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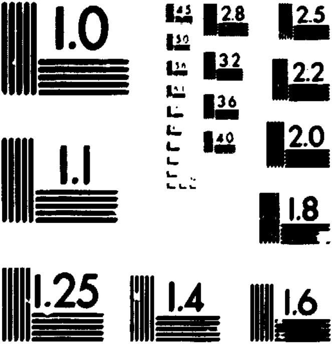

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UNITED NATIONS
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SMALL HYDRO-POWER

(SHP)

B U L L E T I N

No. 1*

prepared by

Secretariat of Regional Network
(Asia and Pacific)
for Small Hydro Power (RN-SHP)

2539

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FOREWORD

The development of new and renewable sources of energy has become a global priority. For many developing countries the generation of electric power from small hydro power plants represents a particularly attractive method of providing an inexpensive and renewable source of energy for industrial and economic development of rural and remote areas.

Most of the developing countries in the ESCAP region have rich hydrological resources in the form of scattered streams, rivulets, water falls, etc., which are often not fully exploited. It was felt, therefore, that these resources could be profitably exploited through the establishment of a Small Hydro Power Network in the region.

UNIDO and ESCAP have already recognized the value of the Network for Small Hydro Power (SHP) in the region and organized the first Seminar-Workshop on the Exchange of Experiences and Technology Transfer on Mini Hydro Electric Generation Units, in September 1979 at Kathmandu/Nepal. The Second Seminar-Workshop/Study Tour in the Development and Application of Technology for Mini-Hydro Power Generation (MHG) was organized in October/November 1980 at Hangzhou/China and Manila/Philippines. Both meetings highlighted the need of a system for Small Hydro Power (SHP) Network to promote regional co-operation between and among the developing and developed countries at national level and recommended the creation of SHP national focal points which would stimulate and carry out activities that could be beneficial to the national efforts.

The People's Republic of China in response to the recommendations of the First and Second Mini-Hydro Power Generation Meetings took a decision to establish, with the support and co-operation of UNDP, UNIDO and ESCAP, the Regional Centre for Small Hydro Power at Hangzhou (HRC).

UNIDO, together with the HRC and in co-operation with UNDP and ESCAP, organized in July 1982, a Senior Expert Group Meeting on the Creation of a Regional Network System and the Assessment of Priority Needs on Research + Development and Training. The meeting recommended the creation of an SHP Network in the region and formulated its work programme based on priority needs, which includes, inter alia, SHP newsletter/bulletin, compilation of R+D work, bibliography, expert roster, compilation of SHP-related engineering consulting company, directory of equipment manufacturers, training programme, publication of design manual, advisory missions, co-operative research and development activities, etc., related to Small Hydro Power.

This Newsletter/Bulletin provides reports on the major activities and accomplishments as well as on the progress of the Network at national and regional levels, especially in the area of exchanging experiences and information regarding the development of SHP stations.

It is hoped that the Small Hydro Power Bulletin will be a useful mechanism to exchange important information on SHP development and its utilization to rural industries on a regular basis, and at the same time, also serve for increased bilateral and multilateral co-operation among the participating member countries in the region, such as planning, design, construction, operation, management, research + development, and manufacturing of equipment, training and advisory services, etc.

It is planned to issue the Bulletin regularly. In this respect we would appreciate if the reader could send us any news or reports that might be of interest to others who are engaged in SHP development and application. Such information could relate to the following aspects of SHP (where available with photos or diagrams for illustration): new projects; new equipment; application of SHP for industrial production activities; development plans; research + development programmes; training programmes; and any other information including newspaper clippings, reports, publications, etc.

We express our sincere thanks to those who have contributed articles to this Bulletin and to UNIDO for the publication of the first issue. Your guidance, including suggestions and comments for further improvement of the Bulletin is greatly appreciated.

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INSTITUTIONAL NEWS

Asia and Pacific Regional Network for Small Hydro Power (RN-SHP) established - Hangzhou Regional Centre (HRC) as Interim Secretariat

A recommendation was made by the Senior Expert Group Meeting on the Creation of a Regional Network and the Assessment of Priority Needs on Research, Development and Training in the Field of Small/Mini Hydro Power, held in July 1982 at Hangzhou/P.R. China, and that a Regional Network for Small Hydro Power as well as its Secretariat should be established. Furthermore, all the participants of the Third Workshop on SHP, held at Kuala Lumpur/Malaysia, 7-15 March 1983, expressed their support for the findings and recommendations of the Senior Expert Meeting and agreed to the following proposals:

1. In order that the member countries can benefit from the activities of RN-SHP, the importance of initiating practical work as soon as possible was emphasized.
2. The organizational arrangements of an official RN-SHP based upon the agreement and endorsement of member governments should be worked out in parallel to such activities.
3. The joint activities should involve institutions and persons directly engaged in the promotion and implementation of SHP activities in their own countries.
4. Accordingly, the activities included in the tentative Work Programme summarized in the draft work programme for the interim period 1983/1984, relating to Information, R+D and Training, should be initiated as soon as appropriate funding can be secured.

The First Session of the REDP (Regional Energy Development Programme) Steering Committee, held at Bangkok from 10-11 May 1983, took note of the reports of the above two meetings and endorsed the proposal for the establishment of the RN-SHP in principle. At the same time, the Committee felt that RN-SHP was not to be viewed as an institution but as representing a co-operative arrangement for carrying out specific activities. The Committee also endorsed the proposal that the Hangzhou Regional Centre (HRC) should act as the Interim Secretariat of RN-SHP, and suggested that the Director of HRC, who may serve as the Interim Co-ordinator for RN-SHP, should take appropriate steps to initiate the work programme.

Mr. Zhu Xiaozhang, the Director of the Hangzhou Regional Centre, has assumed the post of Interim Co-ordinator of the Regional Network for Small Hydro Power, and is ready to discharge his duties.

The work programme of the RN-SHP forms a part of the ESCAP-REDP (Regional Energy Development Programme) activities. The draft work programme of the RN-SHP for 1983-84 (Interim Period) and 1985-86 was elaborated with the assistance of UNIDO. Four elements are included as the basic framework:

i. Training
ii. Information Services
iii. Research and Development
iv. Technical Advisory Services

The work programme has been sent to relevant SHP agencies to ask member countries for their comments. As its first activity, the Secretariat of the RN-SHP organized, jointly with UNIDO, the First Training Workshop on SHP for the Asia and Pacific region, held at Hangzhou/China from 23 May to 22 June 1983, in co-operation with ESCAP-REDP, UNDP and UNDTCD.

The work of RN-SHP is a common cause within the regional member countries. We hope the SHP focal points of the member countries will give their full support and close co-operation, so that the RN-SHP and the Secretariat may discharge its anticipated duties and tasks satisfactorily for the benefit of all.

SHP ACTIVITIES IN MEMBER COUNTRIES AND ELSEWHERE

The Philippines

The total SHP potential in the Philippines amounts to over 5000 MW if fully developed. The power generated from SHP stations is mainly for use in the rural areas. A SHP development programme has been prepared by the state in order to substitute for oil-fired power generation, stabilize and lower the cost of electricity in the countryside and encourage the local manufacture of SHP equipment.

The principles of constructing SHP in the Philippines are as follows:

1. The unit generation cost of SHP should be equal to or lower than the cost of electricity supplied from the grid.
2. SHP station should be operated in synchronism with the local grid to which it is connected.
3. SHP stations should be owned and managed by the electricity collectives.
4. Each project should be well designed so as to shorten the construction time and lower the capital cost.

SHP stations in the Philippines refer to those up to 10 MW capacity, most stations being in the range 1 - 5 MW and the stations have been designed and constructed by their own efforts. Up to April 1983, feasibility studies of 95 sites had been completed, the total capacity of which amounted to 128 MW. 14 SHP stations are scheduled to be completed in 1983 with a total installed capacity of 18 MW. However, this could reach 300 MW by 1990 and 2000 MW by the year 2000 according to the state programme. The fulfilment of the development scheme will rely as much as possible on their own resources and technical strength.

The mini hydro programme is designed to harness the country's abundant water resources - numerous streams, rivers, waterfalls and irrigation canals - for generating low-cost electricity. This programme is expected to save for the country some 2 million barrels of oil annually by 1990.

Under the programme, small hydro electric facilities, with less than 10 megawatt capacities, will be installed in selected areas of the country where there is abundant supply of water. The mini hydro power plant is to be owned and managed by the electric co-operative.

Since the first NEA (National Electrification Administration)-sponsored mini hydro power plant was commissioned in 1979 at Baliguian, Camarines Sur, seven more power plants were similarly commissioned. And as of July 1983, another mini hydro plant in Balongbong, Catanduanes, with an installed capacity of 1,800 kilowatts was commissioned.

The operation of the Balongbong mini hydro plant gave NEA a new milestone in its effort to develop indigenous and renewable energy sources. It also means that the province of Catanduanes is the first island in the country to be fully self-sufficient in electrical energy and totally free from oil-fired power generation. Up till now, the electric co-op in Catanduanes depends on oil-fed diesel generators. Consequently, the operation of the mini hydro enables the electric co-op to reduce its rate while maintaining 24-hour electric service daily.

Equipment for this project was the first to be supplied under the transfer of technology agreement with the China National Machinery Equipment Import and Export Corporation (CMEC) of the People's Republic of China (PROC) and Atlantic Gulf and Pacific Company of Manila, Inc. (AG+P), a project approved by President Marcos on April 22, 1980. The unit was designed by the CMEC, partly manufactured in China and in the Manila plant of AG+P. This project is an important step towards developing a Philippine capability to design and manufacture mini hydro equipment. (See also chapter on "International Co-operation", page 13).

Pakistan

In 1947, the total installed capacity of power stations in Pakistan was only 29.7 MW. Up to 1982, it had increased to 3783 MW. Of this, 2380 MW or 62.9% came from hydro power stations. This figure includes 115 MW from SHP.

In 1975, a special SHP Council under the Ministry of Hydropower was established by the Government to develop the hydro power resources in the northern district. In the first stage, 100 SHP stations were constructed, each with installed capacity of 100-1000 kW. These stations were built by National Construction Company, which was the biggest of its kind in the country and a joint venture between Pakistan and foreign companies.

The 6th five-year plan, primarily for developing SHP resources in the northern district, commenced in 1983. 39 projects have been scheduled to be completed by 1985 with a total installed capacity of 6100 kW. Apart from that, the State Planning Commission proposes to study the feasibility of construction of SHP stations on the existing barrages and canal drops to improve the reliability of the state grid and indicated that 300 MW could be obtained totally.

Nepal

Nepal has rich hydro power resources. During the past few years, a large amount of hydro power stations have been built all over the country. The unit cost of SHP stations is higher than that of large hydro power stations, but still cheaper than that of imported fossil-fuelled power stations.

In the development of SHP, there is a shortage of manpower, technical know how and site information. The investment cost is high, and the large seasonal variations in flow make it difficult to design. Furthermore, there is poor accessibility and non-standardization in electromechanical equipment. But, with the development of SHP, the environmental conditions will be very much improved and the country will reduce its dependence on imported fossil fuels. The relevant authority therefore has to take measures for training and utilizing local experts, maximum utilization of local material and manpower, extension of the hydrological network in small rivers, etc., which may help to solve some of the problems in the development of SHP projects.

Thailand

During the fifth national plan of the Thai Government (1981-1985), 9-10 SHP pilot stations will be constructed with assistance from Norway, P.R. China, United Kingdom, France, Federal Republic of Germany, Belgium, Canada, Japan, Sweden, Australia, United States, etc. After these projects have been completed, the different design philosophy of SHP stations of various countries can be obtained together with the experience of operation and management, and this may help the country in setting up standardized models for future implementation.

Sri Lanka

The Government of Sri Lanka is clearly aware of the critical situation regarding energy resources. The policy laid down by the Government is to give priority to the development of SHP as well as the associated personnel training and education.

The SHP potential in Sri Lanka, where different types of plant could be developed falls into two categories:

1. In river sections where waterfalls prevail, run-of-river type hydro power stations could be constructed with total capacity of 50 MW and annual output of 210 GWh.

2. Storage plants could be developed on the existing hydraulic facilities in different areas:

a. in humid areas with abundant rainfall, 21 dams giving total 20 MW and annual output of 85 GWh; and

b. 30 existing irrigation reservoirs and 31 proposed reservoirs in the dry zone giving 25 MW of power and 100 GWh of total annual output.

Fiji

In August 1966, the Parliament of Fiji passed an act to establish the Fiji Electricity Authority (FEA) for the purpose of promoting the development of energy resources and the national economy.

FEA has 11 diesel power plants with a total installed capacity of 68 MW and a maximum demand of 40 MW.

With the oil crisis in 1974 followed by the steep increase in oil prices, the Government of Fiji decided to develop hydro power to take the place of diesel power generation and drew up a Power Development Plan for the years 1977-2001. The first phase of the Plan is divided into three stages and scheduled to be completed by 1984. At that time, the Monasavu Hydroelectric Scheme with a total installed capacity of 80 MW will be constructed, and the next project will be the Vature Power Scheme of 12-15 MW capacity.

Recently, FEA has been carrying out office studies and site investigations on all the potential SHP sites which are at a considerable distance from the national grid. The SHP sites investigated so far have capacities ranging from 100 to 180 KW.

Indonesia

Indonesia is rich in hydro power resources. As early as 1923, the first SHP station was set up in West Java. By the end of 1982, 28 SHP stations with a total installed capacity of 15.3 MW had been built.

In Indonesia, SHP refers to stations below 5000 kW. The total potential of SHP resources in Indonesia is estimated at 3000 MW.

With a view to developing SHP resources, a long-term programme has been drawn up by the state. Up to now 143 SHP projects with total installed capacity of 204.4 MW have been identified and are under study. Among them about 50 sites with a total installed capacity of more than 60 MW have been planned to be developed during the fourth five-year Development Programme, which started in 1983. 8 SHP stations having 6.6 MW of total installed capacity were constructed this year.

Malaysia

The Malaysian Government has decided to construct 82 stations during a Four-Year Development Plan from 1982-1985. The implementation is carried out on a regional basis and divided into Region I for the west and Region II for the east coast of the Malaysia Peninsular. Currently the National Electricity Board (NEB) is at the stage of completing 22 trial schemes where four had been commissioned, eight completed and ready for testing and the remaining ten under various stages of nearing completion.

Under the development programme, micro hydro projects in the range of 5 KW to 30 KW are being developed with locally fabricated turbines. Two units of these turbines of capacity 35 KW and 70 KW had been installed and are currently under test. The largest locally fabricated turbine planned so far is Mhycroft - A300 turbine of 300 KW capacity recently awarded for fabrication.

Cross flow turbine designs were purchased from OLADE (Organization of Latin American Energy Development) for turbine range of 5 KW to 1000 KW on a transfer technology programme between OLADE/NEB.

The SHP stations referred to in Malaysia are of 25-500 KW capacity. Local funds, materials and equipment are used extensively in the construction.

Colombia

Located at the northern part of Latin America, Colombia covers an area of 1.138 million km^2 and has a population of 27.5 million.

The country has a varied topography and receives an average annual precipitation of 2600 - 4000 mm, providing abundant water resources. The potential hydro power is estimated to be 120 million KW.

Hydro power plays an important role in developing electrification in Colombia. Upto 1982 there were 5060 MW of total installed capacity, 50% of which comes from hydro power.

SHP construction in Colombia has a long history. Beginning in the late 19th century up to 1946, 155 SHP stations were completed with a total installed capacity of 164.5 MW, of which 54 stations with 5.53 MW are in normal operation. The Colombian Government has paid great attention to the development of SHP in recent years. Construction of 50 stations with a total installed capacity of 25 MW and 10 key stations with a total installed capacity of 30 MW are planned.

$25 million from the ordinary capital to help finance the first stage of a programme to build small hydroelectric plants in isolated parts of the country is foreseen. The plants will serve small- and medium-sized population clusters.

The total cost of the project is estimated at $62.5 million.

The five small plants will be built to allow for future expansion to reach a maximum generating capacity of 35,000 kilowatts. In addition, a national plan for small-scale hydroelectric power plants will be drawn up, instructors in charge of training plant operators will be trained, workshops will be adapted, tools procured, and automatic, self-contained gauging stations will be installed. International public bidding will be held for goods and services acquired with resources of the IDB loan; national public bidding for purchases with national resources. Bidding will be international for two plants, and national for the remaining three.

For further information, contact the Instituto Colombiano de Energia Eléctrica, Division de Licitaciones y Contratos, Carrera 13, No. 27-00, 3er Piso, Bogotá.

Burundi

Burundi has a large hydroelectric potential, estimated at 500 MW of installed capacity. Given the topography and rainfall, the Government has been taking steps to exploit this potential.

The Government agency directly implicated with small hydro power development activities is the Ministry of Publics Works, Energy and Mines. The European Community, the Chinese and German technical co-operations are involved in building dams and carrying out electrification projects. For instance, 14 Km out of the capital, Bujumbura, a dam that was constructed by Chinese subcontractors is now supplying about 80-90 percent of the electricity used by the city. Further, the European Community has about four projects of electrification to be implemented during 1984/5/6. The transmission lines range between 38 and 52 Km. The United Nations Equipment Fund is financing a project of electrification in the southern region of the country (around Lake Nyanza and Rumonge).

P.R. China

Li Peng, first vice-minister of Water Resources and Electric Power, states that rural electrification is essential to quadruple industrial and agricultural output by the end of the century, and that greater efforts should be made to increase the development of small hydroelectric power stations.

Mr. Li Peng proposes three criteria to determine standards of rural electrification:

- whether more than 90 per cent of the pea ants have electricity for lighting, broadcasting and television;
- whether electricity is available for irrigation and drainage, grain and sideline products, processing and rural industries; and
- whether electricity is available for cooking in 20 per cent of the households in fairly developed areas.

He revealed that the Ministry of Water Resources and Electric Power will select 100 counties in southern China where demonstration projects will be built and urged all other counties to map out a development plan.

He mentioned that about 200 kwh of electricity per person per year will be needed to meet the requirements which are in keeping with the goal for living standards of peasants set for the year 2000.

At present, the vice-minister noted, China's rural areas consume about 40 billion kwh of electricty per year. Electricity is available to just over 50 per cent of the peasant population. Localities where electricity is not available are mainly mountainous areas, livestock breeding and remote regions and less-developed places where a minority of the people live. Rural electrification will be achieved mainly by developing small hydroelectric power stations and, in some places, by making use of wind energy through both state and collective or individual efforts.

Water power reserves in rural China a total of 70 million kilowatts, but only about 8 million kw have been utilized, accounting for about 11 per cent. Of the more than 2,000 counties, 1,100 have water power reserves exceeding 10,000 kilowatts. Development of small hydroelectric power stations in these counties is not only practical but also most economical.

In order to accelerate construction of small hydroelectric power stations, the vice-minister said it is necessary to implement the responsibility system to provide incentives and raise work efficiency.

INTERNATIONAL CO-OPERATION

Philippine SHP Completed with Chinese Machinery

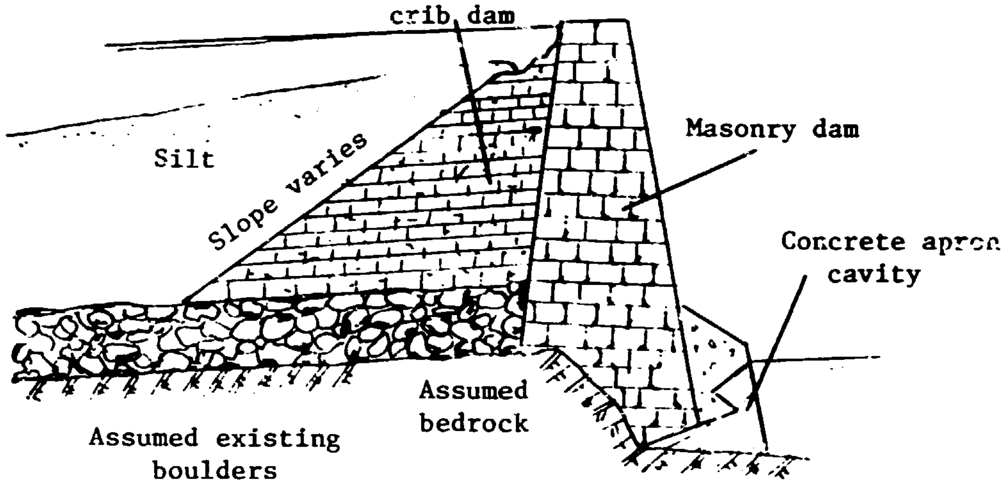
A contract to build a SHP station with 2 x 900 Kw impulse units in Calanduanes Province, the Philippines, was completed and put on line on 27 June 1983. Construction of the station started in July 1982. The complete set of equipment including impulse turbine generator, transformer and switchgear was provided by the Hangzhou Electric Equipment Works, Ningbo Transformer and Jiangshan Switchgear Factories in Zhejiang Province.

According to the stipulations of the contract, the installation, acceptance test and trial run had to be carried out jointly by Chinese and Philippine experts. It has been proven after commissioning, that the equipment of the station is of good quality. Furthermore, China's National Machinery and Equipment Import and Export Corporation has won a $3 million contract to build another 6000 Kw SHP station for the State Irrigation Bureau of the Republic of the Philippines.

Chinese Engineers Assisting SHP Development in the USA

At the invitation of the Oriental Engineering and Supply Company, California/USA, two Chinese senior engineers carried out a field study on Bolton Falls Dam of Green Mountain Power Corporation (GMPC), Vermont, in the eastern part of the United States from 15 May to 10 June 1983. As a result, a better renovation scheme has been suggested, much to the appreciation of the US company.

Bolton Falls Dam was completed in 1898, being one of the early water power developments in Vermont State. The dam is of a timber crib type, with masonry walls as the downstream support. The dam is 60 feet high, 280 feet long, with a spillway crest width of 194 feet. The original powerhouse had an installed capacity of 900 kW. However, part of the powerhouse along with one 450 kW unit was destroyed by a record flood of 98,000 cfs. in 1927 (larger than the 100-year flood). The powerhouse was restored at that time and expanded to an installed capacity of 1650 kW, with a transmission voltage of 12 kV. It was one of the largest power stations in the state at that time. However, the powerhouse was again damaged by a subsequent flood in 1938 and abandoned afterwards.



Section

After having been in operation for 85 years, the dam suffers from leakage and has been undermined at the toe due to lack of repair. The problems are as follows:

a. There exists much leakage point at the reservoir during low water level indicated from slide. There is no doubt that the dam has a large concentrated seepage path. It has been estimated through a survey that the leakage is in the range of 0-30 cfs, more likely 2-5 cfs. However, according to the estimation of GMPC the leakage discharge might be greater than 30 cfs. This is the main problem of the existing dam.

b. Field observations showed that the river downstream the dam is not straight. Serious erosion has occurred due to bad hydraulic conditions during the operation of two sluices. The data from "Bolton Falls Dam Hydroelectric Project Seismic Survey Results" show that the downstream scour depth is 15 feet, and the masonry wall has been undermined to depths 6'-10' on average, with maximum depths 12'-15', thus shortening the seepage length of the dam and causing increased leakage. Furthermore, it would seriously reduce the dam stability against sliding. If not repaired as soon as possible, failure of the dam due to sliding would occur under a larger incoming flood.

In addition, some information about the foundation is uncertain so far; different information sources give different thicknesses of the overburden, 15 feet thick on one drawing and 20 feet on another. And the configuration of the foundation surface, as well as the base width of the masonry wall are also uncertain.

Several renovation schemes had been proposed by domestic engineering firms, but they quoted higher estimates than the owner expected. So Green Mountain Power Corporation called in the Chinese experts. They suggested building a concrete dam, with an overflow deflector bucket over the dam crest below the existing masonry dam and lining the back of the new concrete dam with the original rubble to meet the local environmental conditions required by the historical landmark. In order to improve the hydraulic conditions downstream during overtopping, it is necessary to build a retaining wall at the right-hand side of the existing dam. If the power project fully utilizes and improves the original intake and rebuilds the new powerhouse, then approximately 7.35 MW will be available. (The project design flood will be 145,000 cfs. The design head of the plant is 51 feet.)

Compared with the schemes proposed by domestic firms, the new scheme has the following features:

a. Solves the leakage problem;
b. Provides a better solution to the dissipation of energy and the erosion problem downstream;
c. The concrete volume of the dam could be reduced by 20%;
d. The historical landmark of the dam could be restored by paving the remaining original rock at the back of the new concrete dam;
e. Reconstruction can be easily done using the original dam instead of constructing an upstream cofferdam;
f. It would both reduce the construction cost and preserve the original historical landmark of intake. Also, the cofferdam for constructing the intake would be easily built; etc.

According to the Chinese experts' estimate, the direct construction costs could be reduced by about 20% if compared with the revised estimate of the domestic firms.

China Co-operates with Colombia

China will provide Colombia with 60 sets of small hydroelectric equipment valued at $50 million. This is China's largest hydroelectric export deal, according to the Economic Information Newspaper.

Chinese technical personnel will train Colombian staff and supervise installation. The Colombian will arrange survey, site-selection, design and earthwork construction.

China will supply equipment in the form of 10-year loans. Colombian payment will be in agricultural and animal husbandry products such as cotton, sugar, coffee, cocoa, leather and plywood.

Construction of the 89,000 kilowatt stations will start in 1984. Completion will be in 1988.

NEW IDEAS IN SHP

New Technology in SHP - reported by the Department of Energy (DOE)/USA*

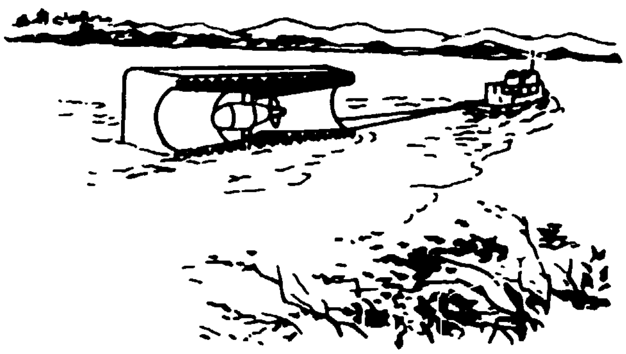
A. Hydraulic Structures

1. Modular float-in powerhouse

A feasibility study for building a central powerhouse construction facility where powerhouse modules could be batch produced and the modules could then be floated to existing dams for installation is being undertaken by Albert H. Halff and Associates of Texas/USA.

The float-in powerhouse concept is initially being investigated relative to 14 locks and dams on the Arkansas River, but obviously could be applied elsewhere as well. Figure 1 shows an artist's concept of the modular float-in powerhouse scheme. Currently the design calls for a 99 feet wide module, 115 feet long, with 28 feet of additional flotation added to the upstream end of the module to make it float level and allow it to travel through the locks and channels of the Arkansas river which has a 9 feet navigable depth.

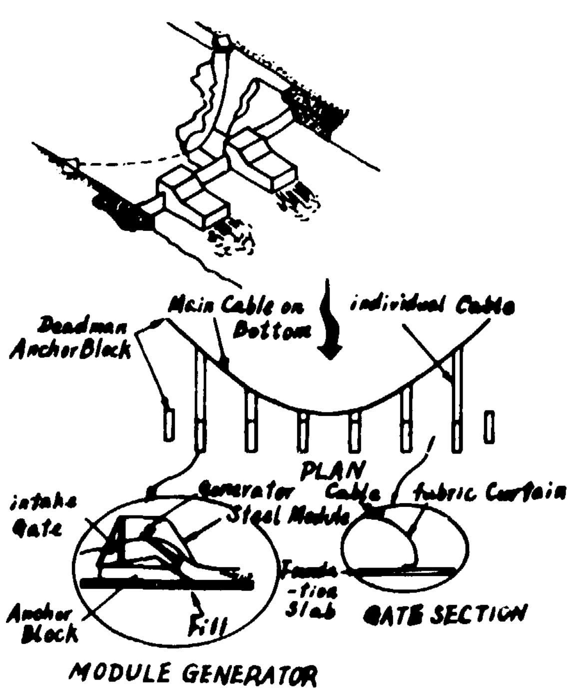
Figure 1: Modular float-in powerhouse



2. Modular hydro-dam

The modular dam construction, developed by Gilbert Associates Inc. Pennsylvania/USA, consists of modules with power generating equipment built into them and separated by fabric curtain dam sections as shown in Figure 2. Although this concept, aimed at reducing costs and speeding up construction schedules, may not be appropriate for building high head dams, the scheme seems quite plausible for low-head installations.

Fig. 2: Modular hydro-dam



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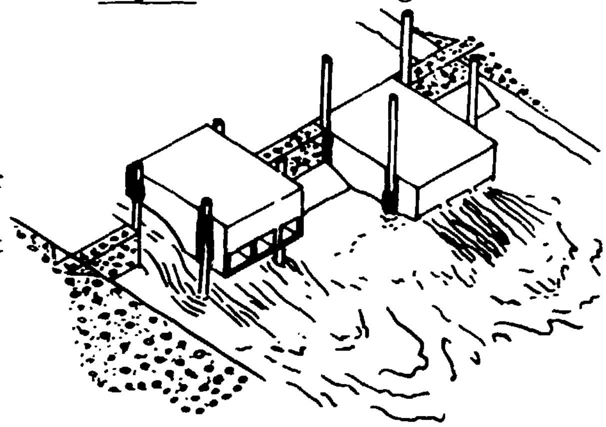
*/ Abstracted from "DOE Small Hydropower Engineering Development Activities", by J.R. Chappell and M.J. McLatchy, Proceedings of "Water Power '79".

3. Powerhouse gate

The powerhouse gate concept, being developed by the Allis Chambers Hydro-Turbine Division in York/Pennsylvania/USA, would place turbogenerating equipment at spillway inlets in locations where spillway gates are presently located. An artist's concept of powerhouse gate is shown in Figure 3. However, the installed hydro power generating equipment, in its entirety, could be hoisted up just like a gate during floods, thus permitting the spillways to maintain their full flood capacity. Most of the work on this project has involved computer analysis to assure that the powerhouse gate design would result in a product that could withstand the stresses to which it would be subjected to when operated as a gate and that the resulting deflections would not be too severe.

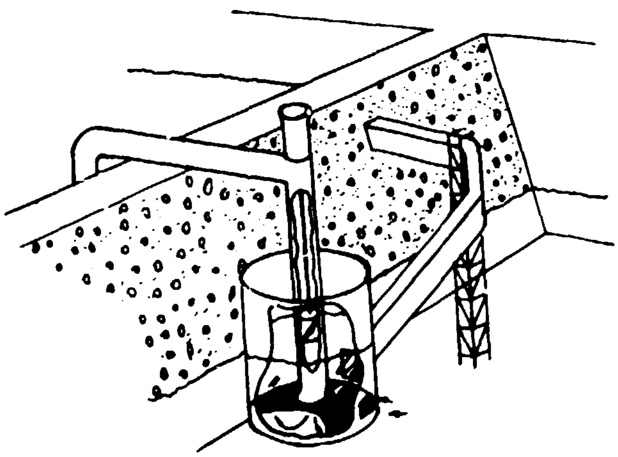
Fig.3: Powerhouse gate



4. Modular fish passages

Modular innovations in upstream fish passages have been proposed by Lakeside Engineering of Mirror Lake, New Hampshire/USA. Figure 4 shows one way in which power can be generated by fish passage water but does not begin to show the variety of fish passages being considered by Lakeside engineers such as a modified Alaska steep pass, glued timber flumes, precast tank walls, precast concrete flume sections, and a rather interesting fish lock elevator scheme. Hopefully, this project will result in a vast improvement in the economic viability of many power projects which are currently severely impeded by expensive fish passage requirements.

Fig. 4: Modular fish passages



B. Turbine-Generators

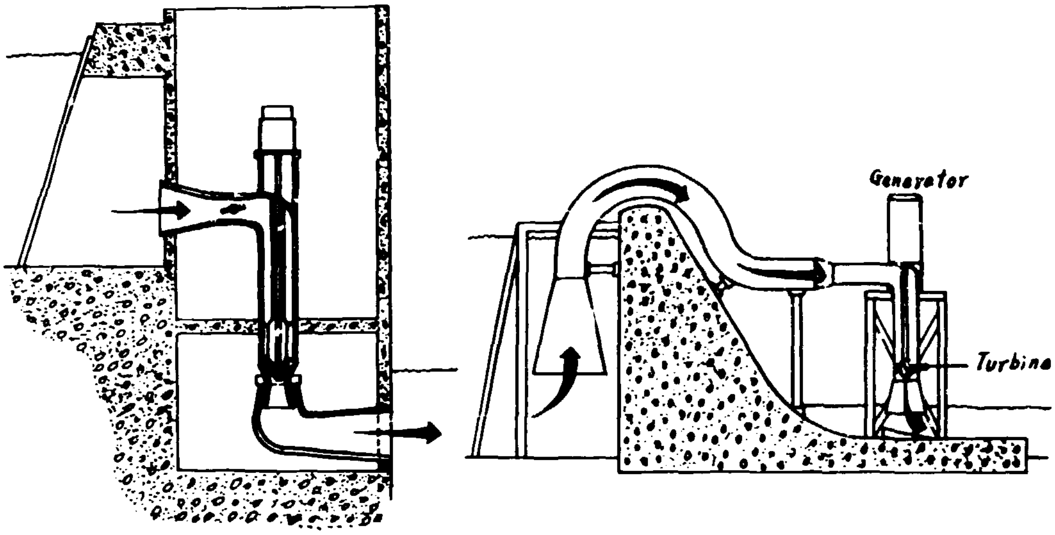
1. Pumps as turbines

There has been an increasing interest in the use of pumps as turbines over the past couple of years. Currently, a large majority of the major pump manufacturers in the US are interested in this concept and at least two have now applied this concept in hydro power settings. In a report, which has just been completed by the Columbia Maryland Offices of Acres American Ing./USA on a generic study of the use of pumps as turbines, several "off-the-shelf" hydroelectric power plant equipment packages of appropriate size suitable for rapid procurement and installation at low cost, for application in a variety of existing dams and reservoirs, are discussed. Induction motors running in reverse as generators form part of the equipment packages.

The principal advantage of such systems is the low initial cost approaching little more than $200 per installed kilowatt for the turbine generator package in some cases.

Although most proponents of pumps as turbines report efficiencies of pumps operating in the turbine mode to be as high as 85%, until recently, there was no firm data to confirm such claims. However, in recent DOE (Department of Energy/USA) sponsored tests conducted by Ingersoll-Rand in their Phillipsbury/ New Jersey facilities, 85% efficiency was obtained and Ingersoll-Rand believes that through minor modifications 87% or better can be achieved. Figure 5 shows a couple of possible pump-as-turbine configurations currently being considered.

Fig. 5 : Pump as turbine configuration

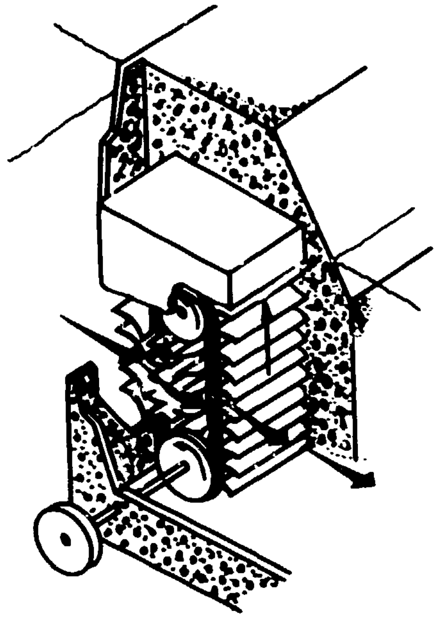


a. Conventional configuration b. Siphon penstock configuration

2. Schneider engine

Model tests of a new type of turbine called a Schneider Engine were completed some time ago, see Figure 6. This device has now received wide-spread attention, because it can conceptually incorporate rather large flow passages needed at low-head sites, relatively inexpensively. A general description of the concept can be found in "Small Hydropower Development - Renewable Sources of Energy", Vol. IV, pages 28-29, prepared by ESCAP/ECDC-TCDC in co-operation with UNIDO. The Department of Energy (DOE) has entered into a co-operative agreement with the Turlock Irrigation District (TID) in central California to test and demonstrate a full size (170 KW) prototype Schneider Engine at a 7 feet drop in their main canal. Subsequent to this project, the Schneider Lift Corporation made additional arrangements with the Richvale Irrigation District in northern California, where a somewhat small unit (75 KW) has now been installed and brought on line.

Fig. 6 : Schneider engine



3. Run-of-river ducted turbine

Run-of-river ducted turbines developed by Aero Vironment Inc. (AV) under the US Department of Energy's Ultra Low-Head Hydroelectric Programme appear to be a cost-effective system for generating electricity from river resources. These river turbine units will operate on the equivalent of less than 0.2 m of head and use a specially designed augmentor required for a given resource and rated power. As shown in Figure 7, the system consists of a ducted turbine, a nacelle containing the gearbox and electrical generating equipment, and a rigid mooring system. Turbine unit designs appear to be cost-effective for small (2-3m diameter) units rated from 5 KW to 20 KW, depending upon the strength of the river current. Units will be grouped in 1 MW arrays, each feeding a group transformer for step-up into the utility grid.

If successful, this project would lead to the miniature application of the Coriolis turbine currently under development by AV Inc. for potential use in harnessing energy from ocean currents.

4. Marine thruster turbine

Figure 8 is a schematic drawing based on a project being developed by Energy Research and Applications, Inc. of Santa Monica/California/USA. They are developing a low-cost, ultra low-head hydro power package based on marine thrusters. Marine thrusters are commerically available, "off-the-shelf" propeller type equipment traditionally used for the propulsion and maneuvering of large ships or other off-shore applications such as oil rig supports.

Fig. 8 Marine thruster turbine

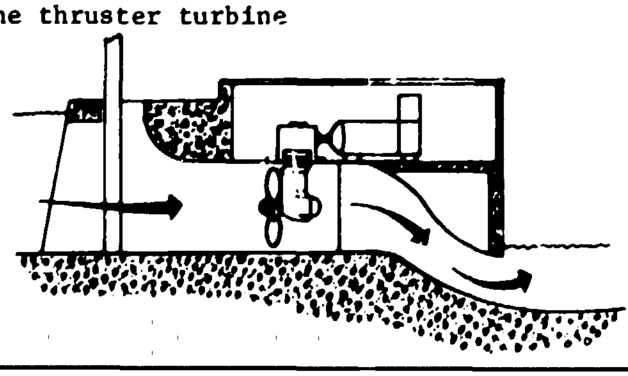
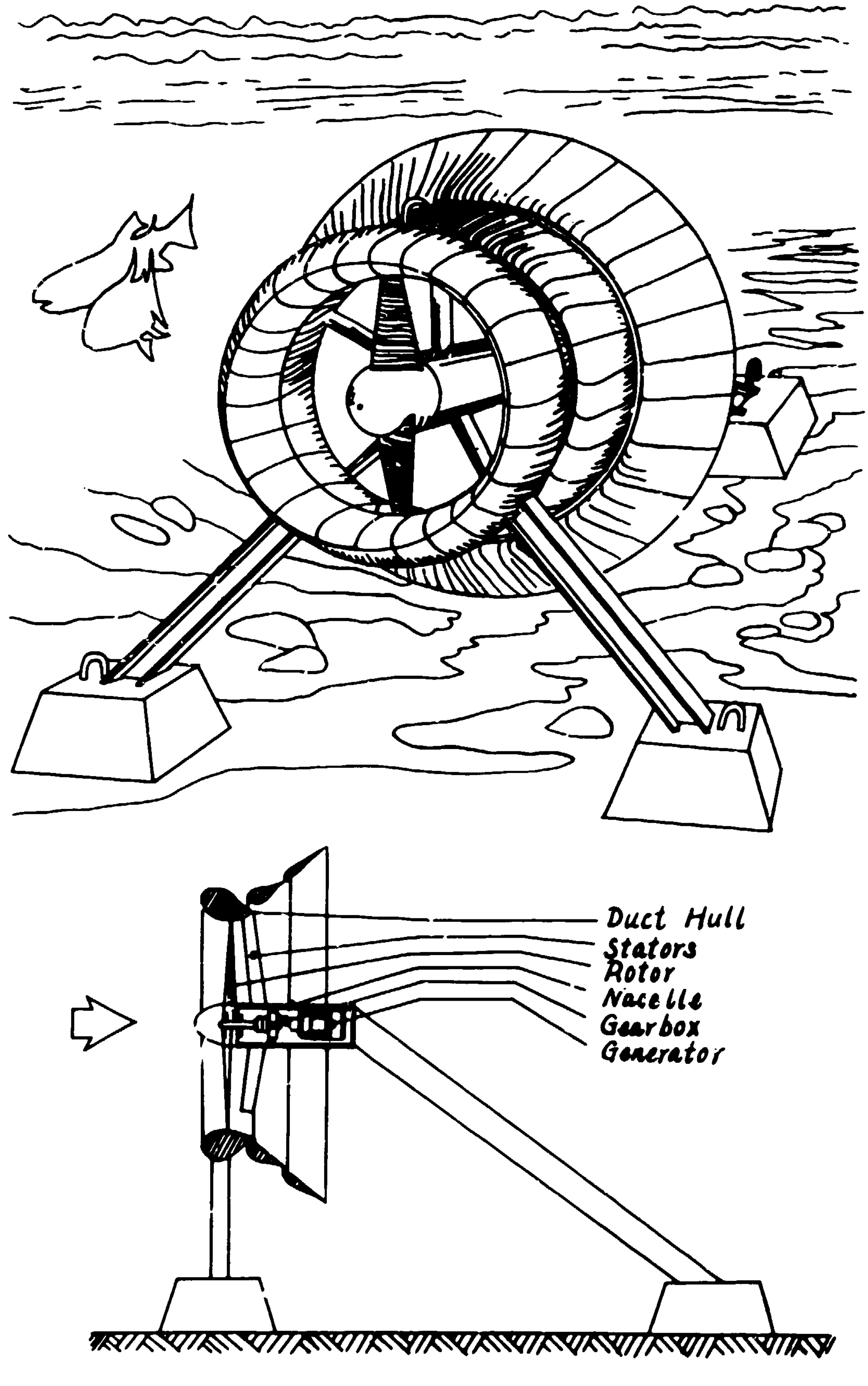


Fig. 7 : Baseline ducted turbine configuration

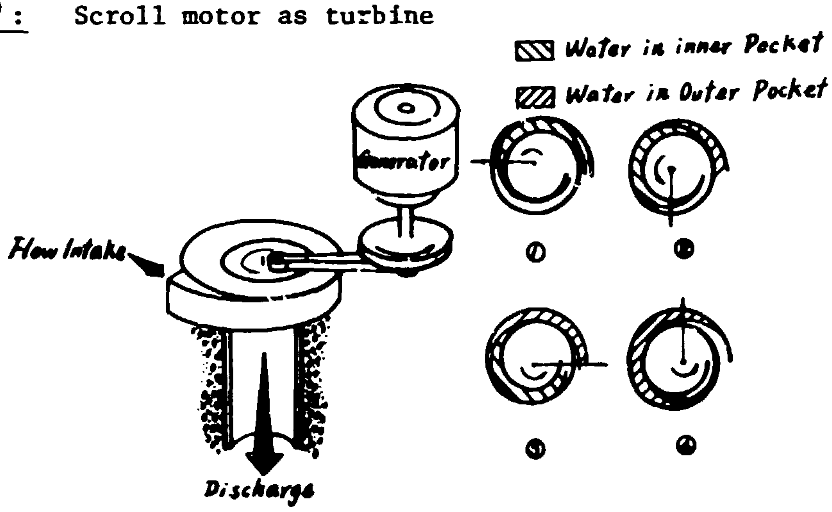


Realizing that it is the "off-the-shelf" mass production aspects of pumps that make them cost effective devices as turbines, it is felt that marine thrusters, operated in the reverse mode as turbines, might also offer similar cost savings. This project is nearing completion and economic analyses performed to date, based on buy back costs of 1.6 ¢ to 6.0 ¢ KWh, indicate returns on investment ranging from 30% to over 100%.

5. Scroll motor as turbine

The Arther D. Little Company of Cambridge, Massachusetts, has developed a device called a scroll motor which has been used as a pump and as an air compressor. In this device there are two interleaved spirals or scrolls with one fixed and the other orbiting relative to it. Figure 9 shows a general schematic of the scroll motor concept. In a certain sense, it can be said that comparing this scroll motor to a piston pump is somewhat analogous to comparing a rotary internal combustion engine to a conventional piston international combustion engine. Through model tests, Arther D. Little is seeking to demonstrate the advantages of scroll motors for ultra low-head hydroelectric power generation. A model fabrication and test loop fabrication has been completed with actual model tests about to take place.

Fig. 9: Scroll motor as turbine

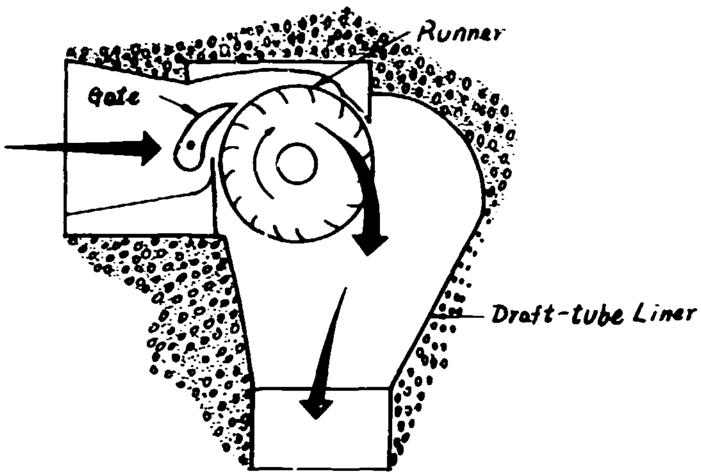


1. Position a. Outer pocket intake just starting, inner pocket intake almost complete.
2. Position a. Plus 90° crank rotation. Outer pocket intake proceeding, inner pocket intake complete.
3. Position a. Plus 180° crank rotation. Outer pocket intake proceeding, inner pocket discharge proceeding.
4. Crank position a. Plus 270° crank rotation. Outer pocket intake complete, inner pocket discharge almost complete.

6. Improvement on crossflow turbine

The New Found Power Company is conducting research in an attempt to improve the crossflow turbine as an economical means of utilizing ultra low-head hydro power sites. There is presently some dispute as to what efficiencies are attainable with present day crossflow turbines. There seems to be less dispute, however, over the fact that such turbines are not presently cost effective in ultra low-head settings. New Found Power is investigating materials and assembly techniques that will make crossflow turbines cost effective in such settings, at efficiencies in excess of 70%. Figure 10 is a cross sectional sketch of a crossflow turbine for that purpose.

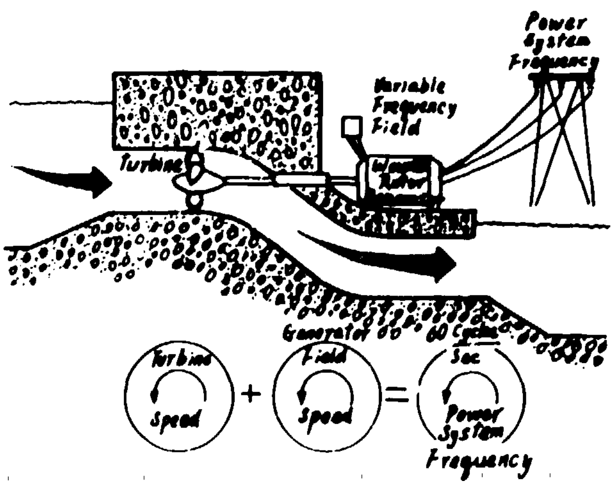
Fig. 10: Crossflow turbine



7. Variable speed generator

The Science Applications, Inc. (SAI) of Palo Alto/California/USA, are working on a polyphase alternator and controls for automatic power transfer from low-head hydroelectric installations. The main thrust of their work is the development of a generator that can produce standard 60 Hz power regardless of the rotational speed of the prime mover and generator shaft. Because in all polyphase induction or synchronous motors or generators, a magnetic field generated by polyphase current possesses an apparent direction and rotational speed, if the coils used to generate such a field are mechanically rotated, the apparent rotational frequency of the magnetic field may be made greater, equal to, or less than the turbine rotational frequency by controlling that frequency of the polyphase exciting field. As depicted in Figure 11, 60 Hz power can be produced even when the turbine shaft speed is zero by mechanically rotating the generator field at 60 Hz. Of course, under such conditions more power is consumed than is produced. On the model being tested by SAI the turbine shaft speed has to be greater than approximately 600 rpm before more power is generated by the system than is consumed.

Fig. 11: Variable speed generator



PAST AND PLANNED WORKSHOPS

First Training Workshop of RN-SHP

The First Training Workshop on SHP, the very first activity of the Regional Network, was held at Huagang Hotel in Hangzhou, P.R. China from 23 May to 22 June 1983.

Based on the proposal made in the Joint UNDP/UNIDO/ESCAP/China Senior Expert Group Meeting on the Creation of a Regional Network and the Assessment of Priority Needs on Research, Development and Training in the Field of Small/Mini Hydro Power, held in Hangzhou/P.R. China in July 1982 and affirmed by the Third Workshop on SHP held in Kuala Lumpur in March 1983, the First Training Workshop was organized by the Hangzhou Regional Centre (HRC) under the joint sponsorship of the ESCAP/Regional Energy Development Programme (REDP), the United Nations Development Programme (UNDP) and the United Nations Industrial Development Organization (UNIDO).

Sixteen participants from nine ESCAP member countries attended the Training Workshop. Most of them were junior and senior executives in the field of SHP. Apart from two Chinese participants, they came from Fiji, Indonesia, Malaysia, Nepal, Pakistan, the Philippines, Sri Lanka and Thailand.

The Training Workshop lasted one month and composed of lectures combined with discussions and study tours. 21 lectures were given by 17 professors and experts, of which four were from Canada, Malaysia, the Philippines and UNIDO. 18 symposia were held and 11 SHP stations as well as 3 turbine and generator factories in Xiaoshan and Xinchang counties and the city of Jinhua in Zhejiang province were visited.

In the latter part of the training course, the participants summed up their experiences by relating what they had learned to the concrete conditions of their own countries, and exchanged information and experiences. Finally, in the name of REDP, UNDP, UNIDO and HRC, certificates were awarded to the participants.

The Training Workshop was carried out in a conscientious manner from the beginning to the end by all parties concerned. Both the UN and Chinese Government officials made special trips to Hangzhou to take part in the opening and closing ceremonies as follows:

- UN officials included: Mr. Tanaka, Head, Development and Transfer of Technology Branch/UNIDO
  and Mr. Pack, Senior Industrial Development Officer DTTB/UNIDO

Mr. Arismunandar, (former) Senior Co-ordinator of ESCAP/REDP

Mr. de San, Regional Adviser of UNDP/Beijing

- Chinese Government officials included:

Mr. Zhao Qingfu, Vice-Minister, Ministry of Water Resources and Electric Power (MWREP)

Mr. Tang Zhongnan, Head, Department of Rural Electrification, MWREP

Mr. Deng Bingli, Deputy Head, Department of Rural Electrification, MWREP

Mr. Lin Qingsen, Deputy Director, Bureau of Machinery (MWREP)

Mr. Zong Boxi, Acting Mayor of Hangzhou

Ms. Zhou Huilan, Deputy Director, Bureau of Water Conservancy, Zhejiang Province

The fact that so many high ranking officials graced the occasion encouraged the participants very much.

It was generally acknowledged that the lecture materials used for the Training Workshop were rich in content and varied in form, hence, good results were achieved. However, if a training workshop with a limited number of subjects was conducted henceforth and the training period shortened, still better benefits could be obtained.

Third Workshop on SHP

Jointly sponsored by ESCAP/Regional Centre for Technology Transfer (RCTT) Regional Energy Development Programme (REDP), United Nations Industrial Development Organization (UNIDO) and the National Electricity Board (NEB) of Malaysia, the Third Workshop on SHP was held from the 7 - 15 May 1983 in Kuala Lumpur/ Malaysia.

The workshop was attended by 28 participants from 19 developing countries, 20 representatives from UN agencies and organizations as well as from other inter-governmental, international and national organizations, and 34 observers from Malaysia.

At the opening session, Messrs. H.E. Datuk Leo Moggie, Minister of Energy, Telecommunication and Posts as well as Y.B. Tan Omar, General Manager of NEB, both made speeches of welcome, and three representatives from UN organizations, i.e. Messrs. W.H. Tanaka, B.R. Devarajan and A. Arismunandar, also delivered speeches of congratulations. The closing ceremony was chaired by Mr. Y.B. Tan Omar.

Mr. Jalaluddin Zarnuddin, Deputy General Manager of NEB, was elected to be the Chairman, and Mr. J.M.V. del Rosario, Vice President of AG+P/Philippines, was rapporteur.

At the First Plenary Session on 7 March, it was decided that the participants would be divided into two working groups, and each of them visited a SHP station on the outskirts of Kuala Lumpur; on 8 March general discussions and country statements were made; 9 and 10 March were devoted to group discussions on country papers; the following three days participants visited SHP stations and the Dispatching Centre of NEB; on 14 March, besides the joint plenary session, the participants from ESCAP region held a sub-working group meeting to exchange views regarding the proposed Work Programme of the Regional Network for SHP (RN-SHP) and the arrangement of an Interim Secretariat for the Network. The closing ceremony was carried out on 15 March.

After full discussions on 14 March, it was unanimously agreed that prior to the formal approval of the "Report on the Creation of a Regional Network System on SHP" by the governments of member countries, the Hangzhou Regional Centre (HRC) should proceed with its work as soon as the required funds became available, and that the First Training Workshop on SHP should be held in Hangzhou from 23 May to 24 June 1983.

There were 30 papers presented to the workshop for the interflow of technology from various countries and UN agencies and organizations, including, 9 papers on SHP development and feasibility studies from the Philippines, Sri Lanka, Norway, Republic of Korea, Zambia, Ethiopia, the United Kingdom, Sierra Leone and ESCAP; 7 papers on the manufacture and improvement of SHP equipment from the Philippines, Thailand, Norway, Guyana, Switzerland and ESCAP; and 3 papers presented by Jamaica, Malaysia and the UN Department of Technical Co-operation for Development (DTCD) on design optimization, reduction of costs and upgrading economic benefits of SHP.

Training Workshop on Hydrology

The draft work programme of the RN-SHP suggested that a Training Workshop on Hydrology for Small Hydro Power be held as the second training activity of the Regional Network for Small Hydro Power.

The objectives of the workshop are:

1. To train middle-level technical personnel from various countries in the Asia and Pacific region, who are engaged in practical hydrological work for SHP;
2. To study and discuss the special characteristics, methods and direction of future development of hydrological work for SHP;
3. To exchange experiences of SHP hydrological work, covering Asia and Pacific region; and
4. To promote inter-country co-operation within the Asia and Pacific region in the construction of SHP.

The major contents of the course are:

- Hydrometry;
- Analysis and computation of annual runoff;
- Investigation of flood and low-water discharge;
- Design flood.

The workshop is tentatively scheduled to be held in the fourth quarter of 1984 at Guangzhou, P.R. China. For more details, please contact: The Director, Regional (Asia and Pacific) Research and Training Centre for Small Hydro Power, P.O. Box 544, Hangzhou, P.R. China.

ANNEX - LIST OF DOCUMENTS SUBMITTED AT FOLLOWING MEETINGS

Second Seminar-Workshop/Study Tour in the Development and Application of Technology for Mini-Hydro Power Generation (MHG)

Hangzhou/China, 17 October - 1 November 1980
Manila/Philippines, 3 - 8 November 1980

Symbol no.	Title of documents
ID/WG.329/1	UNIDO Issue Paper
ID/WG.329/2	Mini-Hydro Application in the Philippines by: Pedro G. Dumol in co-operation with Frank H. Denton
ID/WG.329/3	Small Hydro in Sweden by: Thorild Persson
ID/WG.329/4	Report
ID/WG.329/5	Medium and Small-Scale Hydro Power Plants in Ethiopia; by: Mariam G. Hailu
ID/WG.329/6	Micro-Hydel Generation in India by: Tanaji A. Deodas
ID/WG.329/7	Prospect of Small-Scale Hydro Power Development in Bangladesh; by: Syed T.S. Mahmood
ID/WG.329/8	Mini-Hydro Power Development Programme in Burma by: B. Rallian Sang
ID/WG.329/9	Micro-Hydro Generation in Papua New Guinea by: Gabriel V. Manijuaie
ID/WG.329/10	Mini-Hydro in Malaysia by: Bin N. Hoesni
ID/WG.329/11	Micro-Hydel Project in Nepal by: Shatrughna N. Chaturvedi
ID/WG.329/12	Power Development in Pakistan by: Syed T.S. Mahmood
ID/WG.329/13	Hydro-Electric Energy in Egypt by: Abdel Hakam A. Atallah
ID/WG.329/14	Mini-Hydro Electric Generation in Jamaica and other Countries of the CARICOM Region by: Dennis A. Minott
ID/WG.329/15	Summary Mini-Hydro Project in Thailand by: Chulapong Chullakesa
ID/WG.329/16	Mini-Hydro Electric Plants in Kenya by: Gerald M. Wagana
ID/WG.329/17	Small-Hydro Power Generation in Peru by: Andrés F. Coz
ID/WG.329/18	Mini-Hydropower Generation (MHG) in Turkey by: Tirucin Tumer

ID/WG.329/19	Yugoslav Experiences, Achievements and Possibilities of Co-operation with Developing Countries in the Area of Mini-Hydroelectric Generation Units; by: Darko Bekić
ID/WG.329/20	Mini-Hydro Development in Liberia by: Baseeru M. Sonii
ID/WG.329/21	Development of Mini-Hydro Power Generation in the Republic of Zambia; by: J. Kalolo Chanda
ID/WG.329/22	Multi-Purpose Development of the Jingjiang Basin by: Liu Rudong
ID/WG.329/23	Small Hydropower in China by: Ministry of Water Conservancy
ID/WG.329/24	Integration of Small Hydro Plants of Yongchun County into the Small Local Grid; by: Department of Water Conservancy and Electricity
ID/WG.329/25	China's Small Hydroelectric Machineries by: Bureau of Farmland Water Conservancy
ID/WG.329/26	The Rural Electric Power Network Planning and Operation in Dayi County, Sichuan Province by: Lu Hua, Fang Xinlin and Feng Qishan
ID/WG.329/27	The Application of Prestressed Concrete Pipes in Small Hydro-Electric Stations by: Huang Bingnan and Cai Xuxian
ID/WG.329/28	Application of Relief Valves in Small Hydro-electric Stations; by: Zhong Chenggang, Dai Junnian, Chou Taijing and Fu Wenyuan
ID/WG.329/29	Planning for the Small Hydro-Power Stations and Network in Tungcheng County, Hubei Province by: He Chengji and Peng Nianxiang
ID/WG.329/30	Earth Dam Projects in Small Hydro-Power Construction in Hubei Province by: Chen Yenlu
ID/WG.329/31	Micro-Hydro Power in Guyana by: Joseph N. O'Lall
ID/WG.329/32	Low-Head Hydroelectric Unit Fundamentals by: Howard A. Mayo Jr/USA
ID/WG.329/33	Mini-Hydro Power Development in the Philippines (A Case Study); by: Takeji Yasuda and Noboru Murata/Japan
ID/WG.329/34	Small-Scale Hydro-Power Plants in Yugoslavia by: Dzemal Humo
ID/WG.329/35	Hydropower Development Projects in the Provinces of Bohol and Antique, The Philippines by: Gjermund Saetersmoen/Norway
ID/WG.329/36	Small Scale Hydroelectric Power Technology by: Ola Gunnes and Norwegian Water Resources and Electricity Board
ID/WG.329/37	Mini Hydro Power Development in Pakistan by: M. Abdullah

Third Workshop on Small Hydro Power
RCTT/UNIDO/REDP/Government of Malaysia
7 - 15 March 1983, Kuala Lumpur/Malaysia

Symbol no.	Title of documents
ID/WG.403/1	Computer Optimization of Hydro Power Station Design and Reliability by Dynamic Simulation by: Rodolfo Susa Cordero/Mexico
ID/WG.403/2	Small Hydro Power Development - The Socialist Republic of the Union of Burma by: U Zaw Win and U Myint Aung
ID/WG.403/3	Small Hydro Power Development - Fiji by: D.S. Pickering
ID/WG.403/4	Mini Hydro Power Development - United Republic of Tanzania by: B.E.A.T. Luhanga
ID/WG.403/5	Centralized Versus Decentralized System of Project Planning and Implementation of Mini-Hydro Power Development - The Indonesian Case by: Hartoyo Notodipuro
ID/WG.403/6	Methodology for Feasibility Studies - Republic of Korea; by: Chun Yun Wook
ID/WG.403/7	Ways and Means of Cost Reduction Compatible with Viability and Utility Requirements by: Mohamed Zubir Bin Zainal Abidin/Malaysia
ID/WG.403/8	Centralized System of Mini Hydro Projects Planning and Implementation in Peninsular Malaysia; by: Hoesni Nasaruddin
ID/WG.403/9	Small Hydro Power Development - The Kingdom of Nepal; by: Atma Krishna Shrestha and Hari Man Shrestha
ID/WG.403/10	The Status of Small Hydro Power in the Commonwealth of Dominica; by: Rawlins Bruney
ID/WG.403/11	Report Format Outline for Feasibility Studies Mini-Hydro Power Generation Projects; and Mini-Hydro Power Generation Project Study Guidelines (As used in the Republic of the Philippines) by: Zenaida A. Santos
ID/WG.403/12	Promotion of Local Design and Manufacture of Mini Hydroelectric Equipment in the Republic of the Philippines; by: Juan Miguel V. del Rosario
ID/WG.403/13	Small Hydro Power Development - P.R. China I. General Situation and Fundamental Experiences of Development of Small Hydro Power in China by: Deng Bingli and Zhu Xiaozhang II. Experiences of Independent Operation of Small Hydro Power Grid at County Level; by: Yang Yupeng, Huang Zhongli and Zhang Beichen

	III. How to Establish Indigenous Manufacturing Capability of Small Hydro Turbine Equipments by: Song Shengyi
ID/WG.403/14	Small Hydro Power Development - The Democratic Socialist Republic of Sri Lanka; by: Carlo Fernando
ID/WG.403/15	Local Design and Manufacture of Equipment and Auxiliary for Mini Hydro Power Generation in the Kingdom of Thailand; by: K. Bhadrakom and C. Chartpolrak
ID/WG.403/16	Development of Small Hydro Power in the Republic of Zambia; by: Johannes Kalolo Chanda
ID/WG.403/17	Small Hydro Power in the Republic of Turkey by: Suat Pasin
ID/WG.403/18	Some Aspects of Small Hydro Power Planning and Implementation in Ethiopia; by: Hailu G. Mariam
ID/WG.403/19	Promotion of Local Initiatives in Small Hydro Power Development in The Socialist Federal Republic of Yugoslavia; by: Darko Bekić
ID/WG.403/20	Progress in Small Hydro Power Development in the Republic of Sierra Leone; by: D.L.B. Kamara
ID/WG.403/21	Cost Reduction Considerations in Small Hydro Power Development; by: Dennis A. Minott and Richard A. Delisser
ID/WG.403/22	Factors Affecting the Feasibility of Small-Scale Water Power Plants; by: Asbjørn Vinjar/Norway
ID/WG.403/23	How to Start Manufacturing of Equipment for Small Hydro Power Plants in Developing Countries by: Alfred Hueter/Austria
ID/WG.403/24	Local Manufacture of Mini Hydro Equipment by: Joseph O'Lall/Guyana
ID/WG.403/25	Local Manufacturing of Waterturbines by: Markus Eisenring/Switzerland
ID/WG.403/26	Micro Hydro Power for Rural Development - Lessons Drawn from the Experience of the Intermediate Technology Development Group; by: Ray E. Holland
ID/WG.403/27	Promotion of Local Design and Manufacturing of Equipment and Auxiliaries; by: H. Sinding
ID/WG.403/28	Work Programme for the Regional Network for Small Hydro Power (RN-SHP) at the Hangzhou Regional Centre (HRC); by: Enrique Indacochea/OLADE
ID/WG.403/29	Economic Appraisal of Small-Scale Hydro Power Projects; by: K. Goldsmith/DTCD
ID/WG.403/30	Small Hydro Power Development I. Methodology for Feasibility and other Studies Appropriate for Small Hydro Power Development II. Local Manufacture of Small Hydro Power Equipment (Turbine) III. Ways and Means of Cost Reduction Compatible with Viability and Utility Requirements by: ESCAP Secretariat

ID/WG.403/31	UNIDO Issu Paper
ID/WG.403/32	Draft Work Programme (1983/1984) of ESCAP Regional Network System for Small Hydro Power During the Interim Period; by: UNIDO Secretariat
ID/WG.403/33	Report

OTHER REPORTS/DOCUMENTS

ID/WG.305/22	Draft Report on the UNIDO/ESCAP/RCTT Joint Meeting of the Seminar-Workshop on the Exchange of Experiences and Technology Transfer on Mini Hydro Electric Generation Units, Kathmandu/ Nepal, 10-14 September 1979
IS.182	Policy, Economic and Technological Aspects of Mini Hydro Electric Generation in Developing Countries - Working Group Reports - Kathmandu Declaration (1980)
IS.284	Chinese Experiences in Small Mini Hydro Power Generation; by: the Ministry of Water Conservancy/P.R. China (1982: English/French/Spanish)
ID/SER.N/1	Small Hydropower Series No.1 Mini Hydropower Stations (A Manual for Decision Makers); by: UNIDO/OLADE (IS.225 - 1981: English/French/Spanish)
	ECDC-TCDC Renewable Sources of Energy, Volume IV, Small Hydroelectric Generation (ESCAP-1982)

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