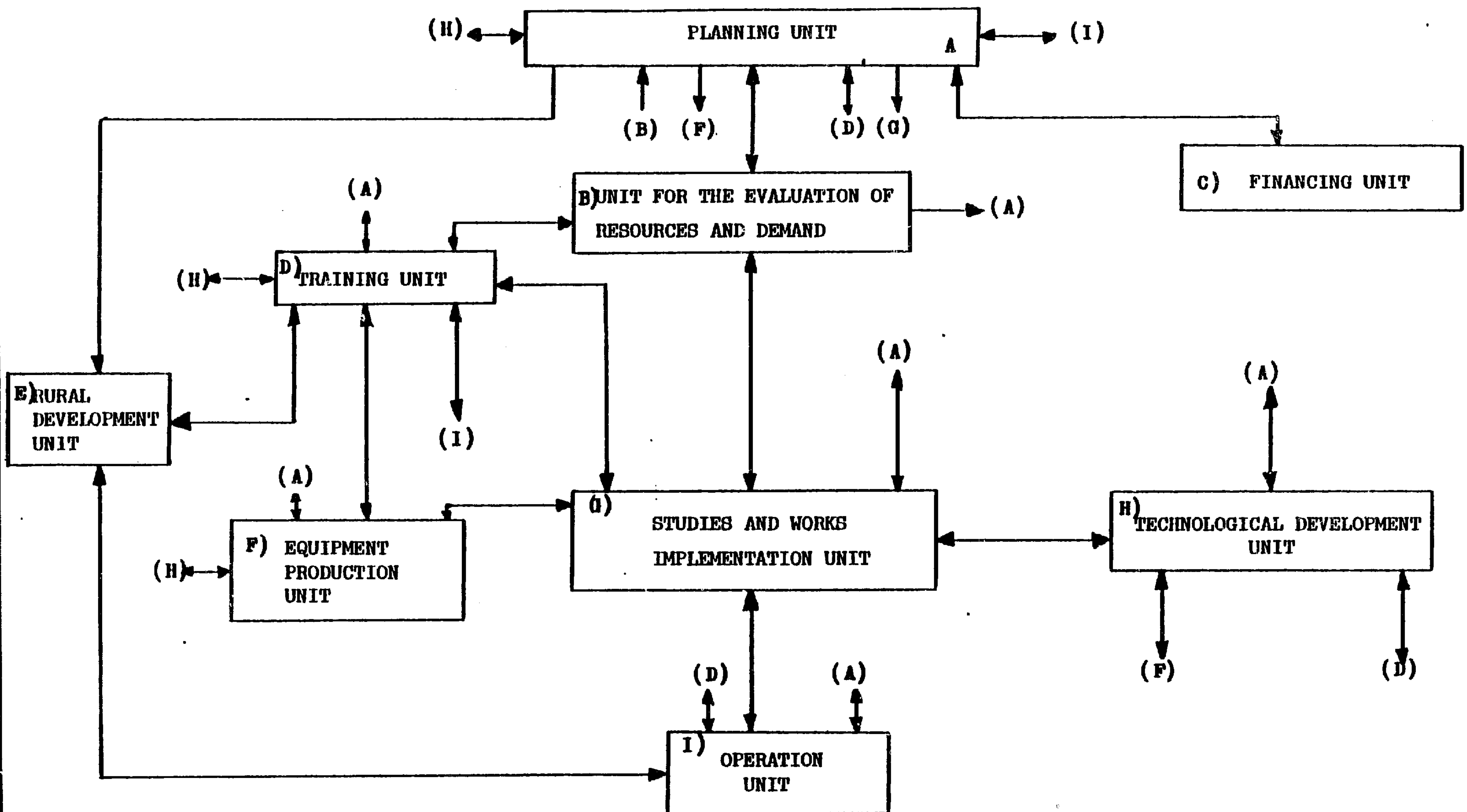


Fig. 9 BASIC RELATIONSHIP DIAGRAM OF VARIOUS SCHEMATIC UNITS TO BE CONSIDERED FOR THE DEVELOPMENT OF MHG

5.2. ORGANIZATION OF PLANNING AND PROGRAMMING

Once it has been decided to develop MHG in the country, it is necessary to define the following:

a) The responsible governmental sector (ministry, State secretariat, State institution, etc.). In general, it will be found within the scope of the ministry or State secretariat responsible for energy affairs.

b) The body responsible for planning, directing and/or co-ordinating the development of MHG may be:

- The central planning organ.
- The planning office of the competent ministry or State secretariat.
- The planning department of an enterprise or institute responsible for energy development.

Within the body responsible for planning, a unit or section should be established which will be specifically in charge of developing MHG separate from the unit or section dealing with larger hydro power sources. The functions of MHG sections or units can be as follows:

- To propose development policies and strategy.
- To formulate development plans.
- To formulate periodic programmes for implementation (studies on civil engineering works and financing).
- To co-ordinate and supervise the units responsible for the programmes for evaluating resources and demand, carrying out civil construction works, and operations of plants.
- To act as an advisory body for MHG development.
- Co-ordination with institutions and enterprises responsible for financing, technological development, production of equipment and training.
- Defining tariffs or the criteria for establishing them.

The compulsory or indicative character of the plan will depend on the country's social-economic system, its political organization and on whether there is a greater or lesser participation of the public or the private sector in the various parts of the implementation of the plan.

Figure 10 gives a diagram of relations in the process of planning the development of MHG, forming a part of the over-all diagram in Figure 9.

As complementary activities, the unit in charge of planning will be able to perform the following functions:

- Keeping records of localities without electricity and a catalogue of suitable hydraulic resourçes, prepared by the body responsible for evaluating resources and demand.
- Alternating requests for financing and actions taken by the local population and deciding whether they can be incorporated in the implementation programmes.
- General negotiations concerning the large-scale purchase of equipment.
- Co-ordination with communal institutions and organizations which can promote the development of MHG in their localities.
- Suggesting needs for technological development to the competent institutions and evaluating the use of non-conventional technologies.
- Suggesting institutional schemes for the construction and operation of MHG.
- Co-ordinating international technical co-operation.

The first thing to be done in a country where systematic projects to develop MHG are being undertaken is to prepare a "short-term plan" with a view to carrying out certain concrete projects while a "development plan" is being drawn up which will require studies on the evaluation of energy needs, the availability of resources and the establishment of priorities, and which will also have to promote activities in various fields connected with technology, the production of equipment, training and financing.

On the basis of the short-term plan, a one or two-year implementation programme will be drawn up, of which the following aspects should be considered:

- Termination of uncompleted works.
- Abandoned works (power stations where civil engineering work has been begun, having acquired equipment which has not been installed, etc.).
- Relocation of existing equipment in abandoned plants.
- Identified needs (new projects, or projects having studies).
- Existence of civil engineering works which may reduce costs (irrigation canals, dams, etc.) and which can shorten times for implementation.
- Installation of pilot plants to evaluate technological alternatives and capacities for implementation.

The development of the short-term plan and its respective programmes offers the following advantages:

- It makes it possible to initiate MHG development projects without involving any delay due to the need to prepare a coherent, overall plan; on the other hand, it provides sufficient time for drawing up the development plan.
- It makes it possible to acquire experience which can be used for the development plan.
- It makes it possible to develop mature projects.
- It helps to demonstrate the MHG.
- It stimulates the development of communal self-help projects.

Simultaneously with the preparation and implementation of the short-term plan and the programme for its implementation, the planning unit will have to begin to prepare the "MHG Development Plan", which calls for a series of preliminary studies and evaluations that will constitute the objective basis of the plan.

STUDIES AND EVALUATIONS NEEDED TO FORMULATE THE PLAN

Identification of populated and isolated centres and micro-regions which are in need of energy development. (Study entrusted to, or contracted with, the Unit for the Evaluation of Resources and Demand).

Evaluation of resources by hydrographic basins and watersheds (first approximation) and approximate evaluation of potentially exploitable resources in areas close to isolated populated centres and micro-regions (second approximation); studies entrusted to the Unit for the Evaluation of Resources and Demand or contracted for outside.

Inventory of existing MHG, evaluation of their condition and operational situation.

Estimate of potentialities and financial sources.

Evaluation of available technology and prospects for its development, adaptation or acquisition.

Evaluation of potentialities for supplying equipment and materials of either national or imported origin. Potential industrial capacities for equipment manufacturing.

Evaluation of the available experts for studies and engineering.

Summary of investment and operating cost indices.

Evaluation of the institutional situation and of experts to construct and operate MHG; possibilities of communal participation.

The plan must likewise take due account of specific policies which can provide the framework for a development strategy. Following are some suggestions for policies and their possible characteristics, which will have to be adapted to the conditions of each country.

POLICY OF RURAL ENERGY DEVELOPMENT

- Increase in added value of production by means of establishing rural industries.
- Development of energy-producing activities.
- Improving living conditions.
- Health, culture, recreation.
- Pumping water.
- Multi-purpose use of dams.
- Development of small rural electricity grids.
- Interconnexion of MHG with national networks or development of isolated localities.

INSTITUTIONAL POLICY

- Position in the context of rural development.
- Participation of electrification bodies or enterprises and communal participation; organizational and entrepreneurial forms; (mixed municipal enterprises, private co-operatives).
- Distribution of institutional responsibilities among the various activities of MHG development.

CONSTRUCTION POLICY

- Gradual implementation aimed at the future large-scale construction of MHG.
- Intensive use of local materials and labour.
- Use of non-conventional construction techniques and material.

FINANCING POLICY

- Basic properties for assignment of resources for MHG.
- Financing criteria; non-recoverable investments and operation financed by tariffs.
- Evaluation of communal contributions of labour and materials.
- Ways of obtaining external financing.

EQUIPMENT POLICY

- Original of supplies; priority for national supplies.
- Promoting the development of domestic productions.
- Adapting project engineering work to national supplies of equipment and materials.
- Quality and criteria for acceptance. Prospectives of standardisation.
- Determining equipment components to be obtained from domestic industrial production

TECHNOLOGY POLICY

- Promoting the development and adaptation of technologies relating to equipment and materials.
- Determining channels for transferring developed technology to industry.
- Promoting the development of non-conventional construction technologies.
- Determining channels for distributing construction technologies to project units and communities.
- Determining what equipment will be developed with local technologies and what will require acquisition of foreign technologies.
- Determining what conditions are unacceptable for contracts for the acquisition of technology.

TARIFF POLICY

- To make energy available to the inhabitants of remote areas with few economic resources.
- To ensure the operational continuity of MHG through funds derived from tariffs.
- Basic proportionality of national tariff systems; subsidies.
- To promote the rational use of electric energy.
- To promote the use of electric energy for productive purposes.

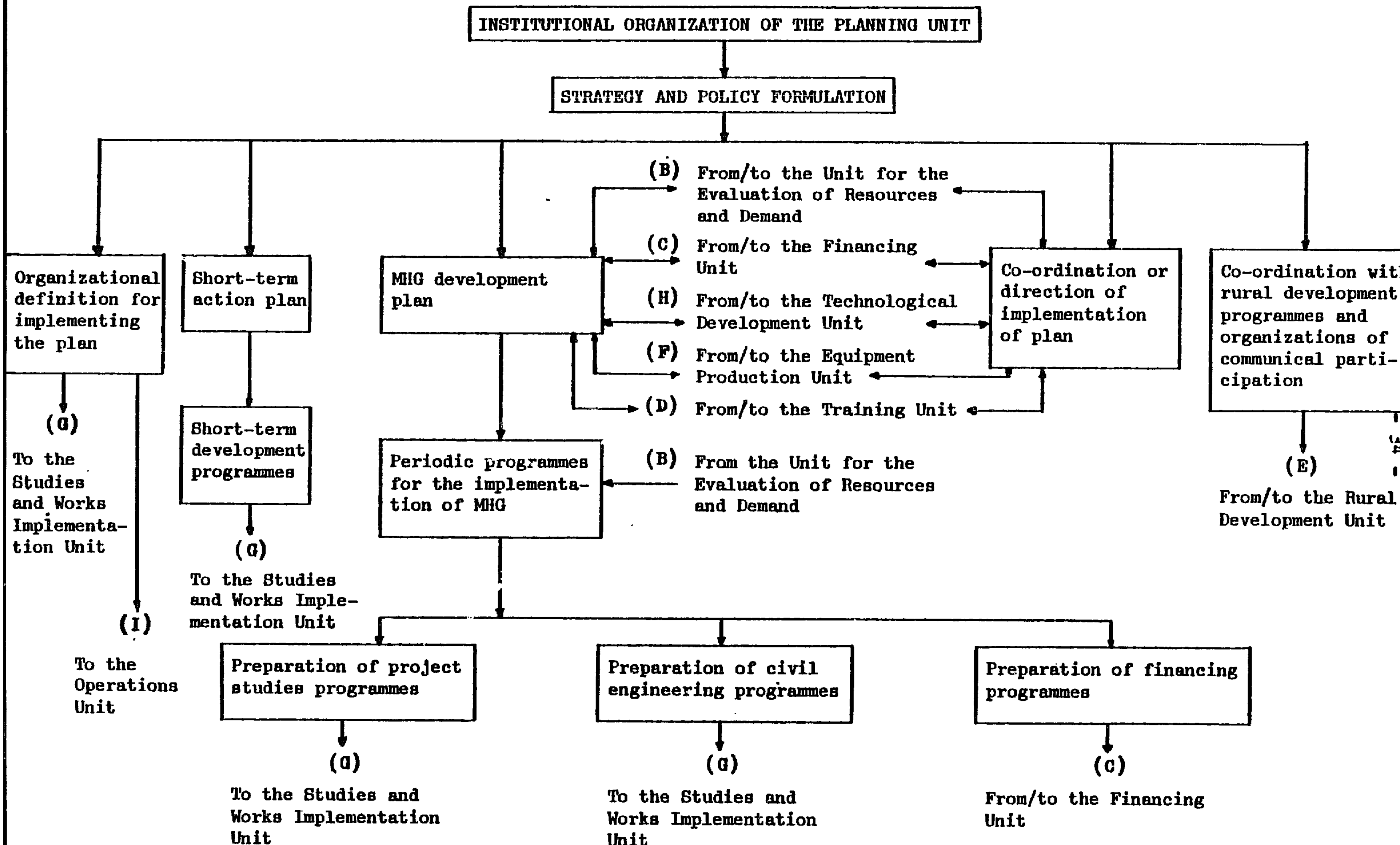
TRAINING POLICY

- To train professional and technical cadres for research, project studies and engineering, construction, and operation of MHG.

OPERATION AND MAINTENANCE POLICY

- Equipment technology to be employed must take into consideration useful life, simplified preventive maintenance, minimise maintenance requirements, ease of maintenance and repairs, domestic manufacturing of components, stocks of spare parts, etc.
- To organise regional maintenance squads.
- Training operators of rural origin in preventive maintenance.
- Establish shop facilities for repairs and reconstruction of equipment.
- To promote the participation of local population in the main-

FIGURE 10 PLANNING UNIT FOR THE DEVELOPMENT OF MHG



5.3. OVER-ALL EVALUATION OF RESOURCES AND DEMAND

This is one of the principal elements to consider when promoting the construction of MHG in a country, as it is the main frame of reference for drawing up development plans and implementation programmes.

GENERAL CONSIDERATIONS FOR THE OVER-ALL EVALUATION OF RESOURCES AND DEMAND FOR MHG

- The over-all evaluations are directed toward the study of the demand and resources for micro-regions and basins and do not go into the studies of specific projects in detail.
- When considering the development of MHG in micro-regions or isolated localities, it must not be forgotten that the over-all evaluation of demand and resources for energy are closely connected, in geographic terms, because of the limitations of the distance over which low and medium-tension current can be transmitted.
- When attempting to connect MHG to existing networks, the geographical link should be established between the area where the hydraulic resources are found, and the transmission lines to which it is planned to connect with.

It is very important to distinguish between the over-all evaluation of sources and demand and evaluations which are made for studying specific projects.

DISTINCTIONS BETWEEN OVER-ALL EVALUATION AND EVALUATIONS FOR SPECIFIC PROJECTS

OVER-ALL	SPECIFIC
- Is needed for the formulation of MHG development plans and programmes.	- Is needed for studies of individual projects.
- Study of the over-all energy needs of a micro-region or propulation groups in a specific area.	- Study of the energy needs of a locality or population group which it is hoped to serve with specific projects
- Study of exploitable resources in a basin or dip, with a preliminary list of specific projects.	- Study of the resources for a specific project.
- General, extensive and multidisciplinary studies to evaluate resources, including: Hydrology Ecology Geology Geotechnics Availability of aggregates	- Detailed studies of a project, reduced to an absolute minimum in order not to increase pre-investment costs: - Water gauging (flow measurements) - Geotechnics (punctual and approximate) - Topography
- The evaluation of the over-all demand in an area must be integral and statistical in nature.	- The evaluation of demand must be based on a detailed investigation of the localities connected with the project.

Section 7.1. refers to the evaluation needs for specific projects.

Depending on the local conditions in each country, the over-all evaluation of resources and demand should be made by an ad hoc technical unit, which should be responsible to the unit in charge of MHG planning; alternatively, these functions can be entrusted to some institution which specializes in evaluating natural resources or in hydrology. Consideration could also be given to having these functions carried out by a specialized unit of some firm engaged in electrical development.

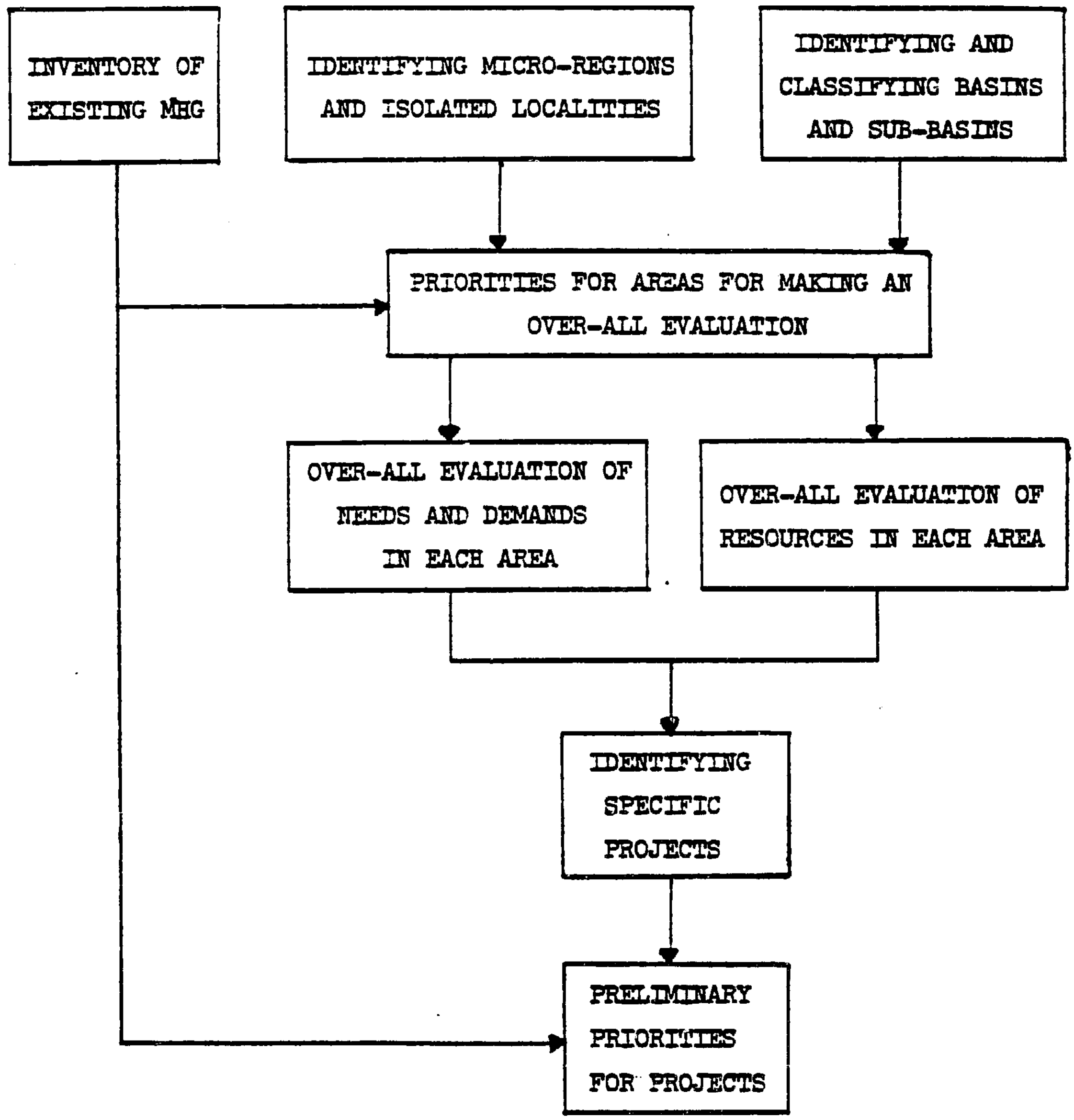
If there are any limitations with respect to the institutional organization for the over-all evaluation, consideration might be given to hiring specialized advisers under the supervision of the planning unit.

The unit in charge of the over-all evaluations will have the following main functions:

FUNCTIONS OF THE UNIT FOR THE OVER-ALL EVALUATION
OF RESOURCES AND DEMAND

- Identifying and evaluating existing MHG.
- Assigning priorities to the areas to be evaluated in co-ordination with the Planning Unit.
- Carrying out evaluation studies of basins, sub-basins and water sheds by direct methods or mathematical models.
- Evaluating energy development needs and potential in rural areas.
- Identifying specific MHG projects and suggesting priorities for their development.

Below is a typical flow chart of the activities of over-all evaluation:



The outlines suggested for evaluating resources and demand should not be applied mechanically in any country whatsoever, since there are special conditions in every case which call for an individual approach based on:

- The characteristics and distribution of small scale hydraulic resources.
- The relative importance of MHG in rural development.
- The existence of institutions, statistics, studies and technical cadres for carrying out evaluation activities.

Some characteristics activities for over-all evaluation must have, are described below.

a) Inventory of existing MHG

This consists of identifying existing and projected plants.

It is recommended that special evaluation forms should be prepared in order to record the following data:

- Data concerning the location.
- Hydrological data and an appraisal of the basin.
- Basic specifications of the power station and its main equipment (capacities, head, flow, type of turbines, piping, generators, etc.).
- State of preservation (for existing plants).
- Data concerning service and the population supplied, including characteristics of demand and types of consumption.

The inventory constitutes a useful tool for organizing plans and programmes, both when evaluating the state of development of the MHG and when determining short-term activities for re-adapting, relocating and continuing projects, as well as for determing the country's own reference indices.

This inventory can be used for studying other existing energy sources, especially with regard to the extension of existing electrical networks and thermal power stations which have been installed.

One example of possible evaluation forms for recording data on MHG units is shown in Figure 11.

Figure 11 Form for MHG Units Data Sheet

Name of the MGH Units:

Location:

(1)	(1)	(1)	Location

(1) Define according to political-administrative devision of the country.

BASIN	SUB-BASIN		WATERSHED	
Capacity	Area (km^2)	Minimum Daily Flow (m^3/sec)	Maximum Flood Flow (m^3/sec)	Multi-year Average Flow (m^3/sec)

(2) Alternatively indicating basin or sub-basin data.

Status of the MHG Unit: Existing Under construction Projected

Condition of the MGH Unit: Good Bad In-operative

Status of the Networks: Existing Under construction Projected

Condition of the Networks: Good Bad In-operative

Power installed or to be installed (kW) (3):

Maximum Demand Foreseen (kW):

Annual Energy Mean (kWh):

Kind of Turbine:

Design Flow (m^3/sec):

Gross head (m) (4):

(3) In generator terminals

(4) Difference between upper level of water in the forebay and the lower level of head utilization in the turbine.

Population Served: Number of Consumers:						
Use of electric energy (%)						
Public Lighting	Household	Commercial	Industrial	Irrigation	Mining	Others
Others (Explain):						

Productive activities using electric energy (Detailed: carpentry, bakery, brick-making, etc.)

OBSERVATIONS:

(b) Identifying and classifying basins and sub-basins

This is a preliminary approximation based on office work on geographic and or topographical maps and on existing hydrographic evaluations.

It includes the approximate determination of the hydrographic and physical parameters of the country's basins and sub-basins, either on the basis of measurements and studies which have been carried out of by inference with mathematical models.

This study may be extended to the systems of watersheds belonging to a sub-basin by establishing correlation parameters when determining run-offs.

This study will lead to the need for preparing hydrological studies for specific basins and sub-basins, where the hydrological data call for greater reliability.

It is necessary to draw up criteria for geographic correlation with respect to the micro-regions and isolated localities which are identified.

c) Identifying micro-regions and isolated localities

This is a preliminary approximation for determining energy needs, based mainly on existing statistical data which can be obtained from censuses and regional studies.

Suitably designed files should be prepared in which to record the principal data concerning micro-regions and rural localities with respect to their population, produtive activities and production, communication routes, availability of supplies, approximate energy requirements, etc. Data for this preliminary evaluation should be restricted to an absolute minimum.

In the process of grouping localities in micro-regions, the following factors should be taken into account:

- Physical proximity.
- Communications.
- Political and administrative division of the country.
- Location with respect to sub-basins and hydrographic water shed.
- Economic and social links

Considering that the available statistical information will frequently not be up to date and will not contain certain elements of information, it is necessary to prepare mathematical models of population growth (or decline) and correlation indices for determing quantitative parameters, which should be checked by field sampling.

The prepared files should be kept permanently up to date, not only with regard to time but also with regard to the accuracy of the information. (One example of possible forms for collecting data concerning micro-regions and rural localities is shown in Figure 12).

d) Priorities to be given to areas or micro-regions in making the over-all evaluation

The information obtained during the three previous stages will provide the basic elements for assigning priorities to the areas where the studies for the over-all evaluation will be carried out, inasmuch as it will hardly be possible or justifiable to evaluate the entire territory of a country simultaneously, because of the following:

- The cost and the limitations of the available financial resources.
- The minor significance of certain areas for the development of MHG because of their hydro-energy potential or population density.
- The limitations regarding human resources and institutional experts to carry out the over-all evaluation.

This work consists of establishing priorities among areas in order to prepare a small-scale evaluation of the hydraulic resources in the sub-basins and hydrographic water shed of the area and an over-all evaluation of the needs and energy demand of the localities situated in it; in other words, priorities will be assigned in order to determine those areas which will require more detailed evaluation studies because of their better possibilities for the development of MHG, as shown by the preliminary studies for identifying basins and populations.

Figure 12 Form for Data for the Identification of Isolated Centers and Micro-Regions

Name of Population Center: ______________________

Location Data:

(1)	(1)	(1)

(1) According to the political-administrative division of the country.

DEMAND

Population		Pop. Density (inhab/km^2)	
No. of abandoned potentials			
Domestic	Commercial	Industrial	Others

WATER SHED TO WHICH IT BELONGS

AREA (km^2)	MINIMUM DAILY FLOW (m^2/sec)	MAXIMUM FLOOD FLOW (m^3/sec)	ANNUAL OR MULTI-YEAR AVERAGE FLOW (m^3/sec)

SPECIFICATION ALTERNATIVES

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
FALL UTILIZABLE FOR MHG (m)(2)				
FLOW UTILIZABLE FOR MHG (m^3/sec)				
INSTALLABLE POWER FOR MHG UNITS (kW)				

(2) Measured from the intake level up to the minimum utilizable level in the discharge.

STATUS OF SERVICE

Available electric service: Yes No
Kind: Hydraulic Thermal Transmission from larger E.S.
Quality of Service: Good Bad Fair
Year of installation or interconnexion:
Level of sub-transmission tension (kW):
Condition of Networks: Good Bad Fair

Hydraulic Generation: Exiting Under construction Projected
Condition of MHG Unit: Good Bad In-operative
Installed Power (kW): Max. Demand: Energy (kW):
Available head (m):
Utilizable flow (m^3/sec):
Distance from SHPS to population center (km):

Note: In case several units exist, indicate the characteristics of each.

Thermal Generation: Existing Under construction Projected
Condition: Good Bad In-operative
Installed Power (kW): Maximum Demand(kW): Energy(kW):
No. of Groups: Potential of each: Kind of Equip.:
Fuel Used: Efficiency (kWh/gal.):

Generation from other Elec. System:
Existing Under construction Projected
Line capacity(kW): Length(km):
Power of Largest E.S.(kW): Total annual Energy(kWh):
Maximum Demand (kW):
Type: Hydraulic:
Thermal Fuel Used
Mixed

ROADS SYSTEM

Road: Asphalted Paved Unpaved
Transitability (mos./yr.):
Distance from other population centers: Center Distance(km)

IRRIGATION

Number:	Existing(E):	Projected(P):	
Irrigation	Status (E or P)	Irrigated Area (km^2)	Flow (m^3/sec)

ECONOMIC ACTIVITIES:

Livestock (head): (Swine) (Sheep) (Cattle) (Others) (Detail)__________

Agriculture (Area farmed): (by types of crops-detail.)__________

Mining: (Type of minerals, reserves, amount exploited):__________

Agro-industry (Types and production capacities):__________

Other industries and handicrafts (Detail):__________

In order to determine these priorities, it is necessary to establish weighted evaluation criteria which must be co-ordinated with the Planning Unit. The following parameters can be considered, however, their weights and values should be established in connection with the priorities defined by the national development plans and government policies.

PARAMETERS FOR ASSIGNING PRIORITIES TO AREAS FOR THE OVER-ALL EVALUATION OF RESOURCES AND NEEDS

- The population which can be served.
- The existence of hydraulic resources.
- The existence of favourable conditions for constructing MHG, in so far as can be determined from the preliminary studies.
- The area's possibilities for economic development and for the use of energy for productive purposes.
- The physical interconnexion between localities in the area and with other regions (road network).
- Possibilities of interconnexion with larger systems.
- Other energy alternatives
- Possibilities of multiple-purpose development.

Some of the above-mentioned criteria would hardly come under consideration in determining priorities, because of the limited information provided by the preliminary identification studies and inventories.

This stage still does not constitute an adequate basis for the "development plan" and the "MHG implementation programmes" derived from it, but it is certainly useful for formulating the "short-term plan", especially in those cases where possibilities for projects with special advantages have been specifically identified.

e) Over-all evaluation of resources in each area

The over-all evaluation will focus on the sub-basins and watersheds which offer the best possibilities and are closely connected with the localities which are potential users; consequently, it will have to be made parallel to and together with the evaluation study of demand and needs referred to below.

As was mentioned before, the over-all evaluation studies of the resources of each area and each sub-basin which have to be analysed may include studies of hydrology, ecology, geology, geomorphology, geotechnics and the availability of aggregates, the possible scope of which is described in the following paragraphs. However, it should be repeated that although these evaluations will make it possible to identify specific projects, they should not be made for each and every project, in order to avoid excessive pre-investment costs for the individual projects. Moreover, the depth and exact detail of the evaluation will depend on its hydro-energy potential and energy requirements, which in many cases can be limited to qualitative or approximate evaluations.

(1) Hydrology

Purpose - to estimate the flows which can be used for mini power stations, by generally determining the minimum flows, i.e. flows where there is an 85-95 per cent probability that they will be exceeded on a monthly basis.

Methodological aspects - The minimum flow is generally ascertained on the basis of flow/duration curves, although they are often hard to determine by direct methods, since in many cases no hydrometric records are available and it is necessary to resort to indirect methods by determining and applying index values.

It is also possible to establish criteria of constant similitude between the sub-basins and the main basins which will help to generalize the information that is most likely available for the larger basins, especially for the precipitation/duration and flow/duration curves.

The available pluviometric information (precipitation measurements) should be supplemented by preparing regression equations of existing data; moreover, the hydrometric information which is generally available should be used by applying interpolation criteria to supplement the flow records. Hydrological models can also be used when there are no representative hydrological series in the sub-basins by simulating run-off series for the drainage area in question. One interesting model which would require some adaptation for practical use is the Norwegian SNFS system in which the transfer through each sub-basin is simulated by a system of tanks.

In the final analysis, the monthly minimum flow or that which is exceeded 95 per cent of the time, assuming the predominant use of "run of river" mini hydro power stations, can be defined as a percentage of the average multi-annual flow. It is possible to draw up equations establishing a relation between the annual average flow or the annual average hydraulic capacity ($m^3/S/Km^2$) (also known as discharge modulus) and the corresponding drainage area of the basin, which, together with the duration curves which have been ascertained directly, makes it possible to define linear expressions for calculating the minimum monthly flows.

Daily flows may vary considerably, since daily minimum values are generally lower than monthly values. However, they cannot be very accurately predicted, which would lead to an apparently insoluble problem, considering that in the case of "run of river" mini hydro stations there is practically no storage. In spite of this difficulty, the problem may be irrelevant, inasmuch as the occurence of daily minimum flows which are less than the monthly ones would affect the operation of the plants only temporarily.

Ideally, it would be desirable to have estimates for a minimum period of three years, concerning the watercourse from which water would be obtained, although this is only practical for groups of projects in a given basin and not for a specific mini hydro power station.

Relevant information supplied by the local population can also help, if properly interpreted, to evaluate historical flows, especially with regard to floods. Maximum flows supply a useful reference point for planning civil engineering works, especially with regard to their protection.

(2) Ecology

Purpose - To describe the environment in which flora and fauna will develop in order to determine its effect on project characteristics, building types, and materials, and equipment to be used; its effects on prospects for conservation and, on the other hand, the effect of establishing mini hydro power stations on the ecology of the basin or sub-basin.

Methodological aspects - For the reasons pointed out above, this kind of study is only suitable for evaluating basins and not for evaluating specific projects; in the letter case, what is needed are merely general comments on the ecological aspects.

This will cover the following aspects:

- Climate
- Biological zones
- Soils (from the point of view of human use)
- Vegetation
- Fauna
- Bodies of water and aquatic biology.

(3) Geology

Purpose - To determine the basic characteristics and composition of the soil and sub-soil of the basin in order to establish some general guidelines for construction, mainly with regard to structural and seismic aspects.

Methodological aspects - It is advisable to undertake studies which apply to basins and sub-basins rather than to specific projects. The most relevant aspects of such studies are the following:

- Lithology (geological formations, using stratigraphical methods)

- Structural geology (faults, determining directions of volcanic activity)
- Seismology (records, probability of earthquakes and their magnitude).

(4) Geomorphology

Purpose - To study the conformation of the surface of the terrain and evaluate it with a view to determining, in particular, the accumulation and deposit of sediment in the watercourses, while considering its eroding effects on equipment and the consequent need for suitable planning for silt basins and selecting materials for the turbines (mainly rotors and injection systems). It is also helpful in making a final selection of the site in order to avoid possible land slides and erosion.

Methodological aspects - The identification of structures on the basis of geomorphological maps, mainly with respect to scarps, slopes and valley bottoms (riverbeds); can be applied to the over-all study of basins and sub-basins.

(5) Geotechnics

Purpose - The study of soils with respect to their characteristics, mechanical properties, stability and water table, mainly in order to help plan the construction of hydraulic works.

Methodological aspects - The application of geotechnical studies to basins and sub-basins is limited, due to the enormous diversity of individual variations; in this case, therefore, it will be limited to descriptive aspects based on geological studies.

A geotechnical study is particularly relevant for the study of soils in possible specific locations for civil engineering works, in order to help to select final locations and to define design requirements.

The extent of its use depends on the size of the individual project, both with respect to study costs and the risks inherent in the construction work itself. In the case of mini hydro power stations, geotechnical studies should generally be reduced to a minimum, depending on qualitative judgements, mainly by excavations and drillings, an approximate estimate of the bearing capacity of the soil and an estimate of safety factors for designing the intake, forebay, some supports for the piping and anchoring the main equipment.

(6) Availability of aggregates

Purpose - To investigate the availability of suitable materials for aggregates (stone, gravel, sand, etc.), an important factor in reducing the costs of works and construction processes.

Methodological aspects - A differentiated study of the existence and characteristics of the principal kinds of materials needed (granular material, riprap material, quarried material, sand, gravel, etc.).

f) Over-all evaluation of energy needs and economic demands in each area

As was pointed out in the preceding section, this study should be combined with an evaluation of the hydro power resources of the area in question in order to ensure its relevance and the subsequent formulation of specific MHG projects.

This stage calls for a detailed study of the data obtained from a preliminary identification of micro-regions and isolated areas through field evaluation surveys, which, however, should be kept at a general and statistical level when describing the characteristics of each locality.

It is necessary to keep an extensive data file for each locality and to prepare card indexes for micro-regions or groups of localities which can be integrated into a small grid.

The social-economic analysis of each locality can cover the points described below. However, it should be borne in mind that this analysis can be more limited and that some elements can be left for consideration in studies of specific projects or else simply disregarded.

SCOPE OF THE SOCIAL-ECONOMIC ANALYSIS OF LOCALITIES

POPULATION	Number, size of families, breakdown by activities, income, cultural levels, etc. Typification of the possible levels of satisfying energy needs. Historical

information about growth (or stagnation); migrations.

Forecasts of growth (estimates), forecast of rise in the indices of energy needs (estimates).

ECONOMIC ACTIVITES	Description of existing productive and supporting activities; economic impact. Potential of the area. Identifying projects in energy-consuming activities. Requirements for project implementation: time limits.
TRANSPORT AND COMMUNICATIONS	Transport systems (personnel and goods); highways, postal system, telecommunications, etc.
SERVICES	Drinking water, drainage, energy supplies; trade.
EDUCATION	Schools and cultural activities; educational needs and their specific energy requirements.
PHYSICAL DESCRIPTION OF THE LOCALITY	Geographic location, distance, physical description (streets, distances, types of construction, etc.).

The social-economic analysis should provide the basic data for each locality, so that the requirements and potential for electricity consumption and the required installed capacity can be determined by using indices.

In this stage of over-all evaluation, it is possible to determine only approximate requirements of installed capacity on the basis of indices, which will be necessary for formulating specific projects.

In addition, preliminary evaluations of energy consumption can be made for various kinds of consumption:

- Househole
- Public lighting
- Economically productive activities
- Miscellaneous (health, education, culture; social, political and religious activities, etc.).

It is also possible to estimate approximate periods of daily use for each category and its seasonal variations. The proposed additional analysis provides the necessary data to determine required installed capacity and demand at the pre-feasiblity level for studies of specific projects.

g) Identifying specific projects

Because of the inter-action between alternative MHG projects which can be defined from the over-all evaluation of resources, together with the evaluation of needs and demand in all the localities of an area, it is possible to determine and define in approximate terms those series of projects which can meet the basic energy needs of the population at minimum cost. For this purpose it is necessary to consider the following factors:

CONSIDERATIONS FOR IDENTIFYING MHG PROJECTS

- The point to which it is economically justifiable to organize groups of localities to form small inter-connected medium-tension grids, depending on their extension and the topographic characteristics or the area.
- To select those projects of relatively greater capacity which can economically replace several less smaller ones.
- According to the topography and characteristics of the site, to select the type of power stations with regards to head; high heads being more convenient, as they involve smaller investments and ensure greater economy of water, although they are subject to more wear-and tear and the greater water-level losses resource decreases the availability of water for other purposes at higher levels.
- To take account of increased requirements of installed capacity, either by over-designing the installations or allowing for enlargement.
- To anticipate construction problems when defining projects.
- To ascertain alternative solutions and projects.
- The above-procedure should be supported by field evaluation.

It should be pointed out that the objective in this stage is to try to define the universe of projects which could meet the basic energy needs of the area in question by trying to optimize combinations, but the aim is not to establish priorities for implementation, which is a part of the next stage.

h) Assigning preliminary priorities to projects

This is the fundamental basis for defining the "development plan" and its "implementation programmes", which is the responsibility of the Planning Unit.

Weighted evaluation criteria must be established in order to determine the priorities, while taking due account of economic, technical and social factors; the following general factors are suggested:

FACTORS FOR ESTABLISHING PRIORITIES FOR THE IMPLEMENTATION OF PROJECTS

- Size and cost, including cost of transmission lines.
- Population to be serviced; load factors.
- Energy used in productive activities including industrial production in relation to energy produced.
- Availability and permanency of the hydraulic resource.
- Possibilities of mutually complementary use in the case of multiple projects or possibilities of interference with the use of water for other purposes.
- Possibilities of using local labour and materials for construction.
- Possibilities of organized participation on the part of the community by contributing with labour and materials.
- Availability of access roads and road connexions.
- Possibilities of creating local employment.
- Possibilities of continuity of service, self-financing of operation and community support.
- Possibilities of supplying equipment, preferably of national origin.
- Engineering requirements and problems involved in the project.

Table 1 illustrates some activities which can be developed in isolated localities and also shows the approximate requirements of installed capacities.

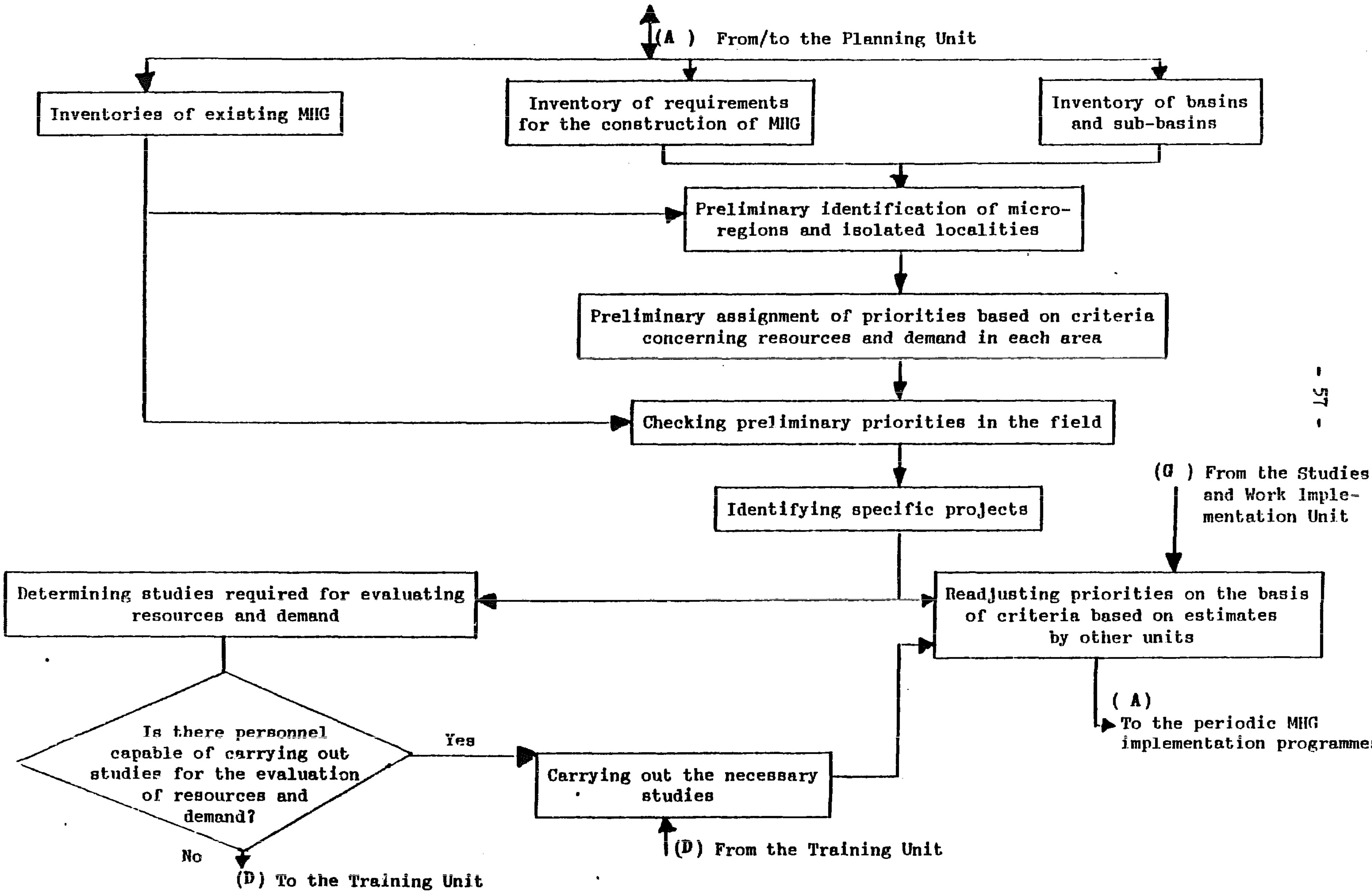
Table 1

Identification of productive activities in isolated localities and the rural area, which could utilize the energy generated by the SHPS.

ACTIVITIES	INSTALLED POWER FOR CONSUMPTION (kW)
Carpentry shops	5 - 15
Bakeries	2 - 5
Artesanal activities	1 - 2
Small saw-mills	15 - 30
Sugar can mill	10 - 20
Grain mill	3 - 20
Weaving	0.5 - 6
Coffee beneficiaries	5 - 30
Quarries	6 - 30
Ice-making	6 - 60
Irrigation pump	2 - 100
Brick-making	1 - 5
Lodging (20 guests)	2 - 5
Restaurant	1 - 2
Vegetable canning	5 - 20
Dairy products (butter, cheese)	2 - 10
Milk-processers (cooling and pre-evaporation)	5 - 20
Silos	3 - 5
Electrical and mechanical workshops (repairs)	5 - 15
Gasoline pumps	0.5 - 5

With this evaluation, it will be possible to prepare lists of projects in order of priority which can be used for planning and programming activities, although this will not automatically ensure that these projects will be included in the programmes, since the Planning Unit will have to establish other series of priorities with respect to questions of regional development, rural industrial development and sectoral policies.

FIGURE 13 UNIT FOR THE EVALUATION OF RESOURCES AND DEMAND



5.4. PRE-INVESTMENT STUDIES

In this chapter we shall be mainly concerned with pre-investment studies for specific project, on the basis that studies relating to over-all analysis of resources and demand have been dealt with in Chapter 5.3., although the dividing line is not always easy to draw, since studies for specific projects may be related to the process of identifying projects and establishing priorities.

Specific project studies serve two basic purposes:

- Technical and economic justification;
- Guidelines for the project's execution.

It may be said that pre-investment studies constitute one of the fundamental differences betwen MHG and larger-size plants, and for this reason preparing studies often poses the following problems:

COMMONEST PROBLEMS IN MHG STUDIES

- High study costs, often amounting to between 30 and 50 per cent of total investments.
- Formal terms of reference not always adequate to the project's needs.
- Over-abundant information, processing of data of little significance and lack of relevant facts; lack of correlation between the study and the realities of the project.
- Limited practical value for determining investments required or for guiding plant construction.

The above drawbacks can be attributed to the following causes:

REASONS

- Uncritical transfer of terms of reference commonly used for large hydro-electric projects.
- Routine division of studies into successive phases (pre-feasibility, feasibility and detailed engineering) without taking account the aim of the particular study.

- Formalistic demands and excessive data requirements made by financing institutions.
- Lack of definition of targets enabling proportions to be established between study costs and total project investment.
- Lack of comprehensive studies on resources and demand by basins and micro-regions respectively.
- Limited amount of direct information and excessive processing of inferred or estimated data.
- Lack of technical and economic manuals on project development.
- Limitations in consultancy systems and in the capacity of public institutions to carry out studies.
- Little consideration of technological alternatives.
- Little consideration given to the prospects for participation by the local population in the project.

It is important that targets be set at the Planning Unit stage regarding the maximum cost of studies as a percentage of the total investments and according to the size of the power station. These targets should obviously be set for each country as part of an approximate calculation of the cost of the components of the studies and the establishment of their scope. It should not be forgotten that the studies are a rough guide for future operations and a means of protecting the project's total investments; they should consequently be kept within reasonable proportions to prevent their becoming a high-risk investment in themselves which could significantly increase total investment or even lead to the absurd situation where their cost could seriously affect the project's feasibility.

Definite targets must be set for each country for the maximum cost of pre-investment studies with respect to total investments in an MHG, which in turn will define the studies' scope. In Chapter 7.6 on costs, there is a reference curve based on the following table, showing that the percentage cost of studies for smaller power values ought to increase within reasonable limits.

POWER IN KILOWATTS %	MAXIMUM PERCENTAGE OF TOTAL COST TO BE ALLOCATED TO STUDIES
10	15
100	11
1,000	8

The scope of the studies is closely related to the proportion desired between their costs and total investment and to where the project stands in MHG development planning, in other words, whether or not comprehensive information on basins and areas for groups of projects is available - and depending on how thorough the studies were which determined the specifications of the projects identified in the over-all evaluations referred to in 5.3.

Bearing these considerations in mind, we shall offer in the following paragraphs some general guidelines for preparing pre-investment studies for the three conventional phases of pre-feasibility, feasibility and detailed engineering.

a) Pre-feasibility/Reconnaissance Study

In the case of MGH it is desirable to establish minimum requirements at this level, and the notion of "pre-feasibility study" could be replaced by the concept of a "reconnaissance study", implying something of more restricted scope.

On the other hand, it is useful to ensure in this phase that the data needed to settle the investment question are available, so that, if possible, the preparation of a feasibility study will not be essential.

The degree of approximation to a pre-feasibility study will differ depending on whether the project in question is or is not independent of the planning and over-all evaluation process, as is shown in the following tabular summary:

CHARACTERISTICS OF PRE-FEASIBILITY STUDIES ACCORDING TO HOW THEY ARE RELATED TO PLANNING AND OVER-ALL EVALUATION

PROJECTS WHICH FORM PART OF THE PLAN AND OVER-ALL EVALUATION OF RESOURCES AND DEMAND	INDEPENDENT PROJECTS OUTSIDE THE CONTEXT OF OVER-ALL EVALUATIONS AND PLANS
- The decision to carry out studies has been taken at the planning stage and was based on over-all evaluations made; it remains for the pre-feasibility study to analyse alternatives, define plant specifications, determine the scope of project engineering and assess its feasibility prospects.	- If the project looks promising in a preliminary survey, the pre-feasibility study can have the scope of the projects planned; if not, it should give alternatives and approximations as to their specifications and investment requirements, and assess the desirability of going on with the studies.
- The over-all evaluation can contain adequate data on hydrology, the assessment of resources, energy demand and installed capacity requirements, so that it only remains to assess this data in a field study, to make some water guaging (flow measurement) measurements and to supplement information or give more details.	- Evaluation of resources and analysis of demand fall within the scope of the study.

Also of importance will be the size of the project, which will determine the scope of the pre-feasibility study in proportion to the estimated investment requirements, and other factors relating to the project's size, as can be seen in the following table, in which power stations are tentatively separated into two power ranges:

CHARACTERISTICS OF PRE-FEASIBILITY STUDIES
ACCORDING TO SIZE OF MHG

LOWER POWER VALUES (LESS THAN 100 KW)	HIGHER POWER VALUES (GREATER THAN OR 100 KW)
- Checking water flows using indirect methods during short periods and generalizing with the help of qualitative assessments.	- Checking flows through measurements taken over long periods or the use of similarity models.
- Very limited topographical surveys, or the elimination of these; the use of artisan methods for levelling falls.	- Detailed topographical surveys of the most relevant areas (intake, channel, forebay, fall, power house, tail race); careful determining of the head and layout of a penstock.
- Visual assessment of the structure of the terrain for construction purposes.	- Applying geotechnical methods to check the characteristics of the terrain in areas where the main construction work is to take place.
- Over-dimensioning and larger safety margins taking into account greater uncertainty factors.	- Less over-dimensioning and more reduced safety margins in view of more thorough studies and the greater investment involved.
- More consideration of the use of non-conventional technologies tending to reduce costs, even if given margins concerning reliability and service life must be sacrificed.	- Less consideration of non-conventional technologies even though in many cases they will be relevant within this power range.

These recommendations should of course be regarded as trends, for the scope of each individual project must be decided in the light of the objective characteristics of that project.

Checklist of pre-feasibility study of MHG

1. Summary - a synoptic review of all the essential findings of each paragraphs.

2. Project background and history
   (a) Project sponsor(s)
   (b) Project history
   (c) Cost of studies and/or investigations already performed

3. Market and plant capacity
   (a) Load demand and market
       Its past growth, the estimated future growth, the connexion with the grid.
   (b) Sales forecast and marketing
       (i) Competition with other energy resources
       (ii) Estimated annual sales revenues from power supply
   (c) Power estimation
       (i) Hydrologic study
       (ii) Firm power
       (iii) Secondary power
       (iv) Waste water
   (d) Determination of installed capacity

4. Location and site (including, if appropriate, the geological study, and estimate of the cost of land and the cost of storage reimbursement)

5. Project engineering
   (a) Prelininary determination of scope of MHG project
   (b) Technology(s) and equipment
       (i) Rough estimate of costs of local and foreign technology
       (ii) Rough layout of proposed equipment and power-house.
            Turbine, generator, gate and valve, auxiliary equipment, etc.
       (iii) Rough estimate of investment of equipment.
   (c) Civil engineering works
       (i) Rough layout of instake, conveyance structure and powerhouse
       (ii) Rough estimate of investment cost of civil engineering works (local/foreign)

6. Plant organization and overhead cost

7. Manpower
   (a) Estimated manpower requirement broken down into major categories of skills
   (b) Estimated annual manpower costs

8. Implementation scheduling
   (a) Main construction method and implementation time schedule
   (b) Estimate implementation costs

9. Financial and economic evaluation
   (a) Total investment costs
   (b) Project financing
      (i) Proposed capital structure and proposed financing (local/foreign)
      (ii) Interest
   (c) Production Cost
   (d) Financial evaluation based on above estimation value
      (i) Pay-off period
      (ii) Simple rate of return
      (iii) Break-even point
      (iv) Internal rate of return
   (e) National economic evaluation
      (i) Preliminary tests
      (ii) Approximate cost-benefit analysis, using estimated weights and shadow price (foreign exchange, labour, capital)
      (iii) Economic industrial deversification
      (iv) Estimate of employment-creation effect
      (v) Estimate of foreign exchange savings

b) Feasibility

It is desirable that the pre-feasibility or reconnaissance studies for MHG cover the elements needed to take a decision on investments, with a view to cutting out feasibility studies and proceeding directly to project engineering studies.

However, feasibility studies are desirable for projects presenting doubtful situations on their technical and economic aspects, or whenever alternatives have to be compared and as long as the scale of the project seems to call for it.

c) Detail engineering

This should cover the following general aspects:

SCOPE OF DETAIL ENGINEERING

- Supplementary topographic details.
- Supplementary geotechnical study (when the scale of the project seems to call for it).
- Final specifications of the project.
- Detailed design of each civil engineering item and specifications of materials.
- Final specifications of electromechanical and auxiliary equipment; quotations, evaluation of alternatives and proposed purchases.
- Electrical design of transmission lines and installations.
- Recommendations for construction, installation and start-up.
- Implementation schedules and work programme.

In the absence of feasibility studies, the engineering study should include a supplementary financial economic analysis dealing with the following points:

FINANCIAL AND ECONOMIC SUPPLEMENT TO ENGINEERING STUDIES

- Investment and financing.
- Schedule of payments.
- Personnel requirements.
- Operating and amortization costs.
- Consideration of tariff schemes.
- Analysis of sensitivity of investments.
- Organizational aspects of construction and operation.

The scope and depth of the engineering studies will also depend on the scale of the proposed investments; the main features can be classified as follows:

CHARACTERISTICS OF ENGINEERING STUDIES ACCORDING TO SIZE OF MHG

LOWER POWER RANGES (LESS THAN 100 KW)	HIGHER POWER RANGER (GREATER THAN 100 KW)
- Less study of detail in design, details to be supplemented as work proceeds.	- More study of detail in design.
- Larger safety factors for design.	- Smaller safety factors for design.
- Proportionately greater use of local materials.	- Proportionately lesser use of local materials.
- Drawings commensurate with capabilities of a construction foreman.	- Drawings commensurate with capabilities of a civil engineer.
- Considerations of price and simplicity will be major items in the final selection of equipment.	- Considerations of reliability and service life will be major items in the final selection of equipment.
- More extended use of unconventional technologies.	- More extended use of conventional technologies.
- More use of semi-standard designs.	- More use of "taylor made" designs.

Standard equipment, including turbines, should be specified and selected for all MHG stations.

Pre-investment studies of projects can be organized in various ways:

- Projects and engineering section of an Electricity Board or undertaking responsible for implementing MHG.
- Specialized hydro project institution or agency.
- Independent consultants and experts.

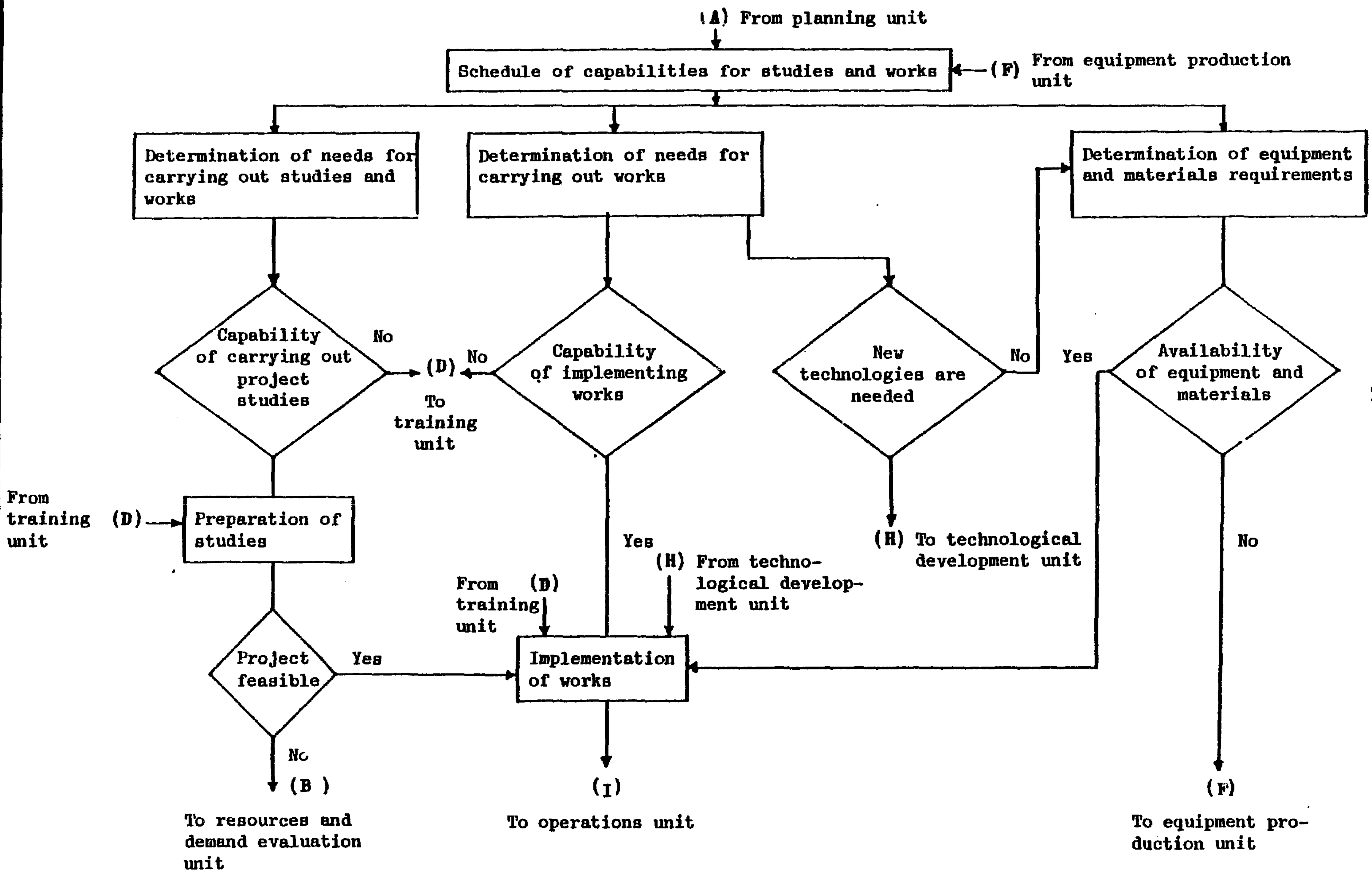
The choice will depend on a country's policies, social and economic system, and technical capabilities.

It is usually helpful if the Electricity Board or enterprise acting as executive agent for the MHG programme has a projects and engineering section capable of making the necessary pre-investment studies and of sub-contracting and over-seeing studies, when its own project development capabilities are overloaded.

Contracting good consultants is often difficult and the supervising agency needs a high level of technical capability in order to be able to define the scope of the studies clearly, evaluate costs and check on the quality of the study contents. The common mistake of developing studies which contain little substance and a mass of irrelevant information should be avoided.

It is also frequent that some financial institutions establish such requisites regarding consultants' qualifications and the scope of studies, that pre-investment costs tend to be very high and the studies contain formal elements which for the most part are useless for project evaluation and implementation.

FIGURE 14 UNIT FOR IMPLEMENTATION OF STUDIES AND WORKS



5.5. FINANCING

This section will deal with the general problems of financing investments for MHG, with the emphasis on aspects likely to reduce investment or its financial and foreign currency requirements.

COMMON PROBLEMS IN MHG FINANCING

- Heavy investment per installed kW.
- Substantial foreign currency requirements.
- High study costs and irrelevancy of studies to operation and implementation of project.
- Individual projects are on too small a scale to be interesting financially and are expensive to administer and to evaluate financially.
- Little experience of systems for financing groups of projects.
- Difficulties of including national engineering in pre-investment studies.
- Unsatisfactory schemes for financing national supplies.
- Underestimating potential community contributions of manpower and materials.
- Lack of MHG financing policies.
- Inadequate economic capability of communities.
- Misconceptions of "rural electrification" based on spontaneous development of productive activities requiring energy.

To deal with the above-mentioned typical problems, the recommendations given in the following table are worth bearing in mind when schemes are being devised; many of them will be commented on in some detail in this section.

GENERAL GUIDELINES FOR IMPROVING FINANCING PROSPECTS OF MHG

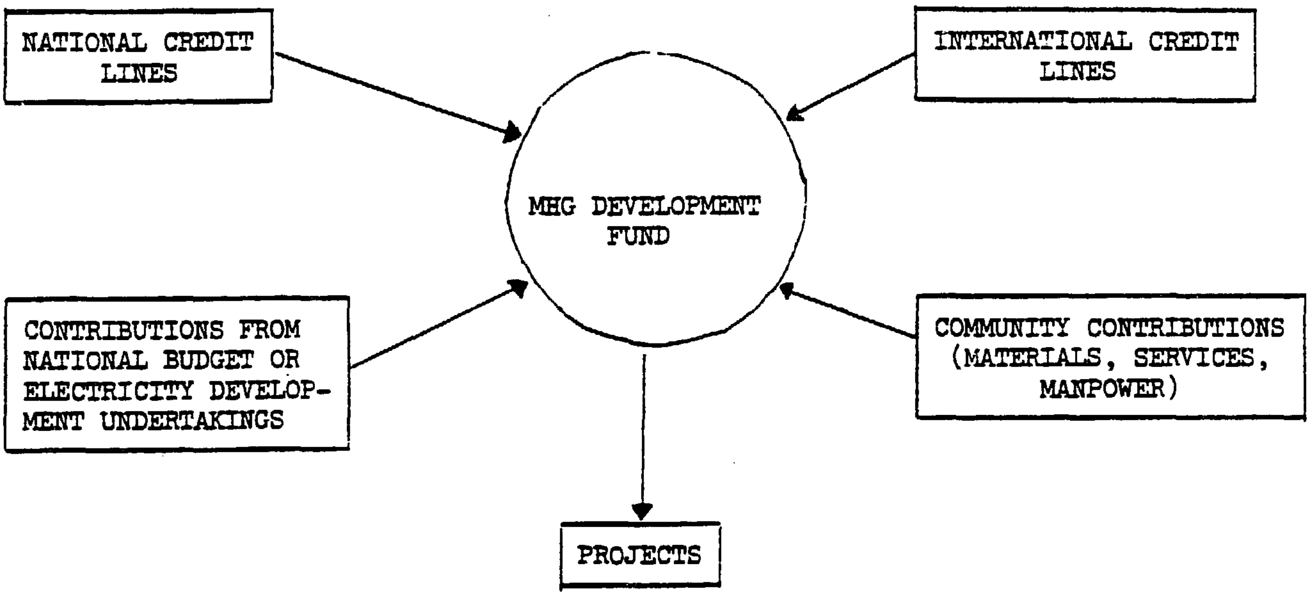
- Reduce investment and foreign currency requirements by means of non-conventional technologies, standardization, national production of equipment and local materials, community participation in construction works.
- Increase relevance and reduce cost of pre-investment studies by over-all assessments of resources and demand by zones and basins, preparation of guidelines for formulation of projects and design handbooks, etc.
- Finance groups of related projects.
- Increase community participation in the building and operation of plants.
- Increase the share of national engineering in projects by strengthening the engineering capabilities of the institutions responsible for implementing MHG projects and giving preference to suitable domestic consultants over foreign consultants.
- Develop systems for financing national supplies.
- Stimulate community participation in project implementation by emphasizing this factor in the study of priorities, developing appropriate systems for the financial evaluation of community contributions and the requirements for technical assistance.
- Determine a national MHG financing policy.
- Promote the parallel development of energy intensive productive activities.
- Develop guidelines on the rational use of energy.

Special attention should be paid to reducing investment needs including pre-investment studies, and to reducing foreign currency requirements.

GENERAL GUIDELINES FOR REDUCING INVESTMENT COSTS AND FOREIGN CURRENCY REQUIREMENTS

- Over-all evaluation of demand and resources should be broken down by zones and basins, thus reducing the costs of individual studies and achieving economies of scale in the multi-disciplinary study of areas possibly involving a number of projects.
- Wherever possible, proceed directly from pre-feasibility studies to detail engineering studies.
- Simplify terms of reference of studies and prepare guidelines for their elaboration.
- Prepare manuals/handbooks on design.
- Consider using non-conventional technologies and the intensive use of local materials right from the pre-investment study phases.
- Use domestically produced equipment and materials and, if possible, nationally developed or adapted technologies not subject to royalty payments or large numbers of imported parts.
- Use standard items of equipment; consider cheaper and shorter-life alternatives for low-power installations.
- Semi-standardization of civil engineering works.
- The use of national engineering in projects helps to save foreign currency, reduce relative costs and improve adaptation to actual conditions in the country.
- Community participation helps to reduce apparent investment and therefore requires less domestic financing.

To promote the development of MHG projects, appropriate policies must be defined, such as setting up an MHG development fund which can be administered by a government-financed agency or by the electricity board or institution concerned.



MHG financing should be organized along the following lines:

a) International credit lines

A clear distinction is necessary between untied credit lines, such as some international finance agencies can provide, and tied credit lines from financial institutions in countries wishing to promote their equipment and engineering sales via financial promotion.

Tied credits are satisfactory provided that the elements concerned are not produced domestically and after analysis of their technical characteristics, pricing and financial conditions has shown them to be the best option. The temptations of "soft" financing often lead to the purchase of equipment which is too expensive or inadequate.

Specific credit lines defining some financing conditions should be negotiated in order that the financing of groups of projects may be negotiated subsequently.

The criteria and terms of reference for studies should be realistic, and preferably be made known by the publication of guidelines for project preparation and assessment.

b) National credit lines

These should be used mainly to finance domestically produced supplies of equipment and materials.

They can be arranged with agencies concerned with industrial promotion financing.

Credit lines for site development and works can be arranged with agencies concerned with rural promotion financing.

c) Contributions from national budgets or electricity development undertakings.

In the light of the development plans and their annual implementation programmes of MHG, resources could be allocated under given proportions to the credits obtainable.

Some of the investment finance can be in grant form.

A proportion of the profits of electricity "lost fund" boards can be used for financing MHG development.

d) Contributions from the community

This should be determined during the studies phase.

The community contribution should be regarded as part of the total investment and therefore needs to be assessed properly.

Community contributions usually consist of unskilled building labour, materials (mainly aggregates for the civil engineering works) and services (local carting, local transportation, storage, site, security, etc.).

Where investments are financed on a basis of partial repayments, financing would be of the nature of a revolving fund.

However, irrespective of the scheme of investment repayment and even in the case of outright grants, projects must earn at least enough to cover operation and maintenance costs, otherwise the plant may be brought to a standstill by the first operating problem to arise or to have its installations threatened by eventual damage. Also, it would be difficult to devise a scheme in which permanently non-recoverable contributions went hand in hand with sustained growth of MHG.

The proportions of financing to come from credits, budget contributions and community contributions should be defined in their general terms. Some countries adopted a method in which the investment is divided into three roughly equal parts, the first to be financed by credits, the second by budget contributions and the third by community contributions.

Investment recovery criteria must also be considered in finance policy in the light of tariff possibilities and the aims of rural electricity development. Three typical cases will now be given, but intermediate solutions are possible.

e) Outright grants

There is no question of recovering investments; budget contributions and financing are a matter for the State or the electricity development board and the tariff systems merely cover operation and maintenance costs.

This system can be used to develop MHG in areas where incomes are very low, but because of its limited financial capabilities, only relatively few MHGs could be built.

f) Partial grant

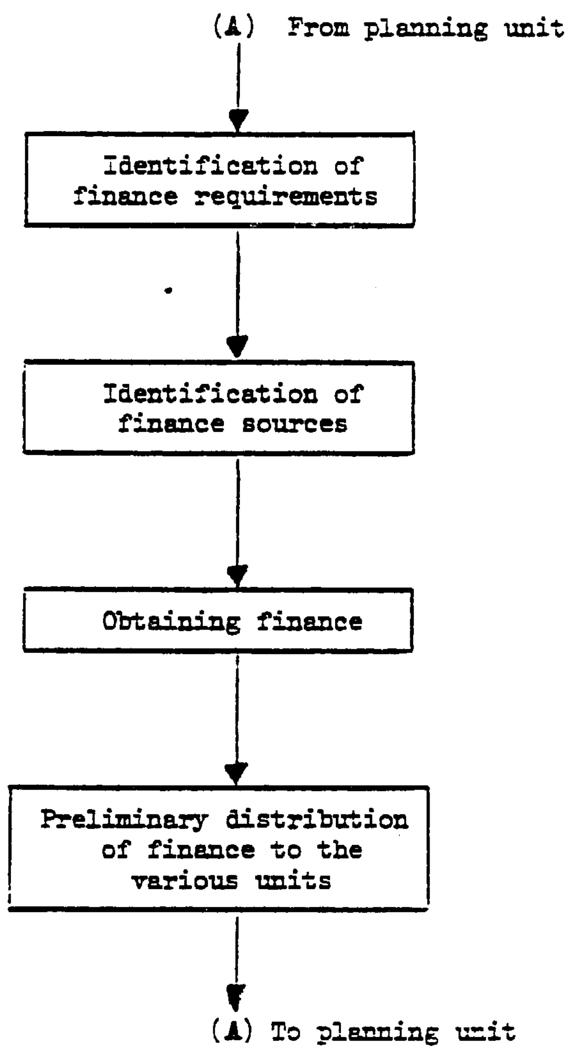
In this case the budget contributions and community contributions are often regarded as part of the grant and the loans obtained are to be paid via appropriate tariff arrangements.

g) Total recovery of investment

Though ideal financially, it usually proves to be impossible for a rural electricity development since it greatly hampers implementation by restricting it solely to cases in which the likely income from supplying electricity will cover capital amortization and loan service charges over a given period.

Schemes of this type can be used for MHG installed mainly to serve profitable productive activities, such as mining, agro-industry and so on.

FIGURE 15 FINANCING UNIT



5.6. CONSTRUCTION AND START-UP

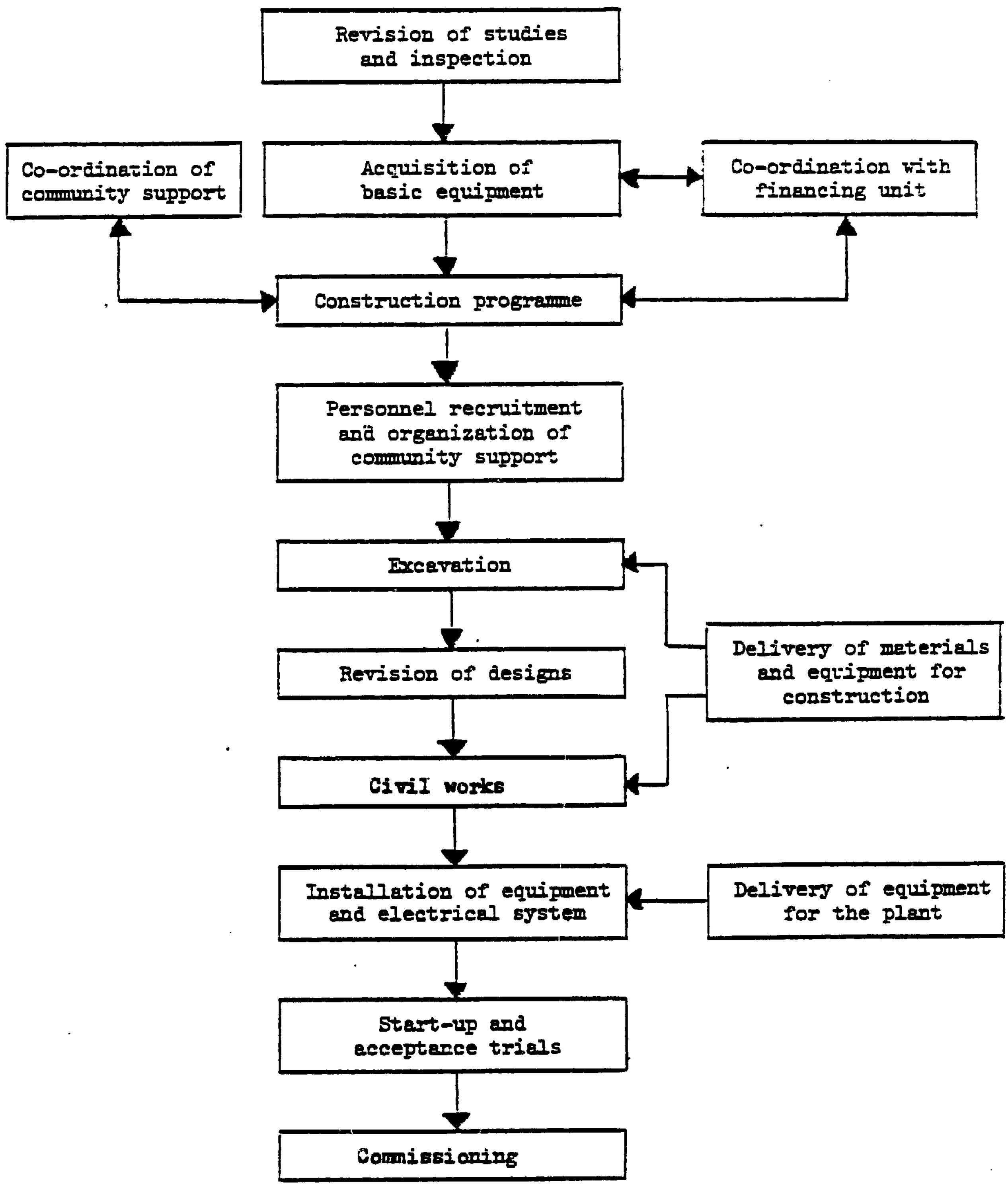
Our discussion will deal mainly with the problems and methods of construction as they relate to such aspects as excavation work, civil engineering, the installation of electromechanical systems and equipment, and the actual starting-up of the plant.

Of all the various types of alternative sources of energy, MHG pose the most exacting construction requirements because of the relatively large scale of the building operations and the considerable size of the installations.

The construction processes will vary according to:

- The planned installed power;
- The nature of the terrain;
- The location of the site;
- The mode in which the plant is to be used (independently or inter-connected);
- The availability and skilled level of labour;
- The construction technology;
- The ease of access and transport;
- The technological sophistication of the equipment;
- The climate;
- Particular factors in the case of multi-purpose projects.

The construction process may be represented, in simplified terms, by the flowing flowchart, whose elements are analysed in the discussion thereafter.


Revision of studies and inspection
Co-ordination of community support
Acquisition of basic equipment
Co-ordination with financing unit
Construction programme
Personnel recruitment and organization of community support
Excavation
Revision of designs
Delivery of materials and equipment for construction
Civil works
Installation of equipment and electrical system
Delivery of equipment for the plant
Start-up and acceptance trials
Commissioning

a) Revision of studies and inspection

The office responsible for carrying out the project (this office may be a part of the electricity board of enterprise) must first of all define the areas of responsibility for the management and supervision of the project.

The next step will be a revision of the studies and a site inspection concentrating on characteristics, specifications, and construction guidelines.

The task of revision may be entrusted to independent professionals or consultants if sufficient trained personnel of this kind are not available or when a project is designed for direct implementation under the auspices of a municipal government or private firm.

b) Acquisition of basic equipment

Considering the possibility of problems with delivery schedules, arrangements should be made for the acquisition of the equipment as soon as the revision of the studies has been concluded. In some cases, these arrangements may be begun as early as the engineering study stage.

The heading "basic equipment" normally covers such items as the turbines, speed regulators, generators, main valves, electrical control panels, and transformers. It may also include electrical materials and pressure tubing, together with the related accessories.

c) Co-ordination with the financing unit

This co-ordination is required in order to determine the modalities and time-tables of the release of funds for the various stages scheduled in the Project Construction Programme. At the community level, this co-ordination may also be tied in with co-ordination of disbursements and community contributions. In addition, the procurement of the equipment must be co-ordinated with the financing unit.

d) Co-ordination of community support

Specific areas of possible co-operation must be identified as early as the study and implementation-decision stage. Co-ordination is required, prior to the commencement of construction, in order to produce some sort of formal agreement with the community covering, among other things, the following points:

- Manpower: types and number of man-hours for each phase of construction; supervisory responsibilities;
- Materials: (generally inert filler materials such as stone and sand, wood for formwork, etc.); quantities, location, etc.;
- Services: (transport, storage and warehousing of materials, personnel transport facilities, provision for security, etc.); definition of responsibilities.

Depending on the type of social organization and the traditions of the country, such agreements will be concluded with the most representative authorities capable of mobilizing the support required. These authorities may be community leaders, the senior officials of co-operative organizations, or the members of the municipal government. It is also essential to make certain that these agreements are brought to the attention of the local citizens and are supported by them.

e) Construction programme

The construction programme must be drawn up in harmony with the actions referred to in the preceding sections.

The characteristics of the construction programme are determined by the nature of the project. In the specific case of MHG, allowance must be made for considerable margins of uncertainty in the various phases of execution, this uncertainty being the result principally of the tentative nature of the studies, the logistic problems inherent in any project which involves only a minimum of administrative apparatus, and the difficultires that frequently arise, with respect to organization and adherence to progress schedules, in activities in which there is an element of relatively voluntary community participation.

QUESTIONS TO BE CONSIDERED IN PROJECT CONSTRUCTION PROGRAMMES

- Excessively detailed programmes should be avoided, and programmes should be limited to a discussion of the principal elements only.
- The planning should include sufficient latitude for unforeseen developments, particularly with regard to design modifications, supplies, and work to be performed by the community.
- Preference should be given to the use of logical systems for the progress time-tables as a means of clearly defining the "critical paths", but with only the principal events considered.
- In programming the work to be performed by the local community, consideration should be given to the possibility of interference with other activities requiring the attention of the inhabitants, particularly during the planting and harvest seasons.
- Arrangements should be made for technical support to meet requirements arising out of unforeseen design changes, particularly with respect to civil engineering.
- In planning for the transport of materials and equipment from outside the area, consideration should be given to possible problems of access, especially during the rainy season.
- The modes by which materials are to be hauled should be the subject of advance planning, particularly when draught animals are to be used.
- All work-related responsibilities must be set forth in the programme.

f) <u>Personnel recruitment and organization of community support</u>

The basic construction team may be organized along the following lines:

- One supervisor (generally an engineer, who may be in charge of more than one project);
- One site construction foreman;
- Skilled workers (masons, carpenters, etc.);
- Unskilled workers.

The supervisor engineer normally reports to the office responsible for the implementation of the project.

The construction foreman is frequently a contractor in charge of his own crew of skilled workers; the unskilled work force is provided by the local community. In situations of this kind, provision must be made for the prevention of any conflicts of responsibility between the contractor and the community.

In organizing community support, specific personnel should be assigned to the construction manager.

The installation phase will require a supervisory engineer (mechanical or electrical) at the head of a team which might consist of:

- One mechanic/fitter;
- One installation electrician;
- Assistants

The technical installation team will, in many cases, be provided by the project implementation office. The assistants may be drawn from the potential local operators of the plant..

Obviously, these recommendations regarding the composition of the construction crews are intended as guidelines only and are subject to considerable modification depending on the size and particular features of the project. The general aim should be to keep the technical team to the indispensable minimum, considering that it is a major cost factor, particularly in the case of small plants of less than 50 kW output.

It is essential to remember that the presence in the community, during the execution of the project, of skilled technicians and workers may give rise to unusual socio-economic situations. The effect of these situations may be beneficial, by providing an opportunity for social and cultural exchanges, but it may also be negative if the outside personnel fail to adapt themselves to local customs or if, by their behaviour, they create problems.

In order to facilitate the participation of local communities in the project, consideration should be given to the formation of work groups or brigades, encouraged to fulfil assigned plan objectives.

g) Excavation

Higher or lower levels of mechanization will be employed, depending on the structure and socio-economic development of the country and on the size and characteristics of the project. In the case of MHG, frequent intensive use of local manpower with low levels of mechanization is preferred. On the other hand, it is important to avoid underestimating the value of the community effort simply because it is not included in the cash budget, since a frequent error is to fail to provide for a minimum of mechanization capable of economizing on a large number of man-hours.

The excavation of the channel is the major task at this stage. After this come the intake and the surge chamber with the silt basin and finally the power house and the penstock support structure.

h) Construction

The civil engineering works pose greater requirements with respect to skilled labour, which may be supplemented through community efforts in the form of assistants and personnel engaged in hauling the materials. As a means of broadening community participation, consideration should be given to the possibility of training local personnel, particularly as masons.

The timely transport of materials is one of the most important factors in avoiding excessive costs and delays in scheduling.

Depending on the conditions in the country and the nature of the terrain, the use of locally available draught animals may be of great importance. In instances when these animals are used, it is necessary to arrange for the preparation of appropriate paths and to plan carefully the movement of the loads so as to avoid interference.

The safety of the personnel requires that consideration be given to their skill levels and experience, and that there be no scrimping on the use of the materials and equipment needed to ensure this safety.

Since the engineering plans are to be supplemented or corrected during the actual work on the project, the experience of the construction foreman is a critical factor. In the case of modifications which depend mainly on the terrain or on existing structures, the views of the local inhabitants may be very useful.

i) Installation of equipment and electrical systems

The installation of the equipment normally requires skilled and trained personnel. Nevertheless, an effort should be made to involve in this work any local inhabitants who appear potentially capable of being trained as operators, in order that they may become familiar with the equipment and the installation.

The safety and security of the electrical systems is a matter of major importance for the continuing good operation of the plant and the protection of its operating personnel. It must be assumed that the plant itself will not be inspected or repaired with any great frequency.

j) Start-up and acceptance trials

In this stage, which is one of transition to normal plant operation, the following points must be kept in mind:

- The acceptance trials must be standardized in documentary form according to plant type and size.
- The actual start-up of the plant must be carefully planned, with duties and responsibilities clearly assigned and safety aspects provided for. The emergency procedures must be clear and well understood by all those taking part in the trials.
- As part of the start-up operation, the indigenous operators designated to be responsible for plant operation must be evaluated and their competence certified.
- It is desirable that the suppliers of the main equipment be present at the start-up of the plant.

5.7. OPERATION AND MAINTENANCE

In the four preceding sections our analysis has been chiefly concerned with MHG implementation from the point of view of the comprehensive evaluation of resources and demand, pre-investment studies, financing, construction and start-up, and indirectly with operation and maintenance.

In this section, a number of considerations are discussed regarding the next phase in the establishment of the MHG, namely its use and on-going operation. This phase is, of course, of decisive importance, since even projects which have been efficiently managed throughout their implementation may fail unless organizational schemes and operating modalities are established which guarantee the optimal utilization of invested capital.

FREQUENT PROBLEMS IN MHG OPERATION AND MAINTENANCE

- Unsuitable administrative, organizational, and financial arrangements.
- Insufficient liaison between the plant management and the local community and its organizations.
- Limited capabilities for plant management and operation in rural communities.
- Operating and maintenance costs disproportionately high in relation to the energy produced.
- Excessive bureaucracy in the centralized management of small plants.
- The high cost and problems of social adaptation associated with operators brought in from outside the community.
- The frequently inadequate skill levels of locally recruited operators.
- Excessively high tariff rates, inhibiting development in rural areas.
- Rates too low to cover the costs of operation and maintenance.
- Absence of technical support for maintenance and repair.
- Inadequate component standardization and lack of spare parts.

Per se, the problems of MHG operation and maintenance are simple, as described in greater detail in Chapter 7. The chief difficulties are institutional in nature and have to do with the running and management of the plants as well as with the origin and technical background of the operators and maintenance personnel.

Among the various administrative arrangements that may be adopted for MHG management, three typical ones are discussed below.

a) Direct sub-ordination to a state or regional electric power authority

Advantages

- The possibility of centralizing actions of greater technical complexity and of taking advantage of the economies of scale inherent in the over-all management of groups of plants.
- High skill levels on the part of the personnel.
- Solid financial and technical backing.

Disadvantages

- Each plant is by itself too small in the context of a large organization, with the result that, because of the extended decision-making channels, it may be neglected.
- High operating costs as a consequence of high general expenses (overhead), operator and maintenance costs.
- The remoteness of the authority, and thus of the plant, from the local community and its problems.
- Problems in reconciling the needs of water for irrigation and generation.
- Difficulties in mobilizing community support for maintenance work at the site.

b) A Community Energy Enterprise, possibly in the form of a municipal enterprise, co-operative or other kind of association

Advantages

- Activities centralized at a level facilitating service-related decision-making.
- Greater ease in mobilizing community support for maintenance work.

- The resolution, within the community, of conflicts of interest regarding the use of the water.
- Lower operating costs.

Disadvantages

- Little experience and know-how in business management.
- Problems in collecting electricity bills and in the use of financial reserves for replacement and maintenance (which may occasionally be improperly diverted to other purposes).
- The possibility of faulty maintenance.
- Poor opportunities for economies of scale.

c) Private Power Enterprise

This arrangement, even in countries with a market economy, runs into problems when applied to public-service MHG in rural areas, since generally speaking, these plants are not regarded as investment opportunities offering an adequate profit margin, but as tools for the promotion of development.

Normally, the best prospects for this alternative are provided by independent producers who require energy for their production activities (agro-industries, sawmills, mines, etc.) and can sell any surplus power to nearby communities.

The selection of the appropriate administrative arrangement will depend on the socio-economic structure of the country, the extent to which such plants have been developed there, the capacity and nature of the electric power enterprises, the size and remoteness of the plants, and finally the traditions, work experience, and managerial skills of the community.

Without advocating any one particular scheme, it is often possible to adopt a combined model involving a communal, municipal, or co-operative enterprise in association with the state electric power authority.

GENERAL GUIDELINES FOR A SCHEME INVOLVING A COMMUNAL ENTERPRISE
IN ASSOCIATION WITH AN ELECTRIC POWER AUTHORITY

- The enterprise is set up in accordance with the contributions made to its establishment. The value of the manpower, materials, and services employed being regarded as the contribution of the community.

- The enterprise has a Board of Directors consisting of a representative of the electric power authority and of the representative organizations or associative bodies of the local community and/or local municipal authorities.

- The enterprise will employ the minimum number of personnel required for its operation with a view to covering four basic requirements: the administration of funds, the collection of bills, the operation of the plant, and preventive maintenance, whereby the number of employees may vary according to the size of the plant and the extent to which its equipment is automated. At small plants, with an output of less than 100 kW, the total staff may consist of one or two operators to be also responsible for administrative tasks and collections in addition to their duties in the area of operation and preventive maintenance. At larger plants which service a small system, there may additionally be an administrator and a bill collector.

- As far as possible, all the personnel of the enterprise should be recruited from the local community and trained by the state or regional electric power authority.

- The electric power authority will train the operating personnel of the plant in preventive maintenance, and will provide technical support, in the event there is a need for repair, in the form of "flying maintenance brigades" set up to service groups of plants at the regional level.

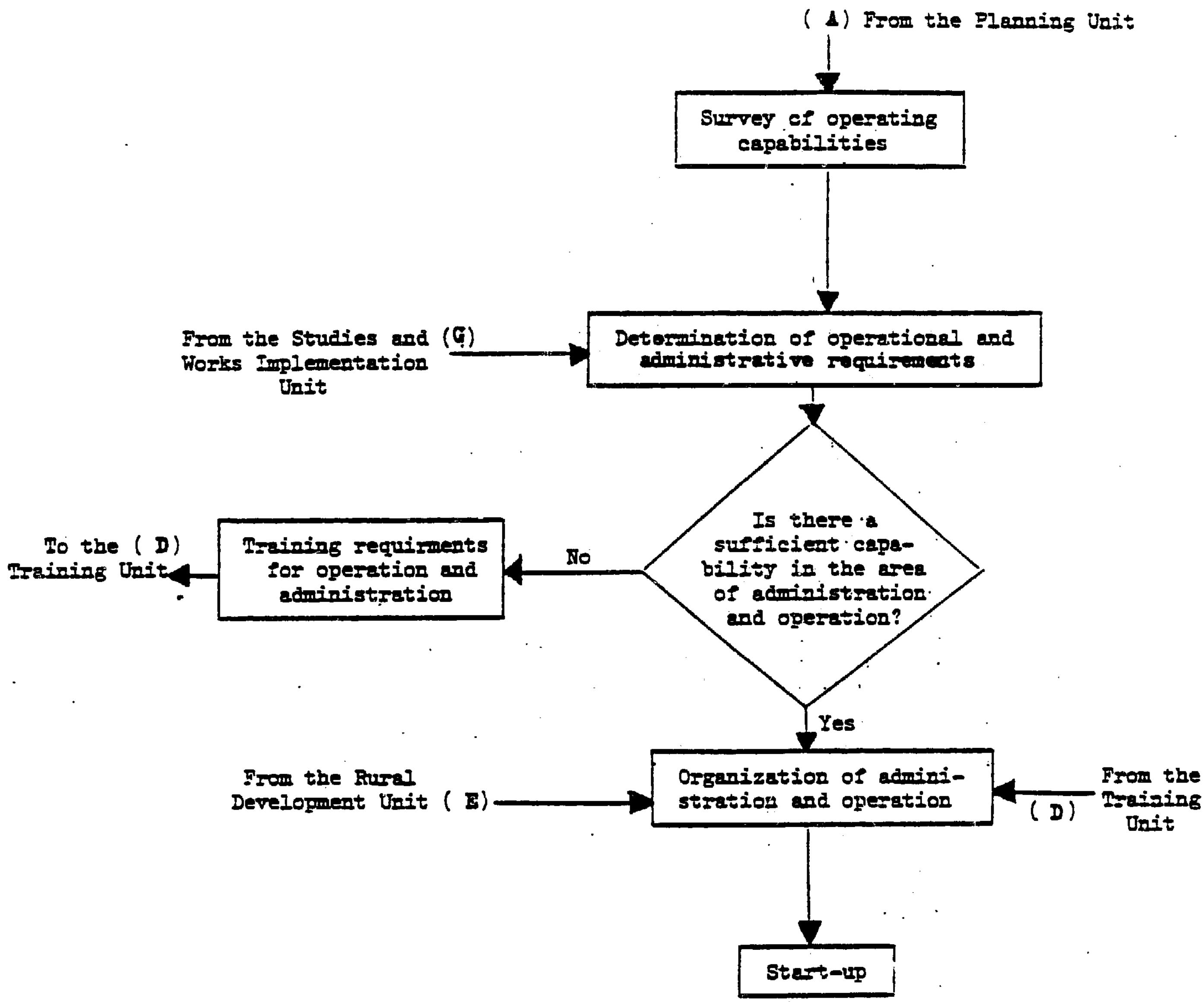
- The community enterprise will collect and administer the funds raised through billing, and will maintain a reserve to finance repairs and replacements and, if possible, the physical expansion of the plant, in addition to covering normal operating costs and staff salaries and wages.

- The community enterprise will be responsible for ensuring that these funds are used only for the purposes established in relation to the development of the local power system. The state or regional electric power authority will be responsible for supervising and auditing the management of these funds.

- The community enterprise and the state or regional electric power authority will define the terms of their co-operation in an agreement or contract.

- Direct investment contributions by the electric power authority and the community will not be returned nor will they earn profit. The financing received under the form of loans may be either assumed by the electric power authority or else returned in whole or in part by the community enterprise with the operation of the plant.

FIGURE 16 OPERATIONS UNIT



5.8. REQUIREMENTS IN THE AREA OF HUMAN RESOURCES AND TRAINING

The successful carrying out of MHG plans, programmes, and projects requires as a necessary condition to promote training including aspects related to non-conventional technologies applied to pre-investment studies, civil engineering design and construction and electromechanical equipment and repair and maintenance.

STEPS TO BE FOLLOWED IN ORGANIZING THE COURSES

- Infrastructure survey of training establishments.
- Securing of the funds for the financing of the course.
- Establishment of a pilot training programme on the subject of the development of water resources, with particular reference to rural areas.
- Establishment of programmes to provide specialized training in MHG.

It would be advisable to carry out a survey of the capabilities of the country with respect to centres of higher education, research institutes and special schools for the training of intermediate-level technicians.

As an initial step, it would be well to establish a pilot technology training programme on the development of water resources in rural areas. On the basis of the experience gained with this programme, a decision could be reached as to the possibility of organizing a specialized course in MHG.

It would be best if developing countries began by organizing exchanges of experience among themselves before seeking to supplement this information from outside sources.

The various types of engineering training courses are discussed below:

TYPES OF MHG COURSES FOR ENGINEERS

- Training courses.
- Undergraduate regular courses in the field of non-conventional technology.
- Specialized post-graduate courses.

The training courses, which are of short duration, are designed to provide current information on all phases of MHG design and installation for engineers whose activities are related to MHG development in their various phases of execution.

A very important factor is the need to improve the standard curricula of the engineering departments of Universities and Institutes of Technology by including in them courses on MHG and applicable non-conventional technologies.

Post-graduate courses as such will be conducted at a more advanced theoretical level and may, in principle, extend over an entire academic year.

It is recommended that engineering courses be designed with the following points in mind:

CHARACTERISTICS OF COURSES FOR ENGINEERS

- The courses must be designed to consolidate the advances already achieved in the country.
- The courses will be organized for all areas of specialization and will be graded differently according to area. The emphasis will be on the preparation of monograph studies by inter-disciplinary groups.
- The courses will cover the areas of civil, electrical, and mechanical and industrial engineering, economic administration, and operations research.

The following are the recommended criteria to guide the preparation of the courses for intermediate-level technical personnel:

CHARACTERISTICS OF COURSES FOR INTERMEDIATE-LEVEL TECHNICIANS

- Theoretical aspects will be considered within the same programme for engineers and as a part of in-plant training.
- It is recommended that a "plant for training" be established for the training of technical personnel and skilled workers. Experimentation in the use of non-conventional technologies might also be conducted at such plants.
- The courses will cover civil construction, electro-mechanical equipment, and administration, all primarily from the technical standpoint.
- It is very important to undertake the training of mechanics and maintenance electricians through the establishment of training units in the major repairshops.

The basic objective of these courses is to help to narrow the existing gap between the number of people with higher education, where there has been a relative advance, and the shortage of intermediate-level technicians, which is a general phenomenon in developing countries.

With respect to training of MHG operators, here the preference should be given to institutionalized arrangements designed to train operators from rural areas. It has been concluded, on the basis of a certain amount of experience, that the first part of these courses should be carried out at the "school plant" and continued at existing MHG plants.

The first part should be of a theoretical and practical nature, in keeping with the educational level of the operators. In the case of rural operators, it should be expected that they will have completed at least their primary education. The course would run three months and cover the following subjects:

SUBJECTS TO BE COVERED IN MHG OPERATORS' COURSES

- Basic sciences (fundamentals of mathematics, physics, and chemistry).
- Basic operating principles of an MHG and its equipment.
- MHG operation and the interpretation of operating manuals.
- Preventive maintenance principles and methods for MHG.
- Maintenance and repair of building structures and installations.
- Maintenance and minor repairs of mechanical equipment.
- Maintenance and minor repairs of electrical equipment.
- Mechanical and electrical "trouble shooting".
- Identification of mechanical and electrical malfunctions.
- Fundamentals of technical drawings and diagram reading.
- Fundamentals of electrical installations.
- The reading of instruments.
- Bench work mechanics (fittings).
- Safety in operation.
- Fundamentals of administration and bookkeeping.

The second part would be essentially of a practical nature and would consist of a two-month period of operator training at an existing MHG under the supervision and instructions of a skilled operator.

IDENTIFICATION OF MANPOWER REQUIREMENTS FOR EACH STAGE
OF AN MHG PROJECT

A. Planning and Programming
- Engineers
- Economists and social scientists

B. Global Evaluations of Resources and Demands
- Civil engineers
- Hydrologists
- Geological engineers
- Geomorphologists
- Ecologists
- Electrical engineers
- Mechanical engineers
- Energy economists
- Social scientists
- Topographers
- Hydrometry specialists
- Draughtsmen
- Engineering assistants

C. Studies of Specific Projects
- Civil engineers (mainly structural engineers, supported by specialists in hydraulic engineering)
- Mechanical engineers
- Electrical engineers
- Topographers
- Technical draughtsmen
- Engineering assistants
- Test inspectors

D. Construction
- Civil engineers
- Electrical engineers
- Mechanical engineers
- Topographers
- Draughtsmen
- Building inspectors
- Electrical technicians

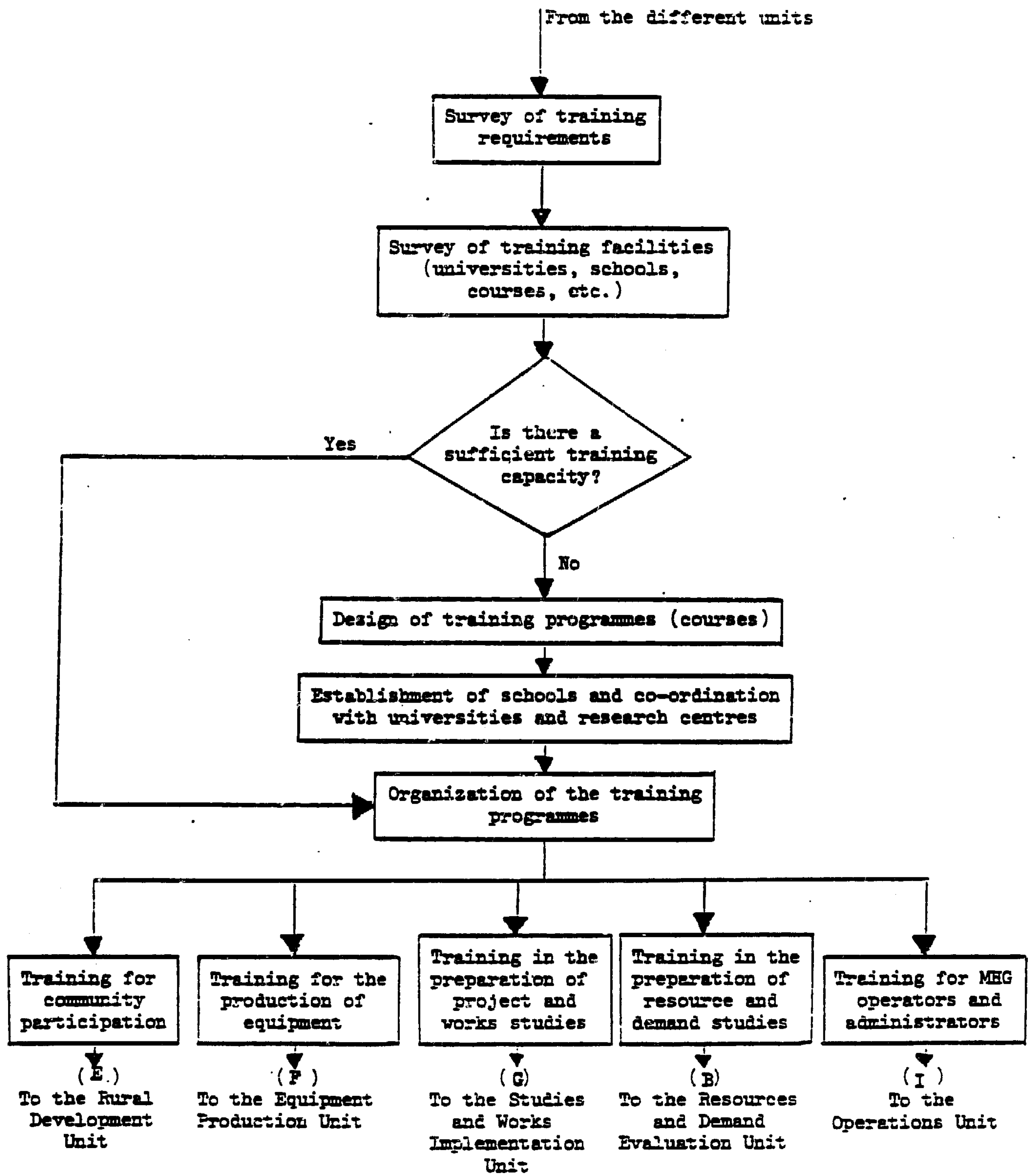
E. Operation and Maintenance
- Electromechanical engineers
- Mechanics and electricians

F. Each country must determine its manpower requirements for technology development and production of equipment and materials in accordance with

This statement of manpower requirements represents an ideal situation. In actual practice, countries may begin their programmes with fewer human resources, since it may be expected that as the work proceeds they will be able to find solutions to their temporary deficiencies in qualified personnel.

Figure 17 contains the flowchart for the training unit.

FIGURE 17 TRAINING UNIT



5.9. SYNTHESIS OF THE MHG BUILDING PROCESS (PLANNING THROUGH COMPLETION)

As indicated in the preceding sections, the decision-making process involved in the building of MHG must be of a comprehensive nature, for the reason that a number of different factors need to be considered.

As may be seen in Figure 18, this process begins with a preliminary assessment of the prospects for these stations. This phase must include a study covering the problems to be solved, the available water resources, and the country's capacity to undertake a project or projects in this area within the context of its national development planning, specifically in the area of energy development. Following the completion of this preliminary study, a political decision must be made as to whether to mount the necessary effort to build these facilities.

If it is decided to move forward in this direction as part of the national development policy, the next step is to establish an organizational framework for planning and programming and to devise procedures for the evaluation of resources and demand at the basin and sub-basin level to serve as a basis for the formulation both of a short-term development plan permitting the immediate implementation of specific projects and of a more long range plan envisaging the building of MHG on a large scale. In parallel with this process, policies must be defined and actions taken in the areas of financing, the development of human resources (training), community participation, and technological development. This final aspect is critical to the determination of guidelines regarding the transfer of technology and the promotion of domestic equipment production.

It is within the context of these plans and policies that the undertaking of specific projects should be approached. The first stage in this connexion consists of the pre-feasibility (survey) study, where required. A pre-feasibility study should be considered only in doubtful situations requiring this kind of preliminary analysis, the fact being that in many cases it may be eliminated altogether in favour of moving immediately to the detailed engineering study, which will then merely include a supplementary economic and financial analysis.

The next phase of the project is concerned with the actual building of the plant and the installation of its equipment, followed by the start-up of the facility (for details see sections 5.6 and 7.4).

Finally, there is the task of establishing the plant's operating procedures, which also include the areas of maintenance and administration. The essential work of this stage is described in sections 5.7 and 7.5.

Flowchart of actions required for building of MHG on a large scale

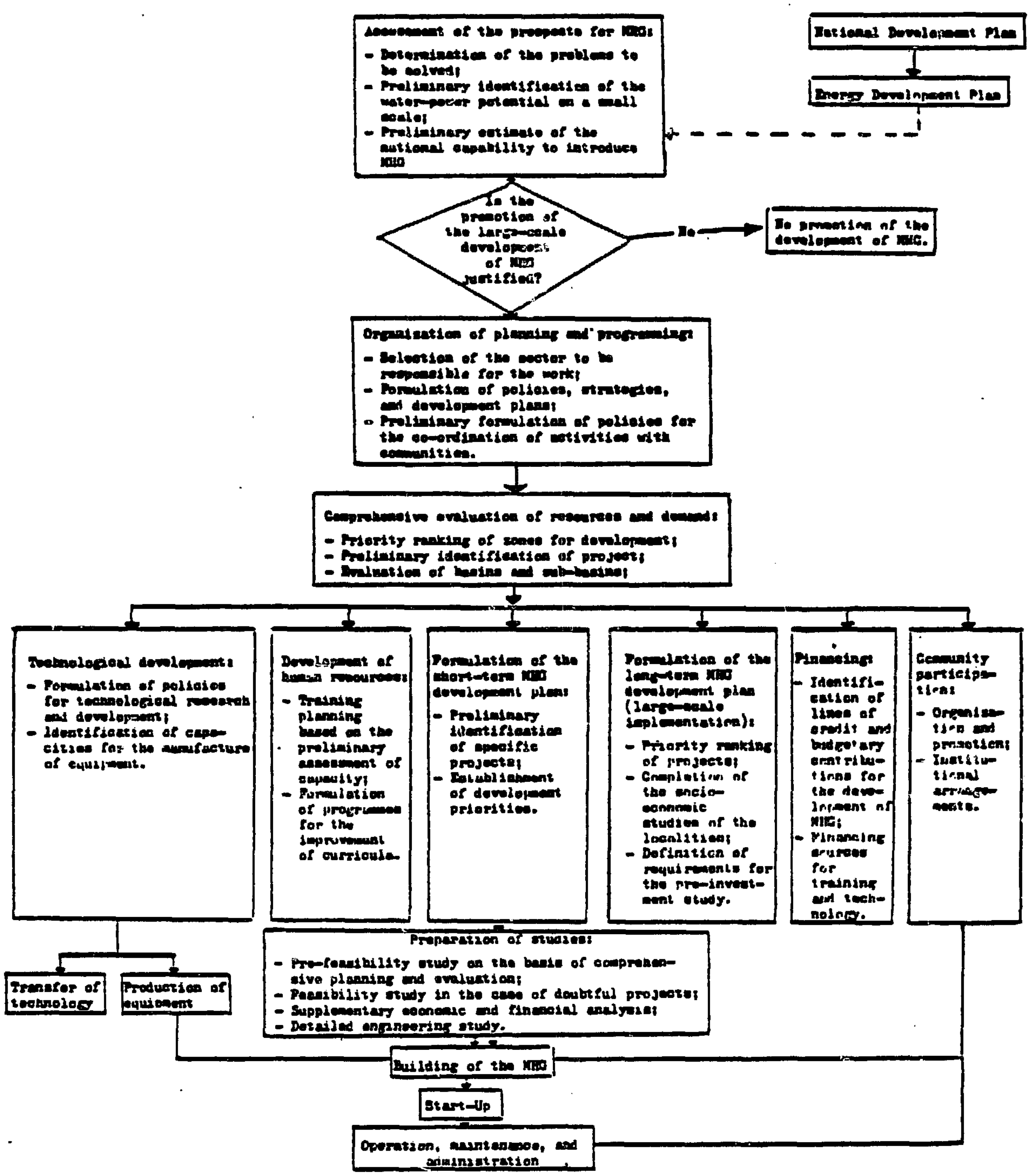


Figure 18

6. DEVELOPMENT OF TECHNOLOGICAL CAPABILITIES

6.1. ASSESSMENT OF TECHNOLOGICAL CAPABILITIES

The technological development of a country should be started with an inventory of its human resources and industrial potential. In the case of technological development for the construction and equipping of an MHG, the inventory should have as a point of reference identification of human resources and also of the production of the equipment and materials as shown in the following two tables.

As regards the materials or equipment not produced in the country, the possibility of developing technology for the production of such equipment or acquiring foreign technology, provided the national or regional market justifies doing so, should be considered. Otherwise, the alternative will be to import the material or equipment.

IDENTIFICATION OF PRODUCTION OF MATERIALS AND EQUIPMENT USED IN MHG

A. Materials for civil engineering work

- Granular materials; clay and silt.
- Cement.
- Steel construction bars.
- Pressure pipes for penstocks (steel, PVC, polyethylene, asbestos-cement).
- Gate and butterfly valves.
- Grates and gates.
- Wood.
- Steel cables
- Bricks.
- Tiles.
- Nails.
- Explosives.
- Galvanized wire mesh.
- Bolts, nuts, washers and screws of various types.

B. Production of equipment and tools for civil engineering works

- Pick-axes.
- Spades.
- Wheelbarrows.
- Motor pumps.
- Concrete mixers.

C. Production of electro-mechanical materials

- Copper and alloys.
- Structural steel.
- Stainless steel.
- Shafts.
- Bearings.
- Electrical conductors.
- Posts and accessories.
- Electrical materials.

D. Production of electro-mechanical equipment

- Hydraulic turbines.
- Speed regulators.
- Electricity generators.
- Measuring instruments (voltmeters, ammeters, power factor meters, frequency meters, kilowatt meters and energy meters, manometers).
- Mechanical transmission systems (gears, belts and couplings).
- Measurement and high-tension power transformers.

E. Industries

- Casting.
- Metalworking and engineering.
- Precision engineering.
- Electrical engineering and allied industries.

6.2. EQUIPMENT

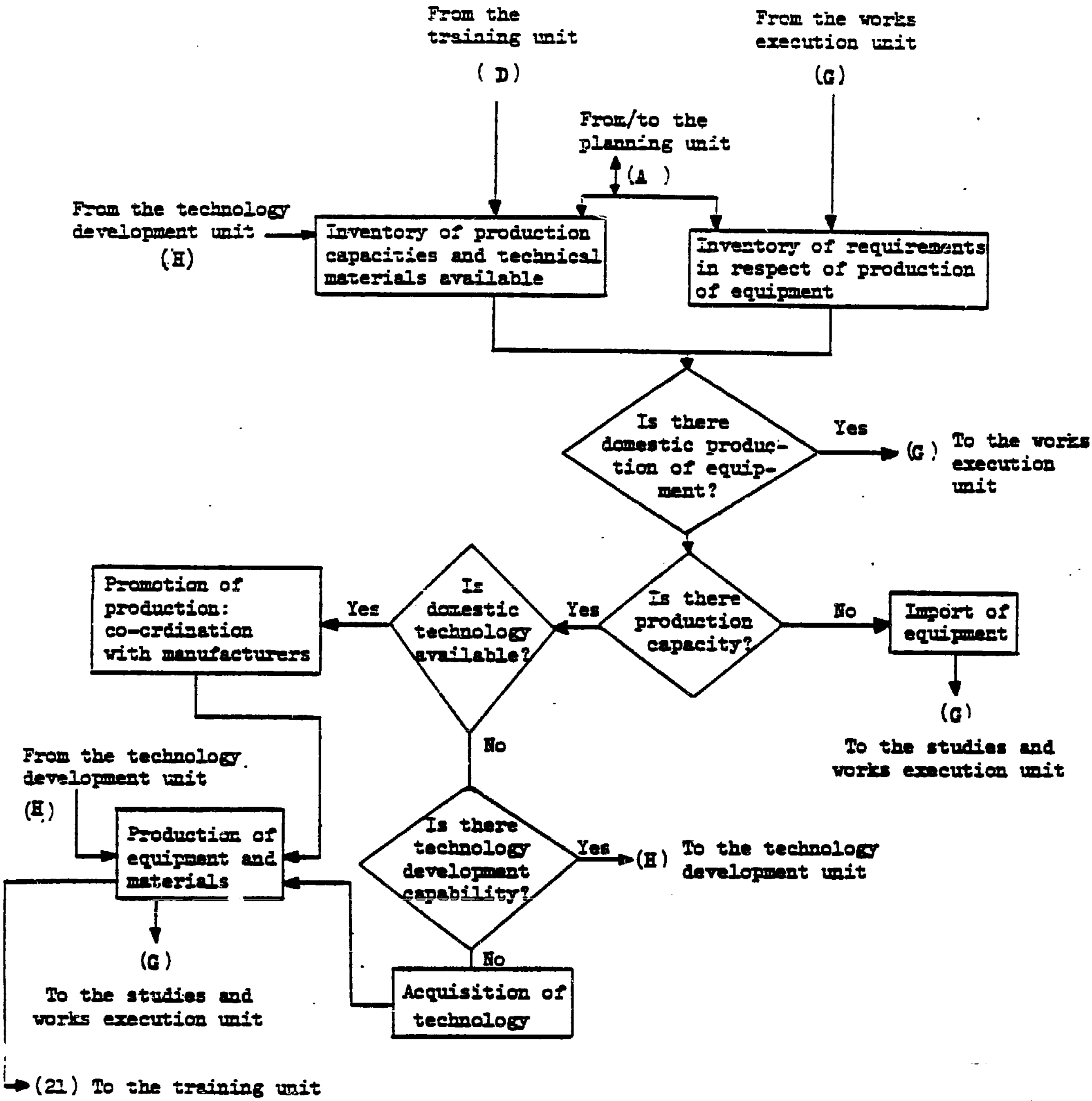
a) Manufacturing capacity

Once the materials and equipment for MHG produced in the country have been identified, an analysis must be carried out to determine the advisability of producing the equipment not being manufactured. Some of the requirements which should be taken into account for the production of MHG equipment are given below.

REQUIREMENTS FOR THE PRODUCTION OF MHG EQUIPMENT

- Adequate technical information for production is required. There are the following alternative sources of technology.
  - Research by the manufacturer himself;
  - Research by centres and institutes in the country;
  - Purchase of technology from foreign manufacturers and research centres.
- In order to supplement the requirements in respect of production of equipment, emphasis should be placed on those items which are of a size and type making them appropriate to the productive infrastructure of the individual country.
- The use and adaptation of materials of domestic or regional origin should be maximized.
- The equipment produced should be standardized.
- Production lines associated with those for related equipment should be set up, since exclusive production of equipment for MHG is not justified owing to small-market size.
- The production of spare parts, mainly those subject to wear, should be contemplated, and a permanent stock of such parts maintained.

FIGURE 10 EQUIPMENT PRODUCTION UNIT



ALLIED INDUSTRIES FOR THE PRODUCTION OF SOME MHG EQUIPMENT AND MATERIALS

EQUIPMENT OR MATERIAL	ALLIED INDUSTRY
PRESSURE PIPES FOR PENSTOCKS	FACTORIES MANUFACTURING PIPES WHOSE MARKET IS DETERMINED BY DOMESTIC INDUSTRY RATHER THAN MHG.
HYDRAULIC TURBINES AND SPEED REGULATORS	METALWORKING AND ENGINEERING ENTERPRISES, FACTORIES MANUFACTURING CENTRIFUGAL PUMPS, VALVES, VACUUM EQUIPMENT, FANS, MIXERS AND FOUNDRY SHOPS.
ELECTRICITY GENERATORS	FACTORIES PRODUCING ALTERNATORS FOR THERMAL ELECTRICITY GENERATION UNITS FACTORIES PRODUCING ELECTRIC MOTORS.
TRANSFORMERS, ELECTRICAL MATERIALS AND ACCESSORIES	ELECTRO-MECHANICAL MACHINARY INDUSTRIES.

b) Development and adaptation of technology

Technological research and development can be one of the basic tools for promoting and sustaining programmes for the construction of MHG in individual countries, since the technologies involved are mature, and only adaptation and innovation processes of a non-conventional nature, permitting adjustment to the specific conditions of the individual country, are required.

Since it is not possible to establish a single organizational pattern for the development and adaptation of technologies which would be applicable in all third world countries, owing to the great diversity of existing situations in respect of research activities, programmes for the construction of MHG and industrial development, only a few general recommendations and alternative organizational patterns are presented in the next table, for the guidance of those countries which are interested in promoting their programmes for the development and adaptation of technology in respect of MHG.

In the MHG national development plans of each country, the development and adaptation of technologies for equipment will have to be looked upon as part of the planning, and for this purpose it will be necessary to determine specific policies, general objectives and the resources to be allocated.

RECOMMENDATIONS FOR ORGANIZING PROGRAMMES FOR THE DEVELOPMENT AND ADAPTATION OF TECHNOLOGY FOR MHG

- From the stage of programme determination, there must be a well-defined financing prospect so as to avoid the frustration of research projects. owing to shortage of funds.
- In order to achieve correct administration of the programme, there must be operational follow-up as regards results, time required for execution and utilisation of funds.
- From the initial stage of the programme, the form and characteristics of results, which may involve dissemination and/or transfer of technology, must be clearly defined (see figure 6.2).
- A variety of institutional criteria may be adopted for programme implementation, which may take place through universities, research institutes, industrial enterprises and/or electrification boards.
- Normally, the programme will be executed through research lines or inter-related groups of projects. Each of these require a brief but clear specific formulation prior to initiation.
- The programme may be divided into two types of activity: aspects relating to civil engineering works and installations; aspects relating to design and production of equipment and materials.
- Each project should have a well-defined execution sequence. Figure 6.3 shows a typical methodology.
- The programme-execution team need not necessarily consist of "experts". Only one or two experienced professionals are required, and the remainder may be young professionals with a good academic background.
- Guidelines should be established for the preparation, at each stage of the project, of documents and reports, which should reflect positive and negative aspects and failures so as to ensure continuity and the accumulation of knowledge useful for the programme, thus avoiding a situation of dependency on the presence of each individual executor.
- During programme execution, the executing agency must maintain close contact between the industry and the enterprise responsible for electrification, in order to achieve results with practical application.
- Dissemination of results may take place through manuals and/or brochures in the case of installation and construction of civil engineering works.
- In the case of equipment, results may be transferred to industry in order to promote the industrial production of such equipment, the enterprise being provided with all technical information required.
- The development and adaptation of technology as regards equipment should be focused on development of non-conventional technologies, taking as a point of reference the industrial capacity of each country.

FIGURE 20 TECHNOLOGY DEVELOPMENT UNIT

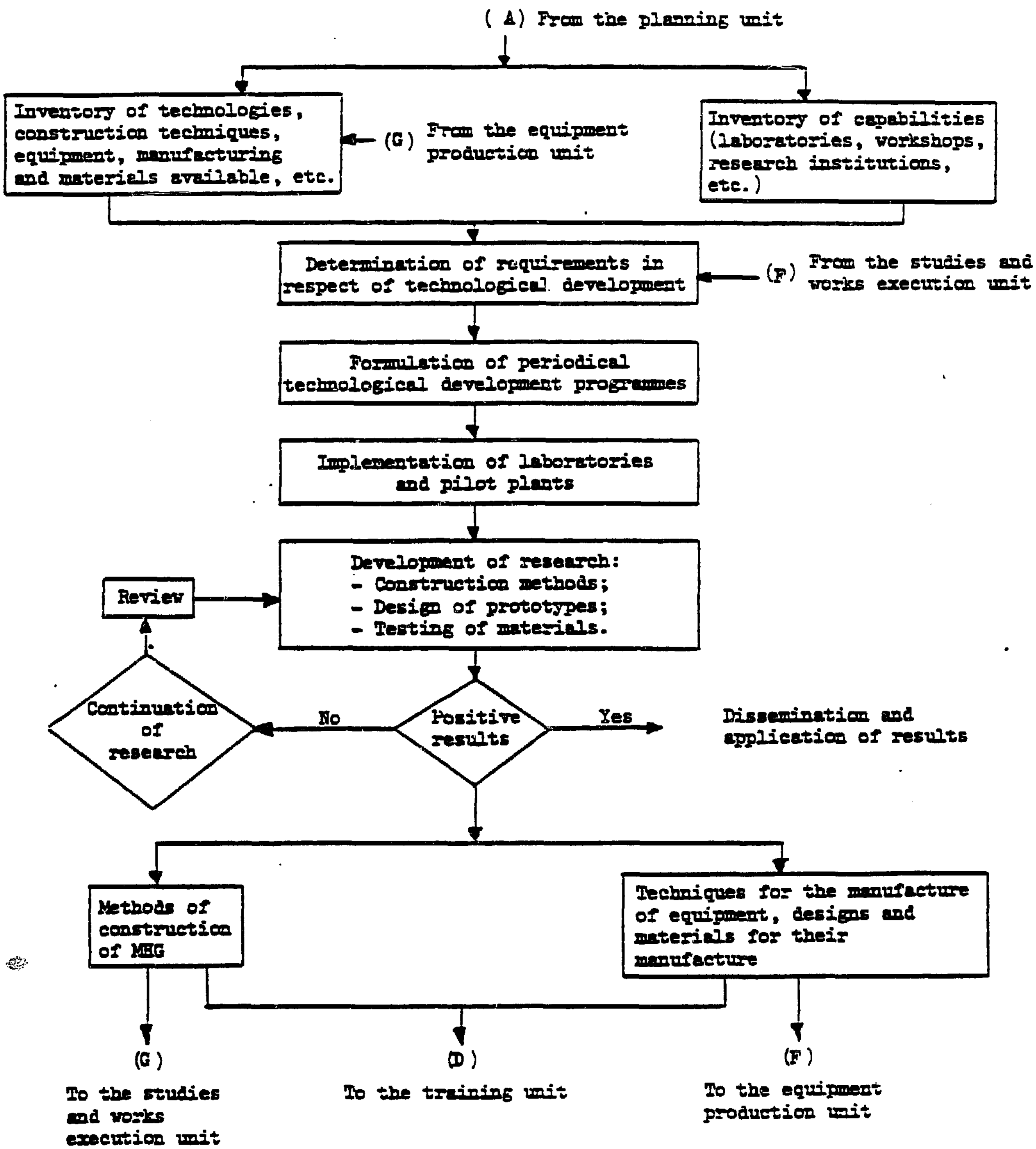


FIGURE 21 TYPICAL SEQUENCE IN THE EXECUTION OF A SPECIFIC TECHNOLOGICAL RESEARCH PROJECT FOR MHG EQUIPMENT

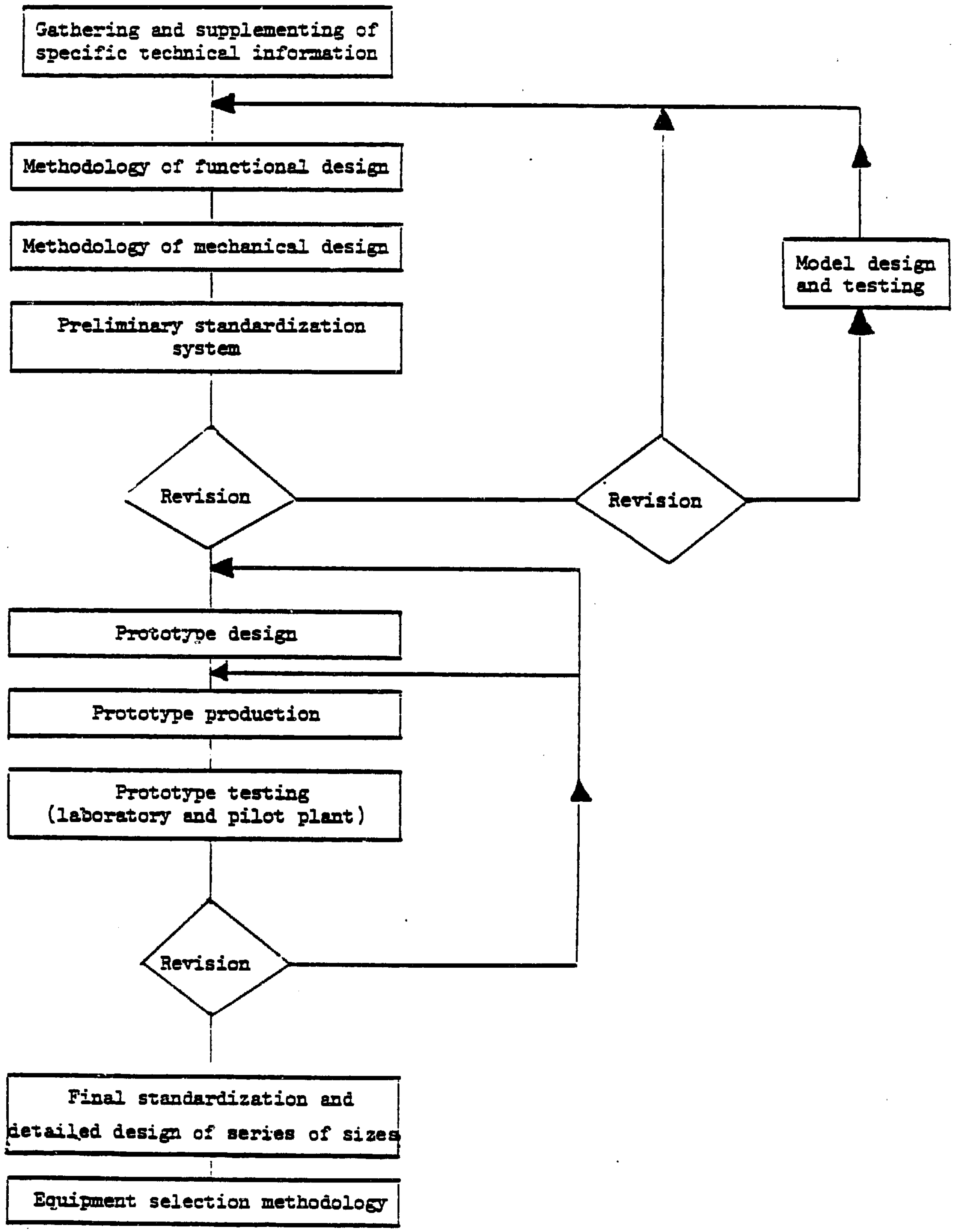
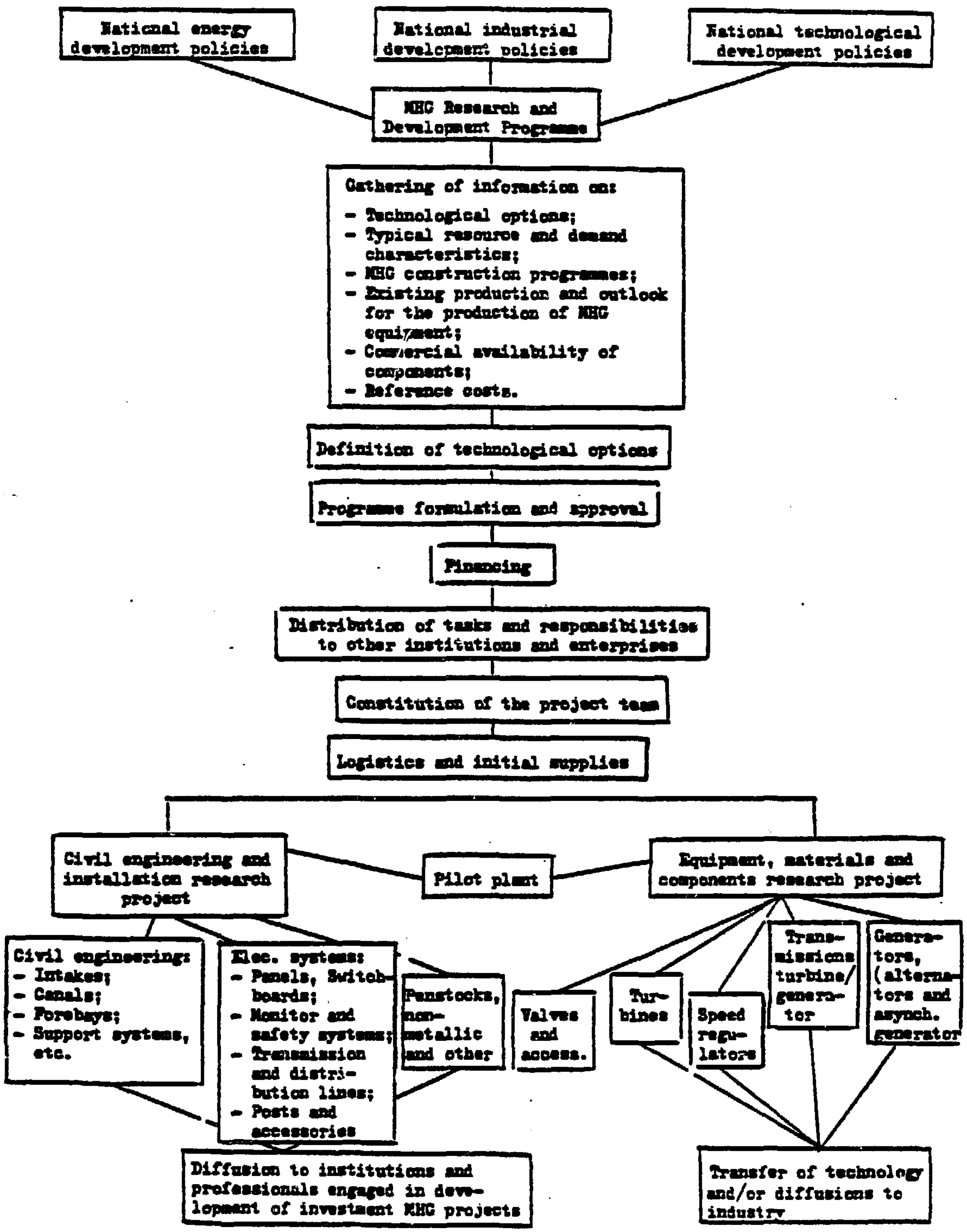


FIGURE 22 STAGES IN THE FORMULATION OF AN MHC TECHNOLOGICAL RESEARCH PROJECT



TECHNOLOGICAL ALTERNATIVES FOR EQUIPMENT USED IN MHG

EQUIPMENT	TYPE	RECOMMENDATIONS FOR TECHNOLOGICAL DEVELOPMENT
Hydraulic turbine	PELTON, MICHELL-BANKI, FRANCIS, KAPLAN OR AXIAL FLOW	- Selection of two or three types of turbines in the light of the characteristic of resources and demand in the country; - Development of hydraulic and mechanical designs; - Study of aspects relating to construction and materials for each part, in the light of the characteristics of the industrial production of the country; - Establishment of methods for the selection of turbines; - Establishment of methods for assembly and disassembly of equipment; - Establishment of recommendations for operation and maintenance.
Speed regulator	OLEO-MECHANIC, ELECTRIC/ELECTRONIC, ENERGY DISPERSION	- Selection of the type of regulator most suitable in the light of the characteristics of operation, industrial capability in the country and technological experience; - Functional and mechanical design; - Standardisation as appropriate for standardised turbines; - Preparation of manufacturing manuals; - Studies on matters relating to construction and materials; - Establishment of methods for selection; - Establishment of recommendations for operation and maintenance.
Electricity generators	ALTERNATORS FOR MHG, INDUCTION MOTORS AS GENERATOR	- Study for the adaptation of the alternators for thermal electricity generation units, mainly as regards runaway speed protection, so that they can be used with hydraulic turbines; - Adaptation of electric motors to operate as autonomous generators; - Establishment of recommendations for operation and maintenance; - General design of generators and most suitable manufacturing process.
Electricity transformers	HIGH-TENSION POWER, MEASURING	- Studies of designs and forms of construction, taking into account the industrial capability of the country; - Standardisation; - Establishment of recommendations for operation and maintenance.
Various electrical equipment and materials	CONTROL PANELS, CONDUCTORS, INSULATORS, LIGHTENING ARRESTERS	- Study for the production of this equipment, after standardisation; - Establishment of methods of selection; - Establishment of recommendations for installation and maintenance

c) Acquisition of technology

Depending on the level of development of each country as regards capacity to geterate usable technologies, project-execution possibilities and prospects for the implementation of production of equipment, it will be necessary to acquire a greater or lesser amount of technology from other countries.

The various means of acquiring knowledge which can be used in production, ranging from technical assistance and the provision of information to the purchase of technological packages to set up production lines, including detailed plans and instructions for manufacturing, assembly and technical services, can be looked upon as purchases of technology.

Most countries have their own legislation regulating the acquisition of technology, and it is therefore impossible to lay down specific guidelines on the matter, but general recommendations can be made regarding the acquisition of technology for manufacturing MHG equipment.

As regards MHG, the acquisition of technology relates primarily to the electro-mechanical equipment and accessories.

Some considerations and recommendations which should be borne in mind in connexion with the acquisition of technology are given below:

- With a view to achieving technological development in keeping with the characteristics and industrial capacity of a country, it is advisable to limit the acquisition of technology to those cases in which the development of technology is not considered to be of interest, or when research work does not afford prospects for the application of results in periods of time shorter than those required for achievement of the same results by industry.

- The acquisition of technologies should take place through a process of selection of alternatives and should be limited to those parts in respect of which the level of technological development attained makes possible full production, in keeping with the priorities laid down for national technological development. The acquisition of technology should be organized in such a way that it constitutes a real contribution to this development in that it permits the assimilation of knowledge by national technicians. Disguised commercial elements of acquisition of technology and technical assistance, aimed only at the granting of exclusive licenses under the appearance of bilateral assistance programmes, must also be avoided.

- The acquisition of technology will be justified when the complexity of the equipment or of some of its parts surpasses the development capacity of the country. Acquisition should be confined to those elements which are necessary and cannot be designed and/or manufactured in the country without foreign assistance. Restrictions making it necessary to import parts which could be locally produced should be avoided and, on the contrary, the local manufacture of components and use of materials available in the country should be promoted.

- The fullest and most careful analysis possible should be made of alternatives prior to any process of transfer of technology. Inclusion of the largest possible number of alternatives under the same terms of reference should be ensured, and evaluation criteria should be laid down prior to the analysis. Technologies appropriate to the industrial and technological level of development of the country, using mainly local raw materials and labour, should be given favourable consideration.

- Contracts for the purchase of technology should be concluded with fixed periods of duration, at the end of which, the obligation to pay royalties ceases, and the royalties should be fixed only on the basis of a percentage of sales, avoiding the inclusion of minimum-payment obligations. Restrictions with regard to the scope of the market for products should also be avoided, and obligations to purchase raw materials from a given supplier should not be accepted, thus preserving the freedom to purchase on the market if more favourable terms can be obtained.

- In order to improve national enterprises' negotiating capacity in respect of the acquisition of technology, it is important that clear policies should be defined with respect to the acquisition of technology and that legislation should tend to limit the imposition of restrictive clauses by suppliers and technology.

d) Import of equipment

If the specific characteristics of a country as regards its industrial policies or production capability are such that the local manufacture of some types or sizes of equipment is not justified, these items must be imported. In these cases, personnel trained in the analysis and selection of alternatives and the technical equipment required for carrying out acceptance testing are necessary. The support which can be extended in this field by institutions engaging in technological research is important.

In purchasing equipment, the following technical considerations must be taken into account:

- The capability for the manufacture and repair of components and spare parts in the country;
- Characteristics of maintenance and operation appropriate to the conditions of use;
- Ability to withstand situations arising out of errors of operation;
- Ease of assembly and disassembly of parts and accessories.

In addition to the requirements in respect of fulfilment of technical specifications, guarantees, costs and delivery date for equipment, suppliers of equipment should be asked for the following:

- General drawing of equipment;
- Information on the materials used in the main components of the equipment which are subject to repair;
- Lists of spare parts;
- Instructions for assembly, disassembly and repair;
- Technical assistance for the training of local personnel responsible for the maintenance and repair of equipment.

For bidding or tendering for the acquisition of electro-mechanical equipment for MHG projects, it is important that the following technical data should be provided:

- Usable head;
- Maximum generating power at the contacts of the generator;

- Generating frequency;
- Generating voltage;
- Environmental conditions under which the equipment operates.

The suppliers of the main pieces of equipment should also be asked to provide the following technical data:

- Type of turbine and its specifications;
- Efficiency curves of the turbine operating under different load conditions;
- Type of speed regulator and its specifications;
- Characteristic curves of operation of the regulator;
- Type of mechanical transmission or direct coupling between turbine and generator;
- Specifications of the control panel or switchboard, including ranges and accuracy of the instruments integrated into it.

When bidding or tendering is carried out, it is recommended that a list of possible suppliers should have been identified in advance. These should be asked to provide information on:

- Reliability and efficiency of their equipment;
- Cost indexes;
- Credit facilities;
- Expected life term of equipment;
- Fulfillment of delivery dates;
- Ease of adaptation of equipment to local industry for the manufacture of spare parts.

6.3. DEVELOPMENT AND ADAPTATION OF TECHNOLOGIES FOR CONSTRUCTION

In this connexion, it is essential to stress the need for research both on methods of construction as such and on the use of non-conventional materials. The research must be linked with investment projects by means of pilot plants.

Although the design and construction of civil engineering works are largely determined by the nature of the site, the possibility of preparing manuals envisaging standardization or semi-standardization of civil engineering works must be investigated.

Furthermore, it is very important to organize research relating to the production of pre-fabricated elements for civil engineering works.

The institutions carrying out research on materials and various elements for MHG, should co-ordinate their activities with the units engaged in engineering activities in the field, which may be carrying out research in the context of investment programmes during and after construction.

The research concerning materials should be oriented towards establishment of their hydraulic and mechanical properties.

In general, there are two technological alternatives as regards civil engineering works, namely, a conventional one based on the use of concrete, reinforcing steel and structural steel as well as considering separately the structures conforming to a MHG, and another which involves a minimum utilization of these materials and endeavours to integrate structures (such as constructing the silt basin and forebay in a single structure), and utilize existing infrastructure (such as existing irrigation canals). As regards methods of construction, mention can be made of the ones based mainly on intensive use of labour (in the optimum case, with participation of the community), the ones based on intensive use of machinery and mixed cases.

It would be very advisable to promote or support surveys to increase knowledge of existing production capacities of materials so as to be able to develop their supply.

Construction technologies should be disseminated by means of manuals for the design and execution of works.

6.4. CHECK LIST OF TECHNOLOGICAL ALTERNATIVES

The technological alternatives most suitable for each country cannot be rigidly stated because the conditions calling for the establishment of programmes for the development and adaptation of technology for MHG will also vary, as will conditions relating to geography, hydraulics, labour, availability of skilled manpower, appropriate financing, etc., all of which have a bearing on determination of technological alternatives.

Taking into account the above comments, a selection of possible areas of interest for technological development is presented below.

a) Construction

The various materials which can be used in the civil engineering works for MHG are analysed below. It is important to stress that, in the context of non-conventional technologies, the following is taken into account: use and improvement of existing intakes and irrigation canals; forebay installed "in-line" with the canal and including the silt basin; penstock conduit in non-metallic materials, dams of artisanal construction, reduction to a minimum of the use of costly materials such as concrete, and use of non-conventional materials such as ferro cement, soil cement, etc.

It is advisable to specify materials taking into consideration the applicable national standards, and when these are not available, use appropriate foreign standards and norms. It is important to promote the development of national standards for the main materials employed in MHG, in order to ensure the drafting of adequate specifications and a good quality control.

TECHNOLOGICAL ALTERNATIVES IN RESPECT OF MATERIALS

MATERIAL	USE	ADVANTAGES	DISADVANTAGES
Clay and silt	Dams or core walls	High degree of impermeability	Possibility of fracturing
Granular materials	Dams or core calls	Low degree of impermeability	Better performance under external stress
Wood	Dams, penstocks, power house, gates	Low price	Short life
Gabions	Dams, canals, protection of slopes	Low cost; easily adapted to the site	Permeable during the initial period
Concrete	Dams, canals and ancho-rages, core walls, fore-bay, power house	Durability; resistance to high compression	High cost; poor performance in torrent, works
Ferro-cement	Linings, silt basin, forebay	Low cost; high general resistance	Low resistance to concentrated and pearcing loads, exacting construction
Soil-cement	Linings, dams	Low cost	Poor durability, low resistance
PVC	Penstock	Low cost, light weight, rapid installation, easy adaptation to profile, low head losses	Relative fragility; it is convenient to bury them; low resistance to solar radiation
Polyethylene	Penstock	Continuous lengths, withstands considerable deformation, ease of transport and installation; good resistance to impact and solar radiation	Joints require special steel couplings which are exacting to install; high head losses

MATERIAL	USE	ADVANTAGES	DISADVANTAGES
Asbestos-cement	Penstock	Lower cost than in the case of PVC; good adaptation to the profile of the fall; no expansion joints required; reduced head losses	Relatively heavy and fragile, so that it is advisable to bury them

b) Equipment

The list below describes the principal items of equipment used for MHG, together with a number of recommendations for the development of technology research projects.

HYDRAULIC GENERATORS

TYPE	GENERAL CHARACTERISTICS
PELTON	- This is a tangential-flow action turbine consisting of one or more nozzles and a runner carrying a certain number of buckets. - The range of application of pelton turbines is limited to low specific speeds. Operating with high heads and reduced flows, this turbine can give an efficiency of approximately 85 per cent. - Its manufacture requires an industrial plant equipped to perform operations of casting, welding, cutting and basic machining (turning, planning, and drilling). The runner and nozzles are normally produced by casting.
MICHELL-BANKI	- This is a partial-admission, cross-flow, action turbine with radial intake, and consists of an injector and a runner having a certain number of curved blades. - This turbine's range of application lies between that of the double-nozzle Pelton and the high-speed Francis turbine, in situations involving medium heads and moderate flows. This turbine can operate with efficiencies in the order of 80 per cent and generate up to 1,000 kW of power. - Because of its particular geometry, the Michell-Banki can be easily produced and is regarded as a low cost turbine. - Its manufacture requires an industrial plant equipped to perform welding, cutting, and basic machining operations (turning, planing and drilling). This turbine can be produced using welded parts.

TYPE	GENERAL CHARACTERISTICS
FRANCIS	- The use of this turbine is restricted to medium specific speeds and, like the Michell-Banki type, to medium heads and moderate flows. Its efficiency lies between 83 and 90 per cent. - Its manufacture requires an industrial plant with the necessary equipment for casting, welding, cutting, and machining.
AXIAL-TYPE	- This is an axial-flow reaction turbine, whose speed control system is incorporated in the runner in the particular case of Kaplan Turbines. Its area of application is limited to fairly high specific speeds. Operating with very low heads and large flows, it is capable of achieving efficiencies of about 90 per cent. - Its manufacture requires an industrial plant set up for casting, welding, and cutting, and equipped with the usual basic machine-tools.

SPEED REGULATORS FOR HYDRAULIC TURBINES

TYPE	GENERAL CHARACTERISTICS
ELECTRICAL-ELECTRONIC (with flow control)	- This regulator consists of an electronic device designed to detect variations in the speed of the turbine on the basis of the variations in generating frequency that accompany a change in load, and an electric motor which drives a mechanism opening or closing the turbine's flow regulation valve in either direction. - As the electronic unit is the same in all cases and does not depend on the power, this regulator is inexpensive to manufacture, the electric motor being the principal variable cost factor. - Its manufacture requires an industrial plant specializing in electrical and mechanical work and with its own electronics shop.
ENERGY-DISSIPATION TYPE (electrical-electronic)	- This regulator consists of an electronic device designed to detect variations in the speed of the turbine on the basis of the variations in generating frequency that accompanies a change in load and a system of electrical resistences that increase or reduce fictitious loads to maintain constant load on the turbine. - The electronic devise is similar to the one required for the electric-electronic regulator with positive water control. - Its manufacture requires an industrial plant with an electronics shop.

TYPE	GENERAL CHARACTERISTICS
OLEO-MECHANICAL	- This kind of regulator consists of a speed sensitive element, usually in the form of a centrifugal pendulum, a force distribution element incorporating a pressurized oil distribution valve and a servomotor, a compensation and reversing system designed to stabilize the velocity of the group, a gear or sliding vane pump, and a number of actuating devices to control the flow-regulation valve of the turbine. - The cost of manufacturing this regulator is, comparatively speaking, higher than the cost of the electro-electronic regulator, and its production requires an industrial plant equipped to perform welding, cutting and precision machine-tool operations.

ELECTRICAL GENERATORS

TYPE	GENERAL CHARACTERISTICS
ALTERNATORS	- These are generators whose design incorporated a voltage regulator and reinforced coils capable of withstanding turbine runaway speeds. - For economic reasons, the use of two- or four-pole alternators is recommended for MHG. - Manufacture requires an electro-mechanical plant with basic machine tools and equipment for the winding of coils, welding, and cutting.
INDUCTION GENERATORS	- These are induction motors operating as generators either independently or in parallel with an alternator. - Their fabrication requires no more than the adaptation of existing electrical motors and can be undertaken at the manufacturing plant itself.

7. APPROACHES TO SPECIFIC PROJECTS

7.1. SPECIFIC ASSESSMENT OF DEMAND AND RESOURCES

a) Demand

An important point to remember is that the demand estimated in the planning phase will be used for the specific projects phase.

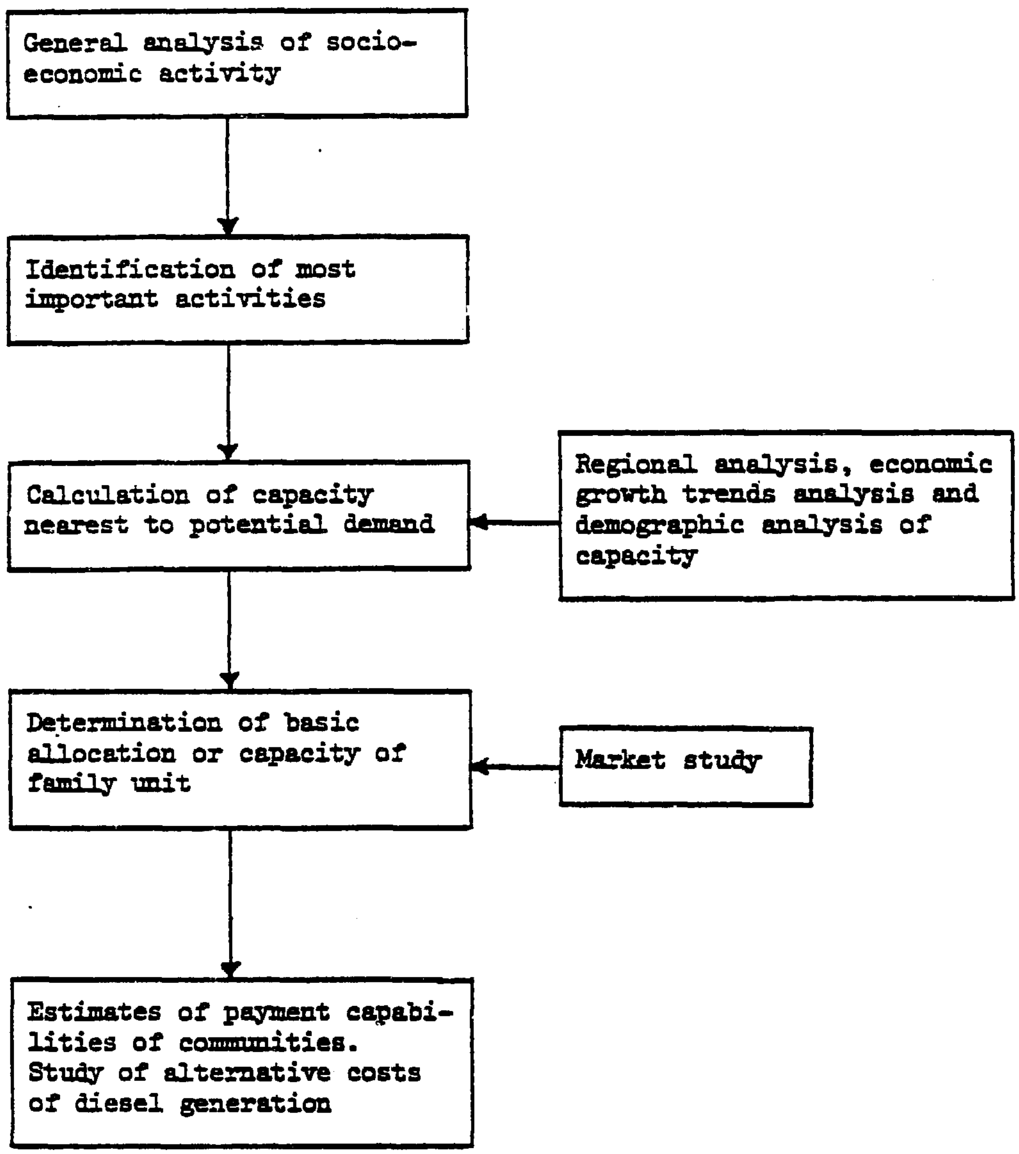
Demand is assessed in the light of local and regional conditions. The potential electricity demand is calculated and a global estimate of future demand growth is prepared by establishing a planning target to be achieved in a time equal to the estimated time required for a grid supply.

These analyses require field investigations and processing of the data discovered.

ACTIVITIES REQUIRED FOR SPECIFIC DEMAND ASSESSMENT

- Identification of the major development complex of the zone.
- Identification of area of influence of development complex.
- Inventory of socio-economic activities.
- Identification of possible future growth factors in the zone.
- Analysis of data yielded by field work and other sources.

Sequence of phases in demand estimation might proceed in accordance with the following block schematic diagram:


General analysis of socio-economic activity
Identification of most important activities
Calculation of capacity nearest to potential demand
Regional analysis, economic growth trends analysis and demographic analysis of capacity
Determination of basic allocation or capacity of family unit
Market study
Estimates of payment capabilities of communities. Study of alternative costs of diesel generation

b) Resources

Resources are estimated on the basis of analysing existing cartographic, geological, geomorphological, hydrological and econological data, supplemented by field surveys, headwater surveys and topographic surveys.

Possible headwaters are identified from information supplied by the local population. Headwaters near - i.e. within approximately 15 km - settlements in the basins under study are researched and their discharges surveyed.

The available head is determined by simple topographic methods. A pocket altimeter is satisfactory for high falls. A precision altimeter should be used for low falls. In both cases a spirit level can be used as well.

7.2. SELECTION OF TECHNOLOGY FOR THE DEVELOPMENT AND DESIGN OF MHG SYSTEMS

GENERAL DESIGN CRITERIA

- Characteristics of region, such as access facilities for possible future use of building equipment.
- Availability of local building materials.

a) Only intake works

CRITERIA FOR SITING INTAKE WORKS

- Look for maximum narrowing of stream channel in order to minimize spillway length and, therefore, excavations and structural work.
- Look for site in accordance with sediment conditions.
- Search for best foundation for structure, preferably on rock outcroppings to ensure stability.
- Choose minimum length of conduit in contact with maximum waters in order to reduce amounts of reinforced concrete.

b) Conduit system

DESIGN CRITERIA FOR CONDUIT SYSTEM

- Suitable design on plan to minimize excavations.
- Minimum water flow rate of 1.0 m/s to avoid sedimentation.
- Duct cross-section close to optimum hydraulic value.
- Check on seepage to determine whether duct walls and base need lining. As a rule of thumb, lined ducts cost twice as much as unlined.

c) Silt basin - surge chamber

CRITERIA FOR DESIGNING SILT BASIN AND SURGE CHAMBER

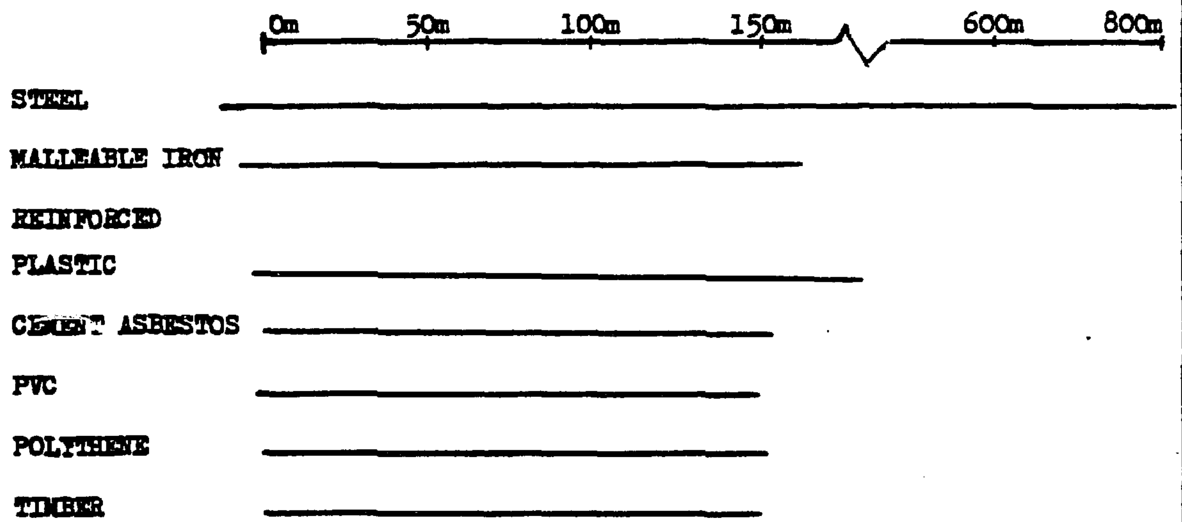
- Check capacity to ensure appropriate supply to penstock, absorption and damping of oscillations arising from opening and closing of inlet valves due to variations in turbine loading, and control of water level at penstock inlet.
- The design dimentions of the silt basin should be determined in the light of the permissable size of the particles that can be allowed to enter the turbine, and the characteristics of the solids in the water.
- The depth of the silt basin should be such as to preclude disturbances due to rising and descending flows caused by temperature changes.

d) <u>Penstock</u>

CRITERIA FOR PENSTOCK DESIGN

- Various materials are suitable.
- Various types and sizes can be used in combination to achieve optimum solutions.

The following shows the various materials which can be used under different heads (in metres).



In order to withstand the maximum permissible water hammer for power stations, the rated pressure of the tubing should be something like 30 per cent more than the gross drop. Water hammer surging can be controlled by appropriate closing timing of the controller.

- Building costs, which increase with diameter as well as with ground conditions, should be balanced against tubing pressure drop, which reduces output. This comparison will help to determine the optimum diameter.

- Anchorages should be designed for safety factors based on overturning, sliding and bearing capacity. The tubing should also be studied for three different kinds of load - dynamic pressure load on tubing, static pressure load on tubing and load on empty tubing. It is also advisable to design a filter to extend along the whole length of the penstock to drain possible seepages.

e) Powerhouse

DESIGN CRITERIA FOR POWERHOUSE

- The area to be built on depends upon plant requirements, on head, water flow and number of units. If enough funds are available, a residential area can be provided for the operator. A water supply system with filter bed purification and a sewage system with septic tank can be provided.
- Drains and/or some other system should be provided around the powerhouse perimeter to intercept surface water and keep down the level of the water table.

DESIGN CRITERIA FOR TRANSMISSION LINE

DESIGN VARIABLES:
- Line voltage.
- Capacity.
- Power factor.
- Length.
- Height above sea level.
- Average, maximum and minimum outside temperatures.
- Wind speed.

7.3. BUILDING METHODS

The various possible methods for building the elements which make up an MHG will now be considered.

Dam

- Gabions are easy to install and cheap. Possible seepage early on can be prevented by concrete or timber bulkheads. Conditions may become critical with very low flows in cases in which significant losses are unacceptable.

- If appropriate materials are available in the region, it is worth considering the alternatives of massive concrete or of brick. Massive concrete has the advantage of using appropriate rock coming from excavation works. This is the best solution for sites with high water heads over dams, but foundation problems are much easier with heads of below two metres. The main diffeculty is that since the structure is rigid, cracking may occur due to differential settlements. If there are facilities for transporting materials and equipment, alternative combined structures for the dam and intake of reinforced concrete can be considered, provided that the structure is of small dimensions.

Intake

- There are various possibilities. If there are old stream beds, they can be enlarged by excavation and the water diverted through them, so that the construction of the intake system can proceed virtually completely dry.

- Another possibility is to use sheet piling. The intake, lock and conduit are constructed first, then the spillway is constructed while the water flows through the lock and intake. This alternative calls for sheet piling of appreciable length and reduces the space available for working during construction. The maximum permissible discharge of the lock increases the risk of flood damage.

- The first alternative may be better if excavation costs are justified by the reduction in risks and inconveniences as compared with the sheet piling alternative.

Silt Basin

- This can be positioned immediately after the intake works, in which case the nearness of the flow is used economically for sediment cleanliness. The water should also be free of sediments along the construction conduit, although sediment may occur in its open run.

- Another alternative is to use a combined sand trap and forebay. This option is of course cheap but requires a faster flow rate through the conduit system to prevent sedimentation. It is usually associated with the use of earth conduits and is useful to MHGs.

Penstock

- Steel pipes are very expensive from both the materials and installation aspects. Cement asbestos pipes are cheaper and easier to obtain, although in some cases there may be limitations due to the maximum commercially available diameters.

Powerhouse

- Here more than in any other part of the civil engineering works, the use of pre-fabricated elements can be considered as a means of cutting costs. It is very important to bear in mind local materials, not only for reasons of cost but also of appearance but also taking into consideration their behaviour under seismic conditions.

7.4. SELECTION OF EQUIPMENT

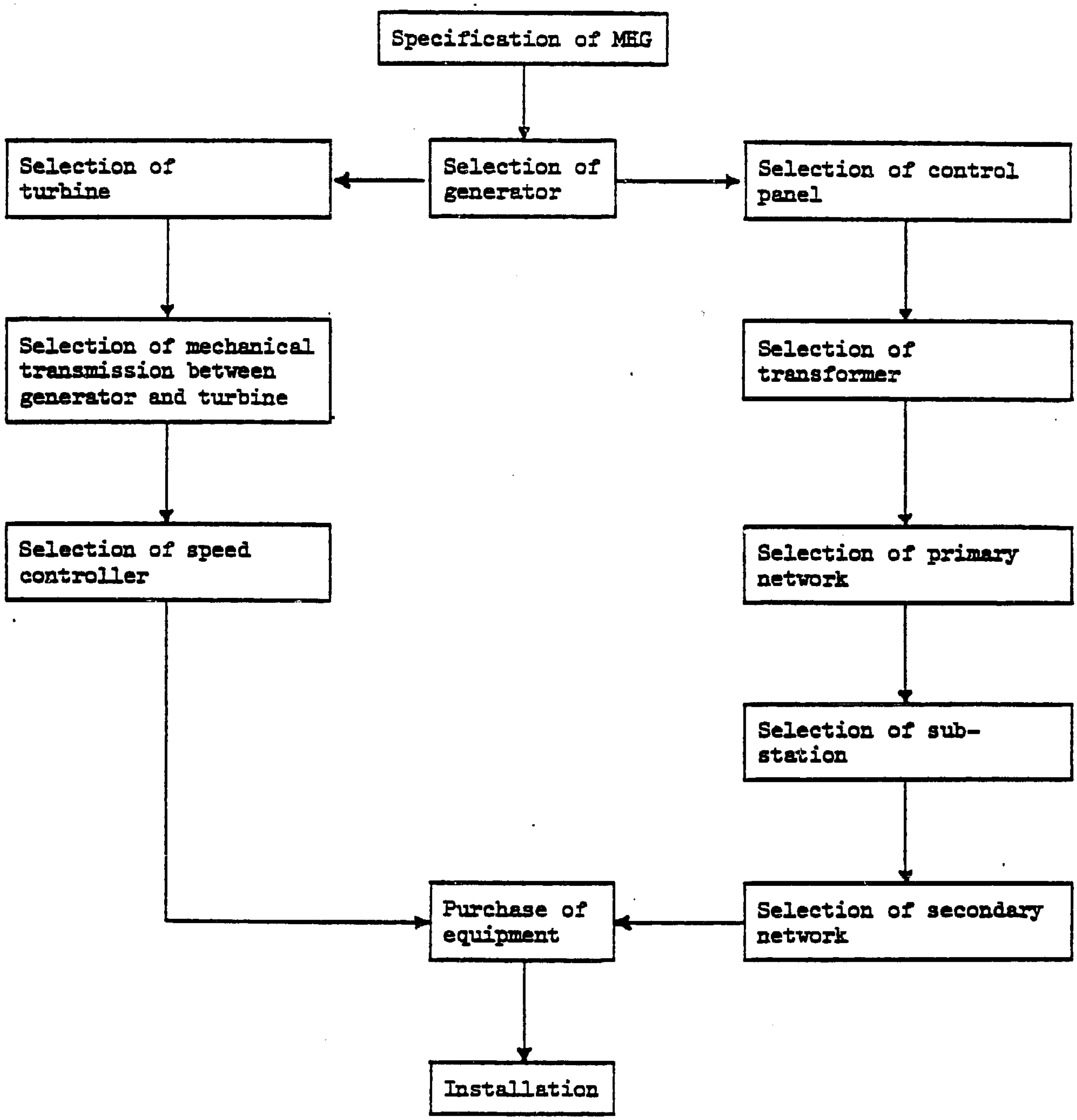
MHG equipment should be selected from the commercial catalogues of national and international makers of standard equipment. The main selection criteria should be reliability and cheapness.

The following table gives details of the procedure for selecting the various items of MHG equipment.

EQUIPMENT	SELECTION PARAMETER	SELECTION PROCEDURE
Trash rack	Allowable particle size	- According to the specification of turbine materials, minimum flow selection and head. This can be for automatic or manual cleaning.
Valve	Pipe size, pressure	- Mainly used gate, butterfly, and spherical valves, according to pipe size, turbine intake, water head and close up time.
Turbine	Head Discharge Power	- Once the characteristics of the turbines as explained in Chapter 6 of this Manual are known and once generator speed is known, a turbine speed can be decided on and the best kind of turbine can be selected using the methodology given in Annex B of this Manual; remember that turbine cost is inversely proportional to turbine speed. - Once the kind of turbine has been decided on, a standard model suitable for the head, discharge and power is selected from commercial catalogues; these parameters will determine turbine speed, which will not differ greatly from the planned value.
Speed controller	Capacity Frequency	- Selection of the speed controller is automatic once the turbine has been selected. - The controller can be elec-mechanical or electro-electronic.
Turbine/ Generator Transmission	RPM Load	- The mechanical transmission between the turbine and the generator should be selected in the light of the speeds of each and bearing in mind that belt transmission is used for high speeds and gearing for low speeds. If the turbine and generator both run at the same speed, a direct coupling is used.
Generator	Capacity	- The generation voltage and frequency are selected with reference to each country's electrical standards for generation. - The most appropriate kind of generator should be selected accordingly, as indicated in Chapter 6 of this Manual. - A generator of the required capacity and generation frequency and voltage should be identified in the commercial catalogues. Bear in mind that generator cost is inversely proportional to its speed.

Control panel for powerhouse	Capacity Voltage Frequency	- A control panel should be selected to suit the generator's maximum capacity, voltage and frequency. The aim should be to use the least possible amount of instrumentation compatible with effective control.
Power transformers	Capacity Voltage	- Transmission voltage is selected in accordance with each country's standards for transformers and the transformer to be used can be selected in commercial catalogues on the basis of capacity. Remember that short-circuit currents may be five or six times the rated current.
Transmission or primary network	Capacity Transmission voltage	- The optimum cable cross-section is selected in accordance with each country' country's standards for electrical conductors and to give minimum voltage drop and power loss.
Sub-station	Capacity	- The distribution voltage is determined in accordance with each country's standards. The transformation ratio can then be found and the corresponding sub-stations selected from the catalogues.
Distribution or secondary network (consumer connexions)	Distribution voltage	- The same criteria and standards as used to select the primary network are used to select the secondary network.

PROCESS OF EQUIPMENT SELECTION FOR MHG



* The selection process can also be started from the turbine.

7.5. OPERATION, MAINTENANCE, AND REPAIR

Operational characteristics depend mainly on:

- The size of the plant;
- The type of service;
- The level of control automation;
- The reliability of the equipment;
- The institutional structure of the electric power system.

Assuming an MHG having a low level of automation, limited to the velocity and voltage regulators and the safety systems, and designed to operate only a certain number of hours a day, a single operator might be all that is required. For a continuously operating MHG, on the other hand, two operators working in shifts would be needed.

These operators must be able to perform their duties with competence and to handle tasks involving preventive maintenance and minor emergency repairs.

An MHG operator must have at least basic knowledge in the following areas:

- Fundamentals of industrial electrical systems;
- Bench machining;
- Welding;
- Administration;
- Operational sequences.

Maintenance and repair operations may be distributed as follows:

ACTIVITY	RESPONSIBILITY
- Preventive maintenance of equipment	Operator
- Preventive maintenance and general repairs to the civil engineering structures.	Operator with community support
- General equipment repairs.	"Flying maintenance squads" of the electric utility and/or the operator.
- Major equipment repairs	Specialized workshops or the manufacturers .

RECOMMENDATIONS FOR THE CIVIL WORKS

- The regular inspections of the channels, diversion dams, spillways, control sluice gates, piping, and conduits are extremely important. The frequency of the inspections varies according to climatic conditions.
- During flood periods daily inspections must be carried out with a view to detecting threatening conditions caused by rising waters or slides. Such threatening situations may include: erosion of supporting pillars, unusual loads on the ducts at or along the riverbed, the accumulation of waste material at the grids or gates of the diversion dams, unacceptable erosion below the diversion dams, or abnormal downchannel water levels.
- Flooding may be more of a problem at low-head installations than at high-head plants for the reason that it may damage the dam and the generating units.
- Slide may damage the canals and ducts, in some instances filling them with debris and causing overflows and abnormally high sediment loads on the turbines.
- The inspections made during periods of emergency must be carried out by experienced personnel who are familiar with the operation of the facility.
- The dam must be inspected annually in order to make certain of the integrity of the dam itself and of its abutments.
- Any structural fissures or leakage through the dam or its abutments must be the subject of frequent and careful inspection for the purpose of detecting possible changes.
- Permanent bench marks must be made on the dam during construction for use in performing measurements designed to record the beginnings of any possible slippage or movement.
- Piezometers must be installed in the foundation of the dam, and their readings must be checked at least once a month for the purpose of detecting any sudden, changes in pressure below the dam.

RECOMMENDATIONS FOR THE ELECTROMECHANICAL EQUIPMENT

- The machinery and valves must be regularly serviced so as to ensure that they will operate properly and reliably when required.
- All gates and valves must be operated through their full range of travel at least once a month.
- In the case of small plants, defective valves and gates may be replaced, with the defective parts taken to a central workshop for repair. This may also be done in the case of turbines, regulators, generators, and transformers when they are small enough.
- In both high and low-head projects, the valves and gates must be test-operated at least once a month to ensure that they will perform reliably when required. If there are a number of gates, they should preferably be of identical design, and consideration should be given to the acquisition of a replacement gate to be used in the event of damage caused by floating debris or wear..
- Generators must be inspected every six months and disconnected once a year for preventive maintenance.
- The turbines must be disconnected and inspected every year for faults.
- The control panels must be inspected every four months and disconnected every year for preventive maintenance.
- The busbars, especially their connexions, must be inspected every four months.
- The transformers must be inspected every six months and disconnected every year for preventive maintenance.
- The circuits must be inspected every six months and must be checked for faults at the time of the annual maintenance.
- The substations must be periodically (every three months) checked for short circuits.

7.6. COSTS

In this section, a number of quantitative guidelines are discussed which may be used to estimate the costs of an MHG for purposes of planning and rough calculation only. The fact is that reliable cost predictions for specific projects on the basis of over-all indicators are not possible, since each individual case requires a detailed cost analysis taking into account the project's parti-

The graphs presented below indicate unit costs for the total MHG investment as well as for the three principal investment components: pre-investment studies, equipment, and civil engineering. As the curves in these graphs are based on available information pertaining to various Latin American countries, it is recommended that the office responsible for MHG planning in each country should adapt them to their own actual in-country conditions. This can be done in at least an approximate way by experimentally determining certain correction factors for use with the graphs presented below.

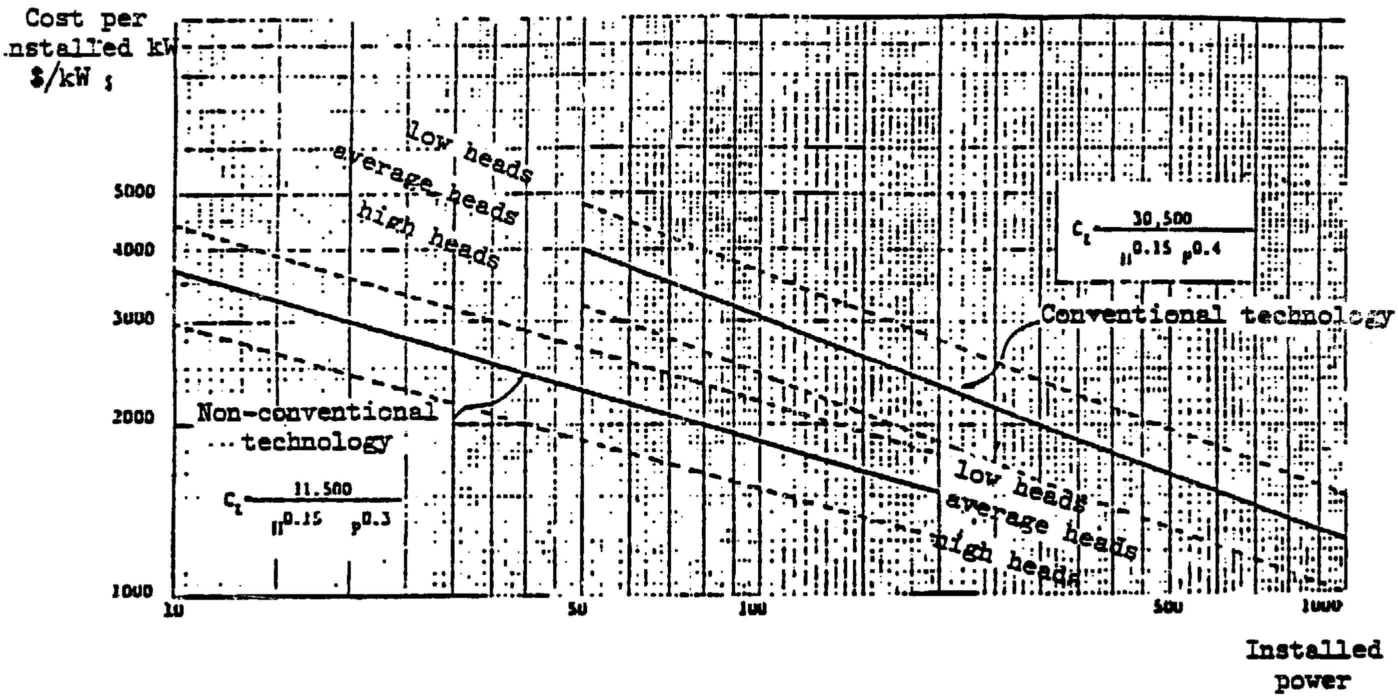
a) Unit costs of the total MHG investment

Figure 23 shows the total unit costs for an MHG in dollars per kilowatt of installed power for different power ratings (output) and heads. The table below outlines the elements and hypotheses considered in the preparation of this graph.

ASPECTS CONSIDERED IN THE PREPARATION OF FIGURE 23

- The data processed were drawn from 35 projects in three Latin American countries, the correlation factors with respect to the graph being in the order of 70 per cent.
- The lower curves, for the non-conventional technology option, were plotted by adding the costs of the studies to those of the equipment and the civil engineering works (assuming domestically manufactured equipment).
- The costs are based on 1980 prices, whereby the data used were adjusted according to the indices given in Figure 24, which is a very rough indicator of the variations in times employed in this manual. For specific cases, it is advisable to study the variations for each equipment component and the civil work costs according to the particular conditions given for each country.
- The curves presented are of only relative statistical value, since in the case of specific projects one must expect significant variations from one country to another.
- The variations from country to country may be due to the following factors:
  - Availability and cost of labour;
  - Availability and cost of materials;
  - Equipment purchase and freight costs;
  - Engineering costs;
  - Geographical conditions and problems of access;
  - Dollar exchange rates;
  - Currency market conditions and controls;
  - Variations in cost indicators over time.
- Variations with respect to each specific project are due to:
  - Distances and access conditions;
  - Physical conditions (geology, hydrology, geomorphology, soil mechanics, ecology, etc.);
  - Significant differences in the scale of the civil construction.
- The graph refers to stations having only one electromechanical unit.
- The definition of high, medium, and low heads is taken from the power and head classification of the Latin American Energy Organization, which appears on page 7.

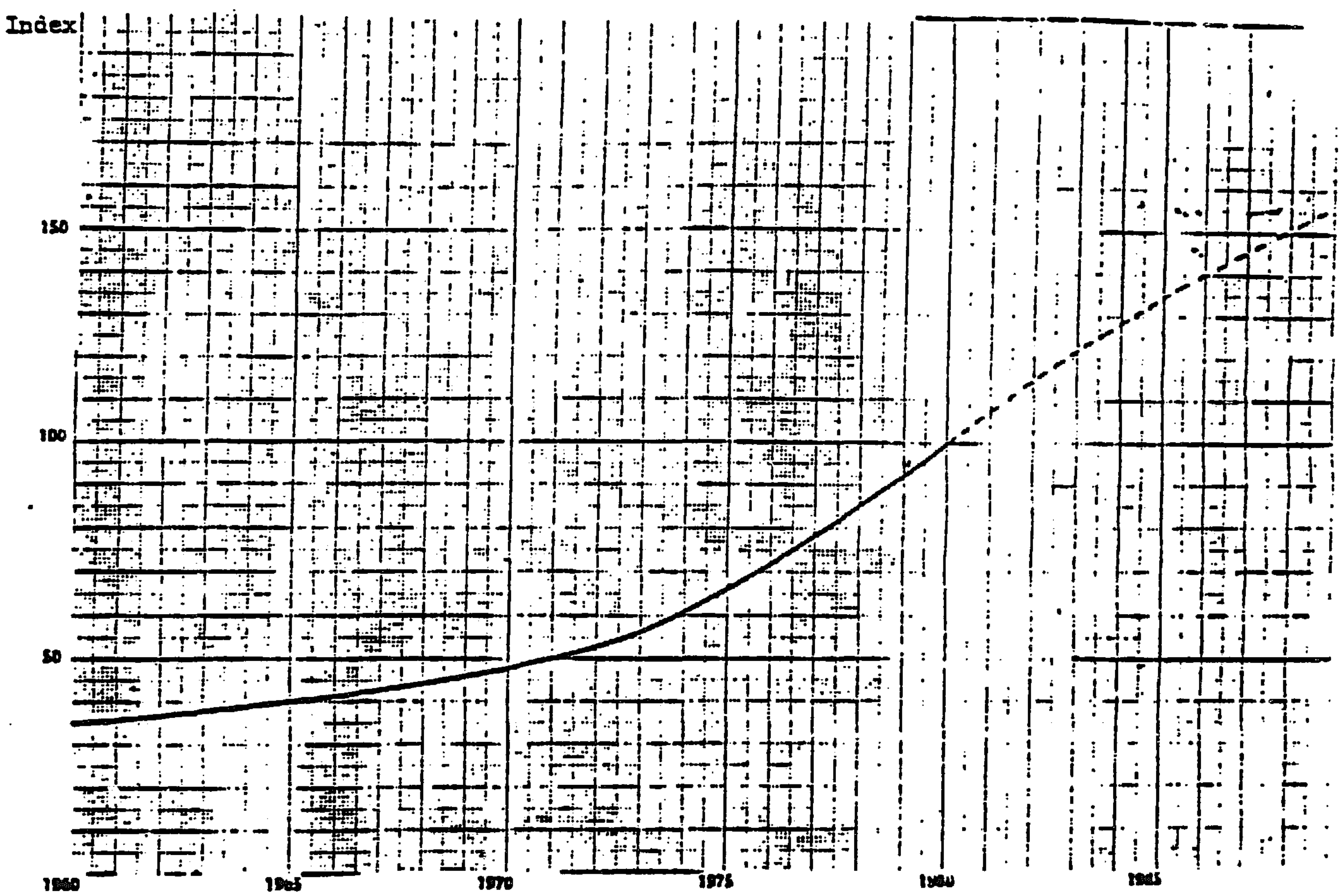
FIGURE 23 REFERENCE INDICATORS FOR UNIT INVESTMENT COSTS



CONCLUSIONS TO BE DRAWN FROM THE TOTAL INVESTMENT COST CURVES

- MHG costs may vary between $US 1,000 and 5,000 per installed kW.
- Unit costs rise rapidly as power ratings decrease.
- Plants operating with low heads are more costly than those with high heads.
- The use of non-conventional technology for the civil construction and of domestically produced equipment and technology makes for lower unit costs than conventional technology and imported equipment. This advantage tends to become less significant as the power rises.

FIGURE 24 APPROXIMATE INDEX FOR THE VARIATION OF THE MHG INVESTMENT COST IN TIME

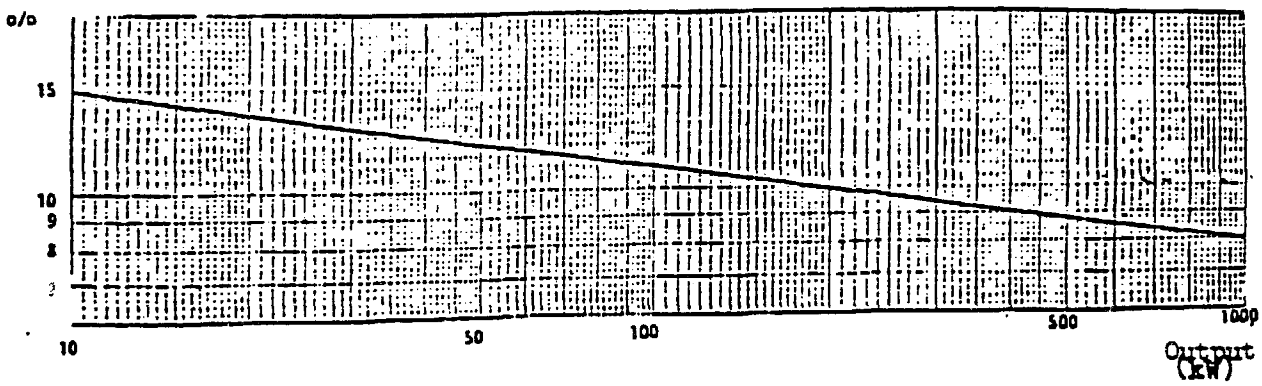


b) Unit costs of pre-investment studies

As pointed out in section 5.4., study costs are frequently disproportionately high in terms of the total investment. For this reason, it is advisable to set limits to study costs as a percentage of the total cost of the project.

For purposes of guidance, Figure 25 shows a proposed graph of maximum desirable study costs as a function of plant output. In actual practice, it is recommended that each country plan these costs as part of its MHG policy and in accordance with the minimum depth and coverage of the studies themselves.

FIGURE 25 STUDY COSTS AS A MAXIMUM RECOMMENDED PERCENTAGE OF TOTAL PROJECT COST, AS A FUNCTION OF MHG OUTPUT



c) <u>Unit costs of electromechanical equipment</u>

Figures 26 and 27 indicate the unit costs of electromechanical equipment in the case, respectively, of equipment imported from manufacturers in developed countries and equipment manufactured domestically using technologies developed or adapted in the country and not subject to the payment of royalties.

ITEMS INCLUDED IN THE ELECTROMECHANICAL EQUIPMENT

- Turbine
- Velocity regulator
- Generator
- Electrical control panel and instrumentation
- Installation (excluding anchoring systems)

ASPECTS CONSIDERED IN THE PREPARATION OF FIGURES 26 and 27

- The data used in preparing Figure 26 were taken from 25 cases, the curves having a correlation factor of 97 per cent.
- The data used in preparing Figure 27 were taken from 10 cases, with the equipment manufactured in a single Latin American country. The curves were plotted on the basis of Figure 26, the correlation factor being lower than in that figure.
- The costs are given in 1980 dollars and are based on an adjustment of the values given in Figure 24.
- Variations from country to country may be due to:
  Freight and insurance
  Import duties
  Taxes
  Local transport
  Laws designed to promote industrial development
  Exchange rates
  Currency market conditions and controls
  Variations in cost indicators over time
- Variations from one particular project to another may be due to:
  Conditions of access and local freight charges
  Installation costs
- Implicit in the equipment costs is the selection of the optimum turbine type according to the head and power of the station

FIGURE 26 COST, PER INSTALLED KILOWATT, OF IMPORTED ELECTROMECHANICAL EQUIPMENT

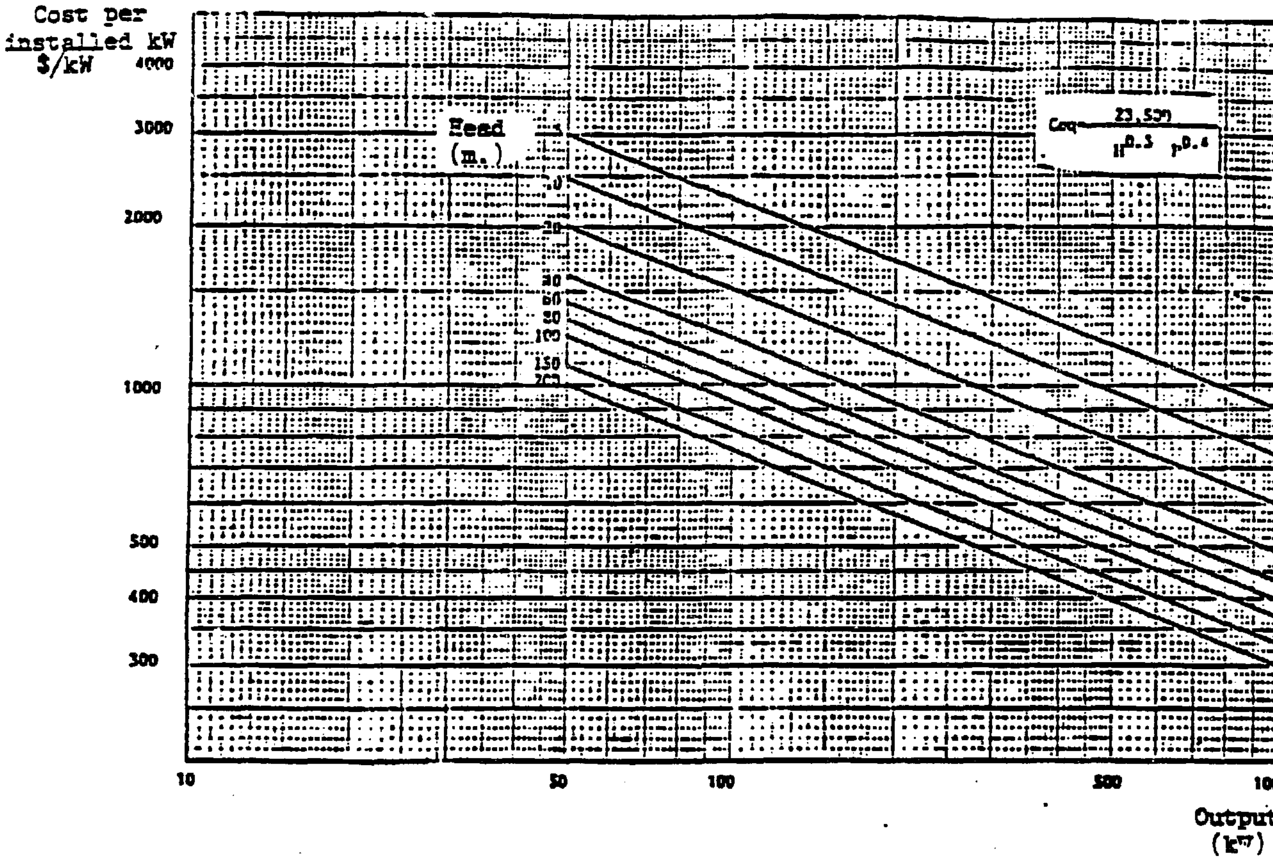
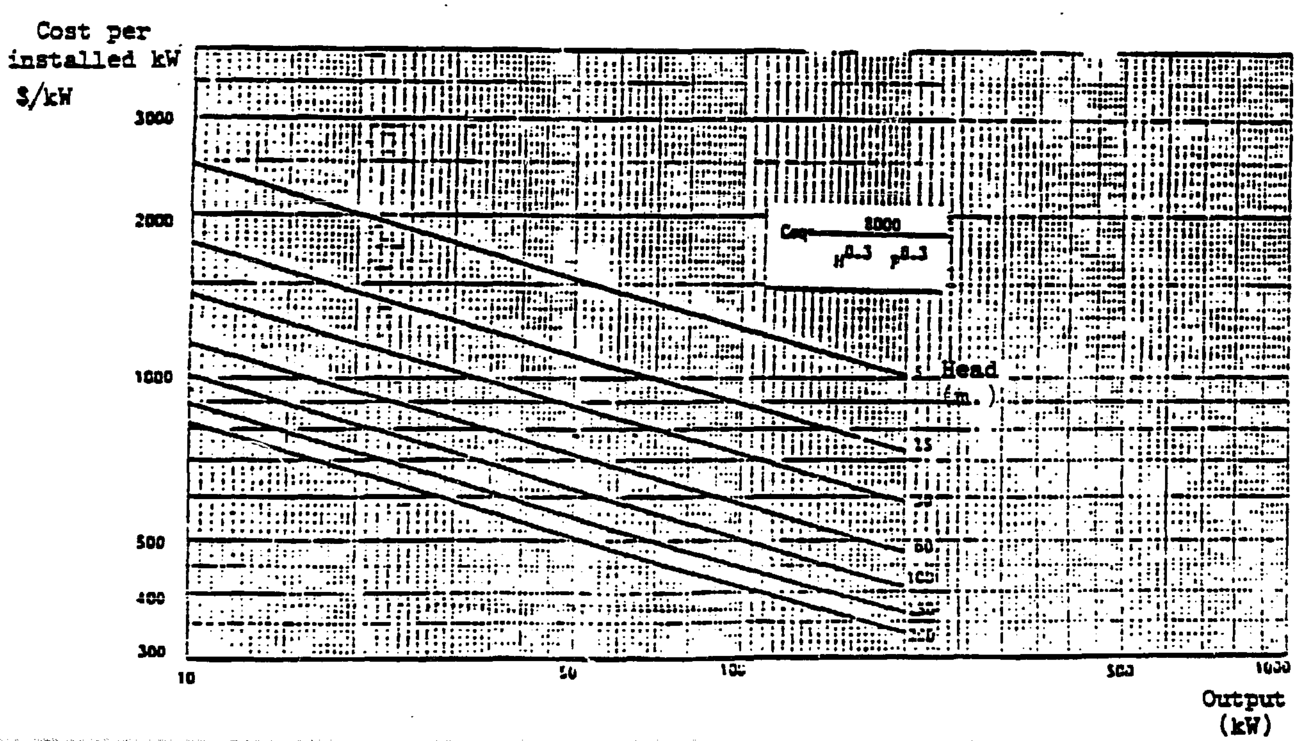


FIGURE 27 COST, PER INSTALLED KILOWATT, OF DOMESTICALLY MANUFACTURED EQUIPMENT AND TECHNOLOGY



A number of general conclusions may be drawn from Figures 26 and 27 for guidance in the selection of equipment.

CONCLUSIONS TO BE DRAWN FROM THE UNIT-COST CURVES FOR ELECTROMECHANICAL EQUIPMENT

- The unit costs of the electromechanical equipment for an MHG may vary between $US 300 and 3,000 per installed kW of power.
- Unit costs rise rapidly for the lower power ratings.
- Unit costs increase sharply as the head decreases (in the proportion of 3:1 for heads of 5 and 200 m, respectively).
- Generally speaking, domestically manufactured equipment and domestic technology may be priced at one-half the cost of equivalent imported equipment and technology.

d) <u>Unit costs of civil construction</u>

Figure 28 shows the unit cost indicators for the civil works associated with an MHG project. As we shall see later on, the diagram is intended for reference use only.

ITEMS INCLUDED UNDER CIVIL WORKS

- Dams and intake
- Canal
- Forebay
- Silt basin
- Penstock and anchoring
- Accessories (gates, grids, etc.)
- Machine room (power house) and equipment support systems
- Run-off canal

It should be noted that these cost elements do <u>not</u> include the power transmission and distribution systems. In the table below some of the factors involved in plotting the civil construction cost curves are discusses:

ASPECTS CONSIDERED IN THE PREPARATION OF FIGURE 28

- The curves, which are based on data for 25 simulated projects having a correlation factor of about 60 per cent, reflect the approximate correlation of the difference in total unit costs less the costs of studies and equipment.
- The variations from one specific case to another are very wide.
- The correlations for conventional technologies rest on the assumption that the technological conditions of the project are as described in Chapter Two (point "e", page 8).
- The correlations for non-conventional technologies rest on the assumption that the project's technological conditions are as described in the preceding section.
- The costs are given in 1980 dollars.
- Variations from country to country may be due to:
  Costs and availability of construction materials;
  Labour costs;
  Geographical conditions and problems of access.
- Variations from project to project may be due to:
  The physical characteristics of the project (geology, geomorphology, hydrology, soil mechanics, canal length, topography, aggregate materials, etc.);
  Building methods;
  Depth of the engineering studies;
  Experience in design engineering.

FIGURE 28 MHG CIVIL CONSTRUCTION COSTS PER INSTALLED KILOWATT

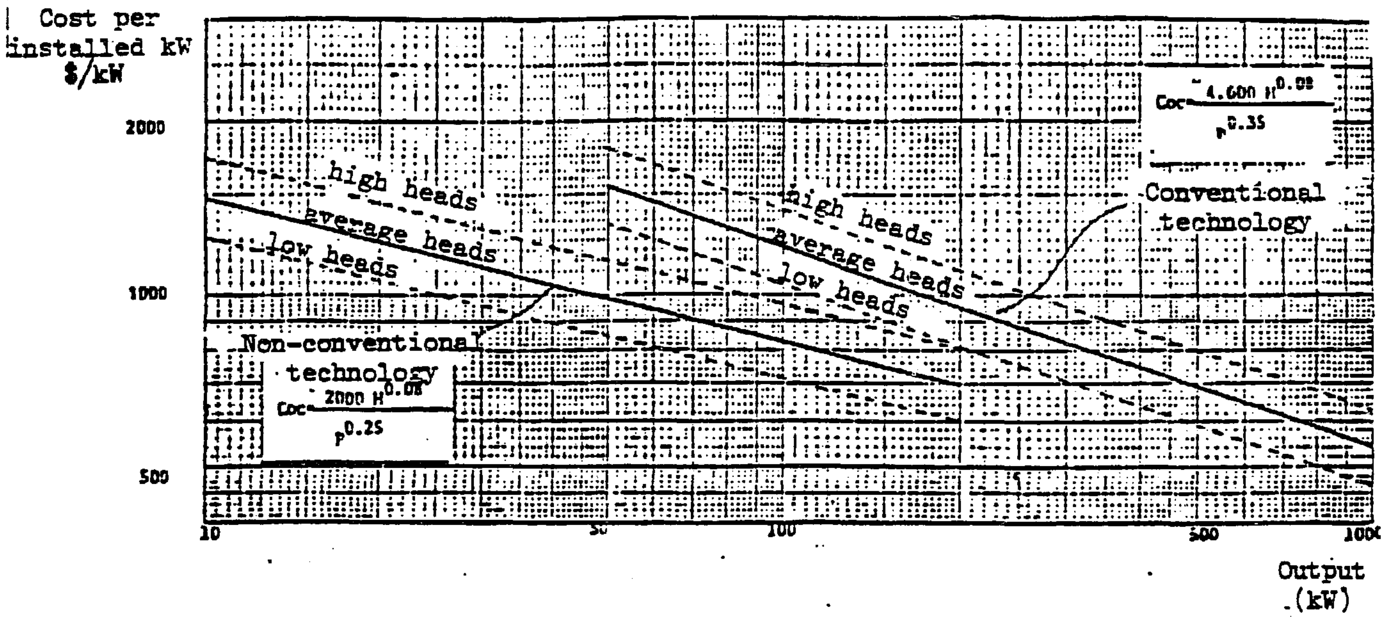


Figure 28 suggests a number of general conclusions regarding the limits of application of the graph itself and the trends revealed in it.

CONCLUSIONS TO BE DRAWN FROM THE CIVIL WORKS UNIT-COST CURVES

- The curves are designed to provide only an approximate estimation, for use during the planning stage. For each individual project, satisfactory approximation requires physical surveys at the actual work site.
- The unit costs of civil works may vary between $US 450 and 1,800 per installed kilowatt.
- Unit costs increase as the power decreases, but not as rapidly as for the electromechanical equipment.
- The unit costs of civil works increase as the head increases, in a relationship that is thus the inverse (and also less marked) of that which exists between unit equipment costs and head.
- All other factors being equal, the use of non-conventional technologies is less costly than the use of conventional technologies, this advantage being greater for the lower power ratings.

8. INTERNATIONAL CO-OPERATION*

The principal possibilities for international co-operation in the MHG field lie in the areas of technology, training, studies, and construction. Co-operative projects may be undertaken at the world, regional, sub-regional, or simply the bilateral level.

As used here, the term "international co-operation" extends to all types of international relations which are designed to pursue the mutual advantages of the co-operating parties and which are the subject of international agreements.

International co-operation is based on the following principles:

- Respect for the sovereignty of the parties;
- Equality of rights for all parties;
- The voluntary participation of all parties;
- Mutual assistance;
- Reciprocal benefits.

8.1 INTERNATIONAL ORGANIZATIONS OPERATING AT THE WORLD LEVEL

The following are some of the organizations that are in a position to provide support in the development of MHG.

* This chapter is intended to be updated and expanded in the next edition subject to the collection of more detailed information on activities of the organizations mentioned in this manual.

ORGANIZATION	AREA OF ACTIVITY
United Nations Development Programme (UNDP)	Financing of development plans, programmes, and projects.
United Nations Educational, Scientific and Cultural Organization (UNESCO)	Co-operation in scientific and educational development programmes.
World Meteorological Organization (WMO)	Co-operation in meteorological and hydrological programmes on behalf of development projects.
International Labour Organisation (ILO)	Co-operation in training programmes for middle-level technicians and skilled workers.
United Nations Industrial Development Organization (UNIDO)	Co-operation in industrial development programmes; currently engaged in promotion of MHG programmes and implementing a number of projects in developing countries.
International Bank for Reconstruction and Development (IBRD); World Bank	Financing of development projects; grants short- or medium-term loans at interest to both the Governments of the member States and to public and private institutions, provided they have the backing of the Government of the country in question.
Organization of Petroleum Exporting Countries (OPEC); OPEC Fund for International Development	Financial assistance for development projects, particularly in the area of alternative energy sources and on behalf of the countries most seriously affected by the petroleum price structure; currently financing an MHG programme.

Problems which arise in relations with international organizations and methods for overcoming them:

PROBLEMS	REMEDIAL ACTION
Poor selection of experts	Request, by the national organizations, of a more extensive list of experts; provision of adequate and sufficiently detailed information to the international organization.
Failure to take full advantage of the expert's skills	Formulation of a detailed plan specifying the activities the institution wishes to have carried out, with this plan to be completed sufficiently in advance of the expert's arrival; assignment of a counterpart (or counterparts) sufficiently competent to work with the expert.

As part of their effort to promote the use of MHG, the international organizations must lend their support to the establishment of local infrastructures in such areas as planning, studies, design, operation and maintenance, administration, financing, and technological development.

As a general rule, contacts with these organizations should be handled through their resident representatives in the individual countries.

Among the international banking institutions with worldwide operations, mention should be made, in addition to the IBRD, of the Export-Import Bank (EXIMBANK) and the International Finance Corporation.

8.2 REGIONAL AND SUBREGIONAL CO-OPERATION

This form of co-operation may involve the areas of studies and construction and can be undertaken by a group consisting of more than three countries. In principle, the term "regional" refers to organizations operating on a continental or subcontinental basis, while "subregional" refers to groups of countries within a less extensive geographical zone.

ORGANIZATION	AREA OF ACTIVITY
Organization of American States (OAS)	Advisory services, consultation, and support for economic development projects.
Common African and Mauritian Organization (OCAM)	
Afro-Asian Organization for Rural Reconstruction	
East African Common Services Organization	Trade, financing, and studies of social problems.
Organization of Central American States (OCAS)	Seeks solutions to common problems and promotes economic, social, and cultural development through concerted co-operative action.
Organization of African Unity (OAU)	Has a Commission for Scientific and Technical Research.
Latin American Energy Organization (OLADE)	Is conducting a regional-level MHG programme.

Special mention should be made of OLADE's work in promoting, co-ordinating, and advising on MHG projects and programmes, as well as its activities in other energy areas.

It is extremely important that all the supporting organizations carry out their work within a framework of co-ordination, promotion, and consultation, in order that they may contribute to the strengthening or establishment of the necessary infrastructure in the various countries.

Among the regional banks, the following in particular might be mentioned:

BANK	PURPOSES
African Development Bank	Its purpose is to contribute to the economic development and social progress of its members. It has established an African Development Fund.
Asian Development Bank (ADB)	Unlike the African Development Bank, this bank has extra-regional subscribers in addition to those from within the Asian region. It grants loans for infrastructure investments.
Central American Bank for Economic Integration (CABEI)	The principal financing institution for the Central American Integration Programme and the main lending institution for regional economic development.
Inter-American Development Bank (IDB)	IDB's purpose is to promote the development of the member countries, individually and collectively, through the financing of development and technical-assistance projects; currently studying the financing of MHG projects in several countries.

8.3 BILATERIAL CO-OPERATION

In the case of bilateral technical co-operation, particular care and attention must be given to how the objectives and scope of the programme are defined, in order to avoid hidden forms of technology sales governed by commercial objectives. Where this is unavoidable, the negotiating terms with respect to the purchase of the technology must be explicit and clear; moreover, the conditions of the agreement must be favourable and must not involve, under the guise of an assistance programme, the granting of any exclusive rights. Similarly, in all cases of international technical assistance, the means by which the know-how in question is to be effectively assimilated by the recipient party must be clearly set forth. It is of vital importance that the counterpart receiving the assistance be perfectly clear as to the objectives and that a work programme be prepared in advance. The counterpart's qualifications must be sufficient to enable him to assimilate effectively the knowledge being

Developing countries may request bilateral assistance through their diplomatic missions or commercial attachés.

As a general rule, it is to be recommended that, in order to deal both with MHG projects and with other matters of technology and co-operation, the developing countries should create a government office for foreign technical assistance to be responsible for co-ordinating international co-operation in the country and advising the organizations affected on how to make the best possible use of this assistance.

8.4 NON-GOVERNMENTAL ORGANIZATIONS

According to the definition used by the United Nations, non-governmental organizations are international organizations which have not been established on the basis of agreements between Governments.

The United Nations Economic and Social Council has devised procedures governing consultative co-operation for a number of non-governmental organizations of interest to the Council.

In 1975 there were 2,500 non-governmental organizations, a number of which were active in the area of science and technology. The Non-Governmental Organizations Section of the Department of Public Information of the United Nations Secretariat is responsible for co-operation with these bodies. It also convenes the Conference of Non-Governmental Organizations, which has its headquarters at Geneva and functions as the permanent organ of the non-governmental consultative organizations.

For the purpose of ascertaining which of these organizations are engaged in MHG programmes, they may also be contacted through the information services of the various countries at their diplomatic or consular missions or their information centres abroad.

Non-governmental organizations may suffer from limitations in the following areas: financing, constitutional or policy restrictions on activities, lack of acceptance by certain Governments, etc.

ANNEX A

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ANNEX B

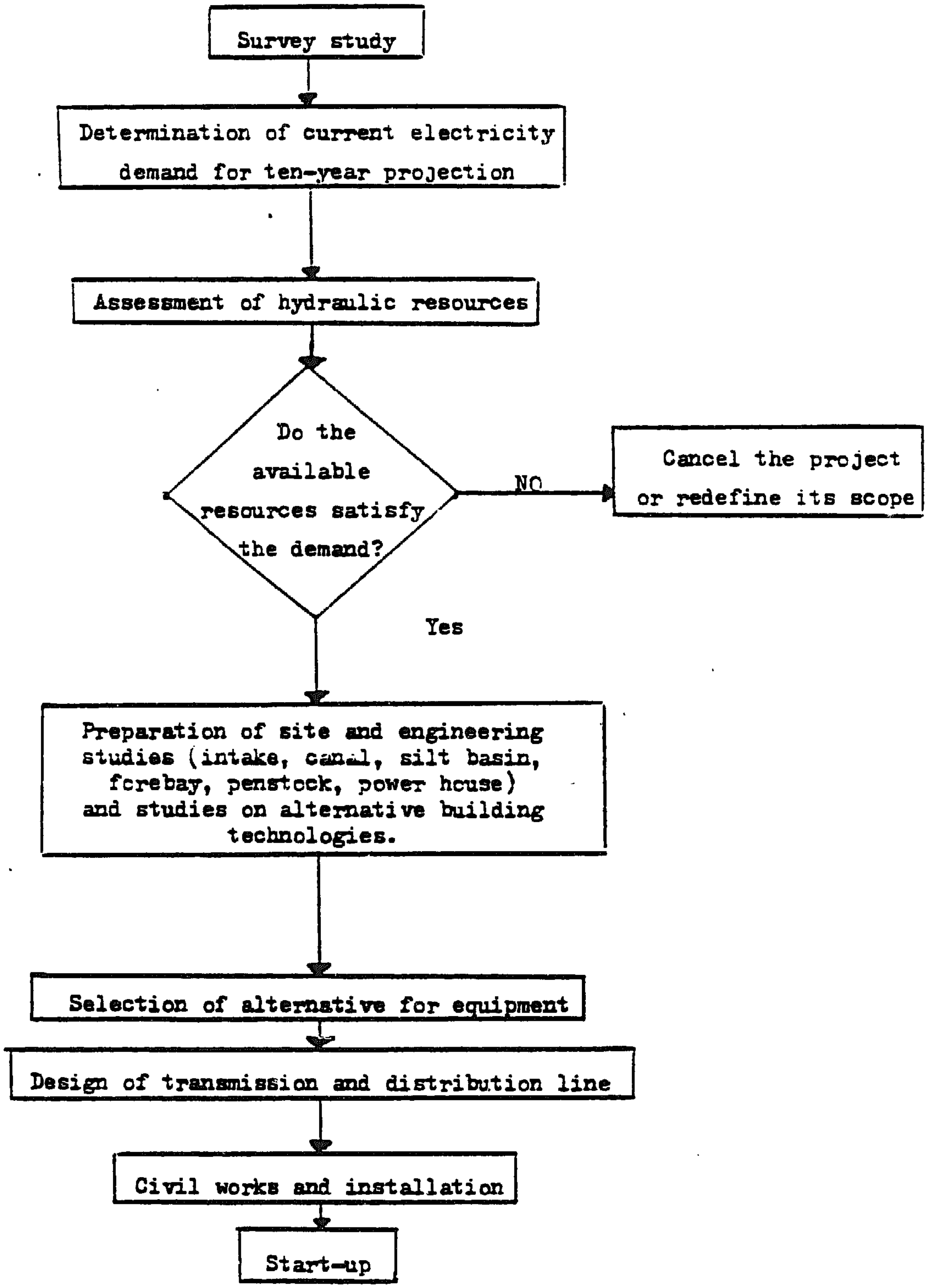
BASIC CALCULATIONS

This annex illustrates the steps involved in preparing a mini-hydroelectric power plant project, using as an example the 16-kW pilot plant project at Obrajillo, Peru.

It should be noted that this project was carried out for research purposes and that an existing irrigation channel was used in the design of the plant.

A flowchart indicating more or less typical steps that might be expected in a given project is presented on the following page.

SEQUENCE FLOWCHART FOR A SPECIFIC PROJECT



The precedure described below was followed in designing the project.

Demand study

The community to be supplied with electric power had a population of 595 inhabitants and a growth rate that could be considered zero, since according to statistics there had been no population increase in recent years as a result of migration to the city.

The town had a bakery which obtained its required electric power from a head-engine-powered generating unit. There was also a small dairy plant which had its own similar power supply. It should be noted that the town in question lacked any street or house lighting.

In order to determine what kind of power would be required from the future hydraulic power plant, the following factors were considered:

- The power consumption by the bakery occurred between 3:00 and 7:00 a.m. in the morning;
- The power consumption by the dairy enterprise occured only between 8:00 a.m. and 6:00 p.m.;
- House lighting was to be provided only during the period from 6:00 to 10:00 p.m.;
- Street lighting was to be provided only between 6:00 and 10:00 p.m.

On the basis of these factors it was ascertained that the generating plant's maximum load would be determined by the street and house lighting. This consumption was calculated using a figure of 25 watts per inhabitant, yielding an approximate required power of 16 kW (provision was made for the possibility of further expansion to permit a higher installed capacity per inhabitant).

Resources study

In the case of this project a canal was already available, which followed a course near the town and was used for irrigation. This canal draws its water from the Chillón River, whose minimum annual discharge is 1.2 m^3/sec.

The water for the canal is obtained through an intake which is cleared and otherwise maintained every year, after the high water, by the town residents as a community activity.

The first step was to locate a fall, which was subsequently levelled using topographic techniques. On the basis of the head determination (56.5 m) and the required generator power (16 kW), the water flow was established and simultaneously the optimum diameter for the penstock was selected. With the 8-ince PVC pipe selected, the result was a net head of 55.3 m and a maximum discharge of 0.048 m^3/sec., derived from the following formula:

$$= \frac{P}{9.807 \eta H_n}$$

where

P is the generating power (16 kW);

H_n is the net head (55.3 m);

η is the total efficiency of the plant (62 per cent), selected from the table below.

Once the discharge had been determined, a hydraulic analysis was carried out in order to determine whether the capacity of the canal was sufficient to supply the plant and provide for irrigation at the same time. This study made it possible to identify certain critical zones where the canal had to be widened.

TOTAL EFFICIENCY OF MINI-POWER PLANTS (%)

Power (kW)	Turbine type			
	Pelton	Michell-Banki	Francis	Axial
Up to 50	58-65	54-62	59-65	58-66
50-500	65-69	62-65	66-70	66-70
500-5,000	69-73	65*	70-74	70-74

* The Michell-Banki turbine operates to a maximum power of 1,000 kW.

The above figures take into account generator efficiency, which is low in the case of the lower power ratings.

Site selection and design of the civil structures

The existing intake had to be improved so as to make it possible to regulate the admission of water into the irrigation canal.

The critical zones of the canal were reinforced and widened in order to provide the necessary capacity.

A forebay was built, which simultaneously functioned as a silt basin and provided a way of returning the overflow to the irrigation canal.

An appropriately anchored PVC penstock was designed. Although the recommended procedure is to bury a line of this kind, the pipe in question was installed above ground so as to make it possible to test it for performance and weather-resistance, and also to test a number of protective coating materials.

Selection of equipment

(a) Selection of the generator

The guiding assumption was the need for 16 kW generation output. On this basis, the specifications called for a 20-kVA alternator with a power factor of 0.8, generation voltage of 220 V, and generation frequency of 60 Hz. This generator satisfied the maximum power requirement. The rotation speed of the alternator was 1800 rpm. As a research alternative, an asynchronous generator was also installed, with a bank of condensors to permit independent operation.

(b) Selection of turbines

Since it was designed to operate as a pilot plant, one of the aims of the Obrajillo project was to study and develop a technology for low-specific speed turbines. The specific speeds of various turbine types are shown in the following table.

SELECTION OF TURBINES ACCORDING TO THE SPECIFIC SPEEDS

Turbine type	N_s	N_q	$H_{max\ admissible}$
Single-nozzle Pelton	10 to 29	3 to 9	1800 to 400
Two or multi-nozzle Pelton	29 to 59	9 to 18	400 to 350
Michell-Banki	29 to 220	9 to 68	200 to 80
Slow Francis	59 to 124	18 to 38	350 to 150
Normal Francis	124 to 220	38 to 68	150 to 80
Fast Francis	220 to 440	68 to 135	80 to 20
Propeller and Kaplan turbines	342 to 980	105 to 300	35 to 5

There are two expressions for the calculation of the specific speed. The first depends on the efficiency of the turbine and is written in the form:

$$N_s = N \frac{P^{\frac{1}{2}}}{H_n^{5/4}}$$

where:

P is the net power, in hp;

H_n is the net head, in m;

N is the speed, in rpm.

The second expression for specific speed makes it possible to arrive at efficiency-independent similitude criteria and is written as:

$$N_q = N \frac{Q^{\frac{1}{2}}}{H_n^{3/4}}$$

where:

Q is the flow, in m^3/sec.

With an eye to low specific speed, it was decided for this project to use Pelton and Michell-Banki turbines, which were to operate under the same head and flow conditions.

In order to ensure that, while operating under these conditions, the turbines would perform within their customary specific rpm range, it was necessary to determine suitable runner diameters to make possible an optimal rotating speed for the turbine.

In the case of the Michell-Banki turbine:

$$N = \frac{39.85\sqrt{H_n}}{D_{ext}}$$

where:

N is the rotating speed of the turbine, in rpm;

H_n is the net effective head, in m;

D_{ext} is the external diameter of the runner, in m.

For the Pelton turbine:

$$N = \frac{41.46\sqrt{H_n}}{D_p}$$

where:

D_p is the diameter of the Pelton runner, in m.

Runner diameters of 200 mm for the Michell-Banki and 600 mm for the Pelton turbine were adopted, making it necessary to use a mechanical belt transmission system between the turbine and the alternator.

Design of the power house

For this project, an existing mill, large enough to accommodate the equipment and carry out research, was used as the power house.

ANNEX C

LIST OF SYMBOLS AND ABBREVIATIONS

W	Watt
kW	Kilowatt
MW	Megawatt
kWh	Kilowatt hour
kWh/gal	Kilowatt hour per gallon
$m^3/s/km^2$	Cubic meter per second per square kilometer
m^3/sec	Cubic meter per second
mos/yr	Months per year
$inhab/km^2$	Inhabitants per square kilometer
gal	Gallon
hr	Hour
m	Meter
km	Kilometer

MHG	Mini-Hydro Generation
EEG	Extension of an Existing Grid
UNIDO	United Nations Industrial Development Organization
OLADE	Latin American Energy Organization