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ABSTRACT

The paper describes a project on generation of Electricity using small perennial waterfalls mostly located in northern districts of Pakistan. Small plants (5-50 KW. range), using indigenously developed cross-flow (Banki) turbines are installed on these falls. Speed is controlled through dissipation of excessive energy through an electronic load controller. After installation, the plants are operated and maintained by the benefiting communities, who also contribut substantially towards the initial equipment costs. The initial success story of this technical-cum- socio-economic project is encouraging.

1. INTRODUCTION

The human beings have been utilizing different types of power resources available to them since time immanorial. As we go back in the history the designers have liked to use those energy resources which were more readily available and accessible. Water wheels utilizing energy of flowing water and using it for such routine operations as grain milling were a common site in many countries during the period upto early 19th century. Even during the recent past, water wheels were being used in the developing countries. However, with the discovery of fossil fuels such as coal and oil, which were more conveniently useable, the use of water wheels gradually diminished and no serious research work was undertaken to upgrade the technology. During the 70s, the harsh reality, that the fossil fuels were going to be depleted in a foreseable future; was brought home by the so called oil crisis of 1973. Since then, interest of researchers and decision makers has enhanced in the other renewable resources of energy supply.

Small hydro-power is specially suitable for less developed countries both technologically as well as economically, because it requires less sophisticated technology for design manufacture and operation of such plant to more remote and unaccessible areas also makes it viable alternative to the more conventional methods. Small hydro-power stations are also suitable in the less populated areas where they may serve scattered communities adequately. The Himmalayan and Hindukash range of mountains which extends from Burma in the East to Afghanistan in the West, has considerable potential sites which could be utilized tapping hydel

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power. Some of the largest sites such as Mangla and Tarbela have been extensively developed to utilize power at a large scale. However, smaller sites many number in hundreds of thousands throughout this range. As a result of this, China, India and Nepal have extensive programmes for utilization of hydel power on small scale. In Northern areas of Pakistan also, most of the territory is covered by this range, thus potential of small hydro-power (including micro and mini sizes) can be utilized quite extensively. The Pakistan Council of Appropriate Technology Development Organization (ATDO) was a pioneer agency to initiate work on this aspect. This work was undertaken in collaboration with Dr. M. Abdullah, Professor of Electrical Engineering, NWFP University of Engineering and Technology, Peshawar. The PCAT providers all the funds and arranges expert's advice and information from abroad as inputs to this project. Whereas Dr. Abdullah was working on the implementation side overseeing the design, manufacture, and installation of these plants.

The programme is specially relevant to those Northern areas because of lack of such amineties as road networks of electrical grids. Mountaneous topography makes the access to various places over more difficult. Quite naturally, therefore, the population distribution is very thin and clustered in the form of small communities of 5 to 20 houses, again separated from each other by very difficult terrain. Because of this, the normal methods of supplying electricity to these people are very very expensive.

The PCAT has been installing the hydel plants of micro-size range between 5 to 30 KW installed capacity. The work done in this way is very relevant in terms of concept of appropriate technology whereby the devices and appliances have to be low cost, indigenously produced, oriented towards overall benefit of the less economically developed section of the populace, etc. Such projects may, or may not be economically exploitable or feasible.

2. Installation Programme

There is no one particular standard whereby the sizes and capacities of hydel plants may be categorised into micro, mini and small series. However, according to the recommendations of the UNIDO Experts (2), following table describes the capacity range for different categories:

	Category	Size Range (KW)
(i)	Micro Plants	upto 100
(ii)	Mini plants	100-1,000
(iii)	Small Plants	1,000 - 10,000

The PCAT has been installing hydel plants in the micro-range. Todate, about 80 plants having capacity range of 5 KW to 30 KW are working at various sites (Table 1&2). Two plants having capacity of 50 KW utilizing the same technology have also been commissioned recently. These plants are of simplest design having a penstock pipe with a manually operated gate valve, trapezoidal flow nozzle and a Banki type cross-flow turbine. The only control devices are, an over- flow pipe to maintain level in the forebay and electronic load controller which automatically dissipates electrical energy in case of reduced demand. Various components of these plants are shown in Figure 2.1

At present, the total cost of these plants averages at about Rs.5,000/- per KW installed capacity (US $ 300/KW). All the components are locally manufactured in small private workshops except the 3 phase generator which is of foreign make although freely available locally. Because of this, the cost of manufacture is reduced to a large extent and makes the whole project economically viable and very competitive to the other alternatives of electrical supply. At present, the cost of plants installed by PCAT is about 20 times lower than the normal public-owned electricity supply agency. Only in some cases, reliability and quality have been low for obvious reasons and the break-down specially of the turbines are more frequent. But this has never been a serious problem because the repairs are arranged locally also and do not involve imported spares, therefore, equally very cheap.

At present, following methodology is used to initiate an installation programme for a particular site. Firstly, the sites are either identified by the PCAT staff, some other government or autonomous agencies working in that area, or, by the people themselves. It is expected that the people of the community which is going to be directly benefited from the plant, make a formal request to the PCAT preferably endorsed by a local public representative. PCAT then organizes the survey of the site evaluating the energy potential of the water fall, total requirements of the community and the approximate expenditure required for development of the site, manufacture of the plant, transportation of the plant to the site, installation, distribution, etc. Some responsible persons from the community(s), say two or more heads of families enter into a formal agreement with the PCAT to contribute about 50% of the cost. This share of the community is, usually, in kind rather than cash; e.g. local labour supply during the installation and transportation, completion of civil works, completion of the distribution lines to various houses, and so on. The PCAT usually provides hardware i.e. the mechanical equipment, installation expertise and training of one or two persons from within the community for future operation of the plant. After the plant becomes critical, it is handed over to the community, and from then onwards, they are responsible for their operation and maintenance throughout the life of the plant. If any break-down occurs, the community arranges the repair either at nearby workshops, or, they may approach the PCAT offical at Peshawar for replacement of part. Usually they pay fully for the repairs and a bus was regularly playing on it. This indeed is a large transformation for that community and is believed to have been brought about by the technological awareness.

Table-1: List of Micro Hydel Electric Plants Installed by PCAT upto 30-11.1987.

S.No.	Name of village	Installed Capacity(KW)
	DISTRICT SWAT.	
1.	Qadir Nagar	3
2.	Liloni-I	12.5
3.	Liloni-II	3
4.	Liloni-III	5
5.	Liloni-IV	5
6.	Banda Cheena	3
7.	Barkaina	10
8.	Gamseer	5
9.	Gamuary	5
10.	Mehragy	10
11.	Alpuri village	10
12.	Shung	10
13.	Shalpin	5
14.	Karshang	3
15.	Shahpur-I	10
16.	Shahpur-II	25
17.	Khalkari	5
18.	Bishband	5
19.	Shingray	3
20.	Nalkote	10
21.	Barkalay	5
22.	Jaba Kohu	5
23.	Ushu	20
24.	Malka	5
25.	Kharary	12
26.	Gambat (Bunair)	5
27.	Karikas	5
28.	Gambat	3
29.	Ghanglalai	10
30.	Susubi	5
31.	Kod Mang	5
32.	Lai kot(Kohistan)	10
33.	Kot kay(Puran)	10

S.No.	Name of village	Installed (Capacity(KW)
	DISTRICT CHITRAL	
1.	Kalatak	20
2.	Kughozi	12.5
3.	Bazindeh	12.5
4.	Reman	20
5.	Herchin	12.5
6.	Gulogh	20
7.	Kasamandeh	12
8.	Kosht Khot	12
9.	Drosh Gui	5
10.	Dukhlondo	20
11.	Sasum	20
12.	Ishriate	5
13.	Murdair	12
14.	Bamboriat	10
15.	Awi	20
16.	Shahgram	12.5
17.	Jajjuraitko	12.5
18.	Ujno	5
19.	Keyar	20

S.No.	Name of village	Installed (Capacity(KW)
	DISTRICT MANSEHRA KAGHAN VELLEY.	
1.	Bela Bila	5
2.	Kawai-I	30
3.	Kawai-II	12
4.	Paras-I	20
5.	Paras-II	12.5
6.	Rareedabad	12.5
7.	Gangool-I	20
8.	Gangool-II	12
9.	Gangool-III	12
10.	Mohanderi	30
11.	Jareed	3
12.	Kindiari	3

	BAJAUR AGENCY		DISTRICT ABBOTTABAD	
1.	Bishat Salarzai	5	1. Salo Bandi	20
	KURRAM AGENCY		DISTRICT LORALAI (BALUCHISTAN)	
1.	Tirah	5	1. Duki-I	50
			2. Duki-II	10
	DISTRICT DIR		NORTHERN DIVISION	
1.	Lamotay	12.5	1. Bunji	10

Table-2 List of Industrial Units Attached to some Micro Hydel Plants.

S.No. Place	SMALL SCALE INDUSTRIAL UNITS
1. Liloni-I	Flour Mill, Rice Husking Machine, Oil expeller, Cotton ginning machine, Saw machine, Grinder, and Welding machine.
2. Bishband	Saw Machine, Oil expeller, Flour Mill, Rice husking machine.
3. Mehraghi	Two flour mills, Rice husking machine, Saw machine, Welding machine, Grinder, and cotton ginning.
4. Barkana	Rice husking machine, Maize sheller, Wheat machine.
5. Barklay	Two flour mills, Cotton ginning, Grinder and Drill machine.
6. Shung	Flour mill.

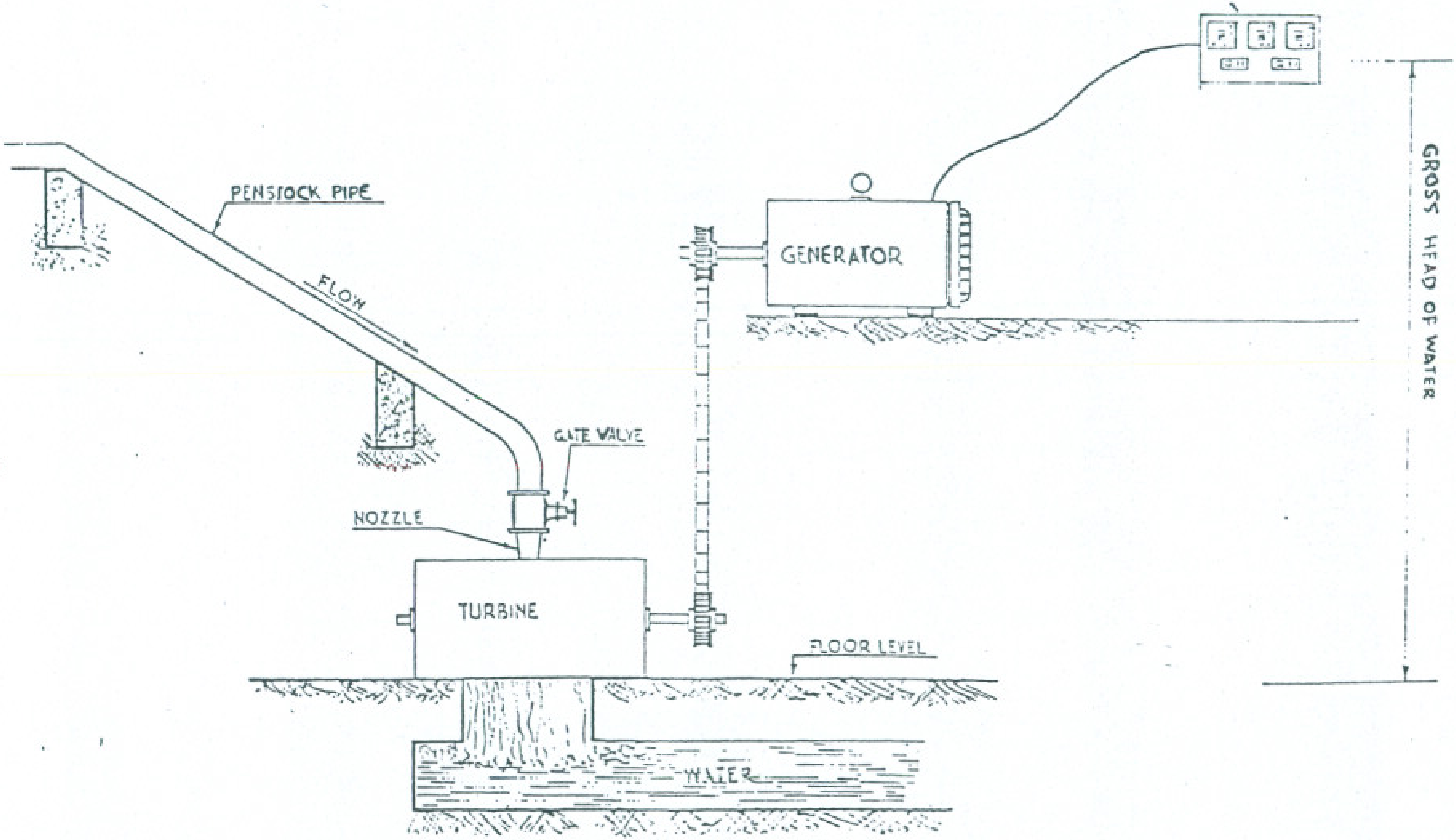

Fig.2.1. Micro Hydel Power Plant.

3. DESIGN / MANUFACTURE OF PLANTS

As stated earlier, the design of the turbine and all other components has been kept simple so as to make its local manufacture possible and economical. The system design has also been kept simple having minimum possible number of components. In a normal medium - sized plant, following components are being used. The details of the plant are shown in figures 3.1, 3.2 and 3.3

3.1 PENSTOCK

This is the main pipe, length and size of which depends upon design head and discharge of the waterfall. It is circular in shape and usually is made from mild steel sheet rolled into circular cross-section. One end of the penstock is inserted in the forebay, while the other end terminates into a gate valve.

The arrangement of handing over the plant to community, also sits well with the concept of appropriate technology (AT) whereby community participation is considered a necessary requirement. The community mainly through the Management Committee, Organizes a collection from the various families/houses on monthly basis to pay for any consumables such as lubricants, repair and the salary of the operator. So far, these arrangements have worked pretty well and thus the micro-hydel programme has been praised at international level also (3). A recent partial survey conducted by PCAT revealed that approximately 80% of the plants were working and the remote villages were making full use of them. In quite a few cases, the Management Committee installed some other appliances utilizing the power during the day time when electricity was surplus. These appliances may be grain mill. a rice dehuskor, a small lathe, a wood-saw and so on.

So far, the PCAT has undertaken this installation programme using the funds entirely provided by the Govt. of Pakistan. Now, however, interest seems to be generating in some International agencies who have expressed willingness to support this programme on larger scale. It is expected that the pace of installation programme would be increased during next five years to about 100 plants/year, compared to the prevailing one of about 8 per year; The plants will be of larger size (upto 250 KW) and are expected to be more sophisticated in terms of quality and reliability, efficiency, as well as control mechanism. Preparations are underway to meet this challenge and a modest but well equipped development cum- manufacturing facility is to be established at Peshawar for this purpose. The development facility would also include such devices as balancing equipment, pressure testing devices, vibration monitors, etc. Some international agencies who have expertise in this field such as Intermediate Technology Development Group (ITDG) London, BYS of Nepal are being approached for help in this respect.

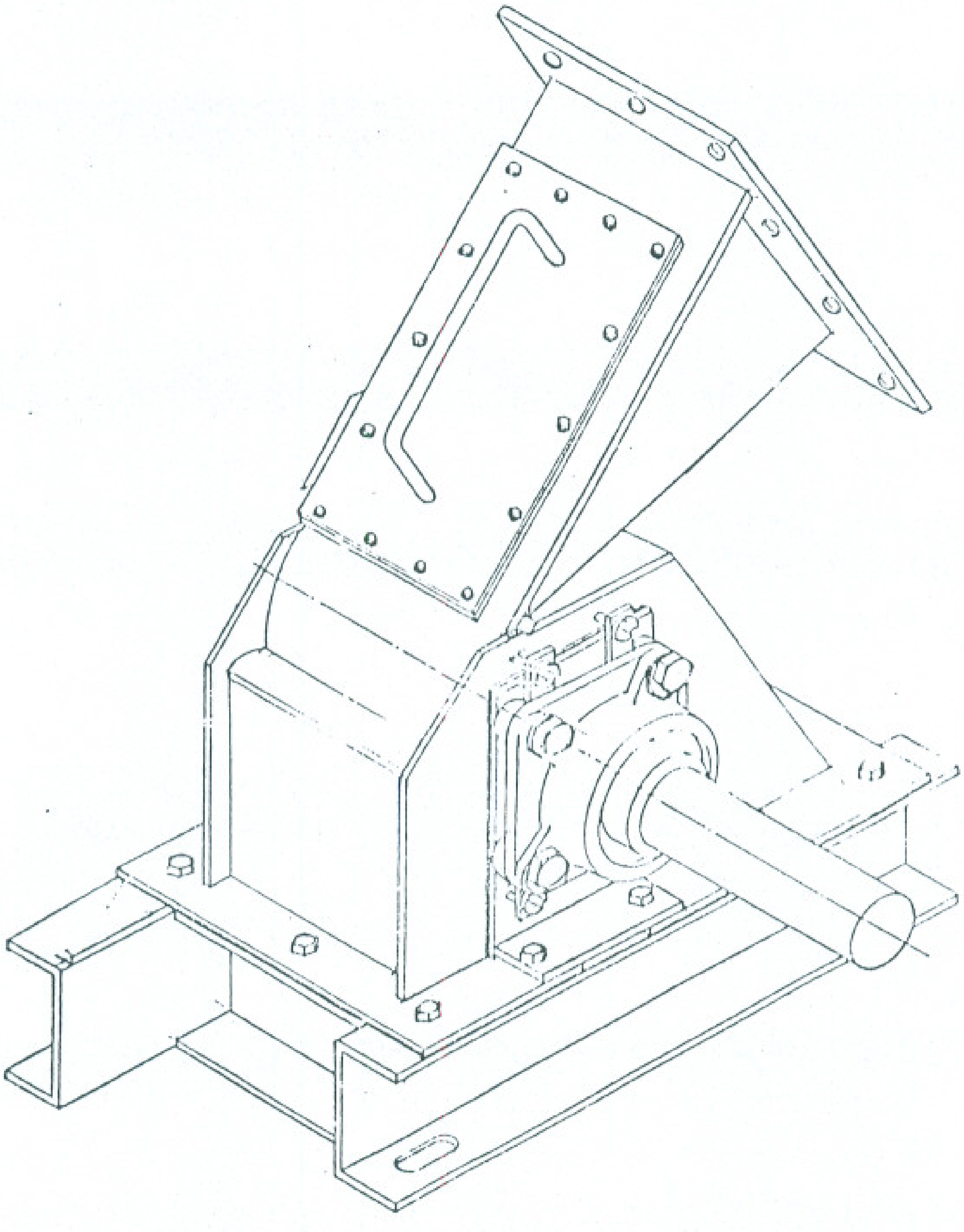

Fig.3.1. Assembled View of Cross-Flow Turbine and Nozzle.

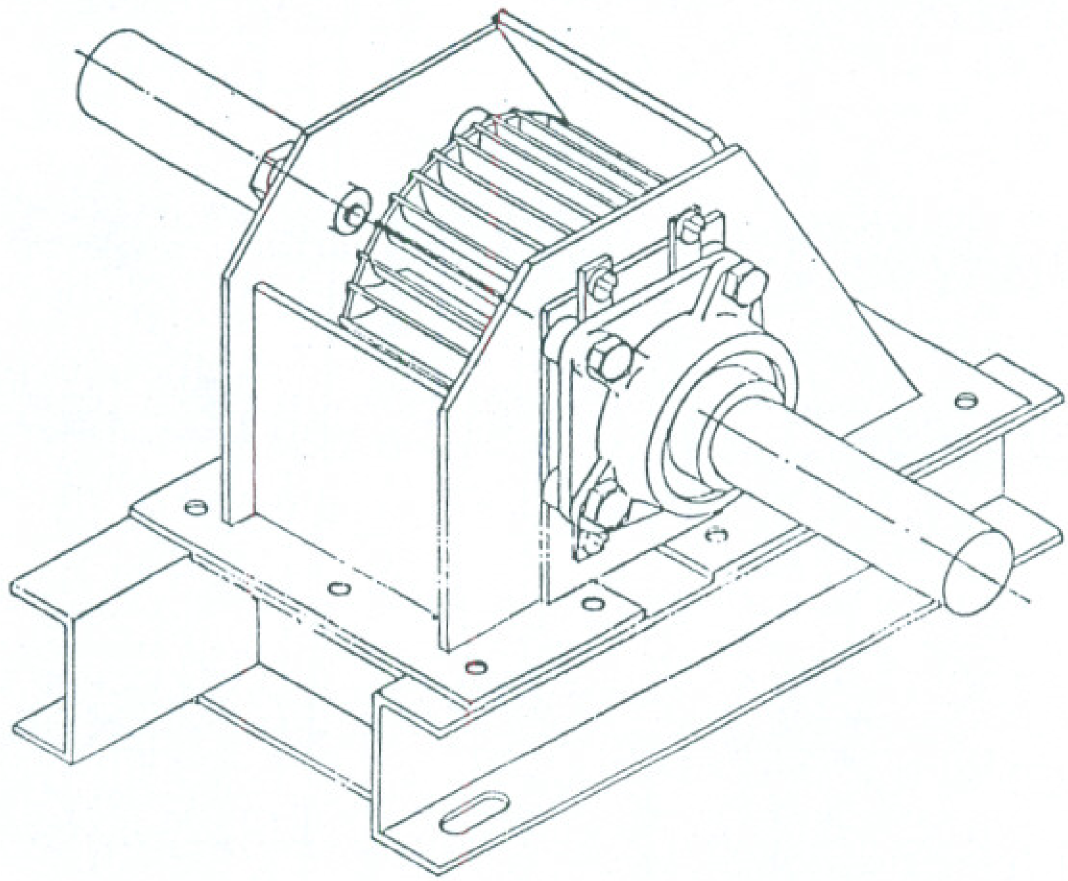

Fig.3.2. Turbine Rotor Assembly.

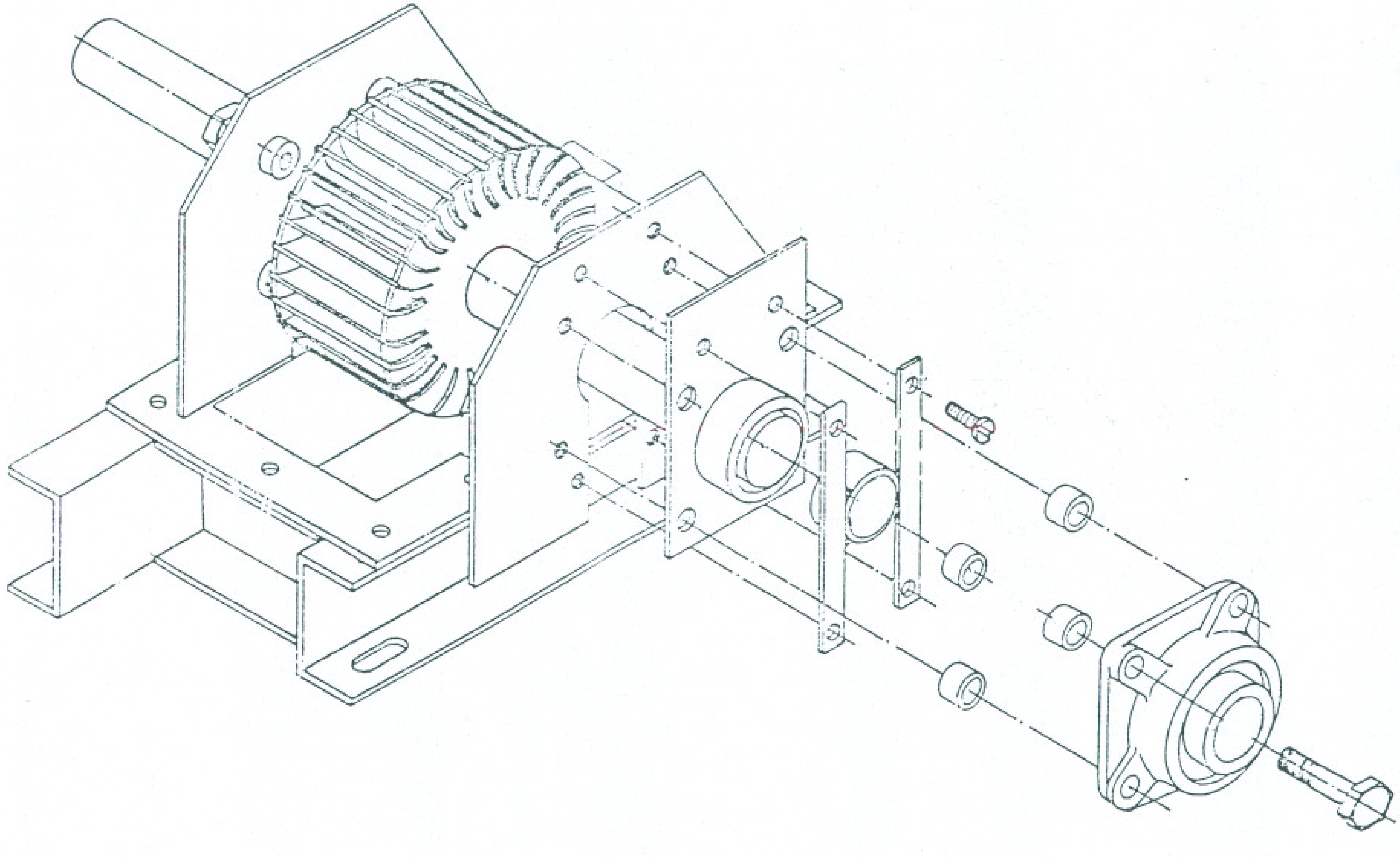

Fig. 3.3 Exploded view of cross-flow turbine

3.2 GATE VALVE

This is a simple standard valve mainly used to stop or start the water flow through penstock, thus acting as the starting or the stopping device for the plant. It is fixed at the end of the penstock, other side being attached to flow nozzle. The flow nozzle is of modified form having rectangular cross - section and converging into a small rectangular opening at the other end, length of which is about 1/4" shorter than the turbine, length on each side and the width is calculated according to turbine blade spacing.

3.3 TURBINE ROTOR

The turbine is cross-flow type originally developed by Banki, and further modified by Michell and Ossberger. This turbine has a very simple design as the blades have curvature on only one cross-section, which is also circular. The manufacture of these blades, therefore, is achieved easily by cutting longitudional portions of pipes of right radius which are then welded into 2 circular plates (Fig. 3.4). The design details are adequately covered by Eisenring (4) and Meier (5).

The casing of the turbine does not have a matching profile. It is rather, a lossely fitted jacket more or less covering the turbine. Flow nozzle described already earlier, is attached to the casing as shown in the Fig. 3.2. More designe details may be obtained from Ham (6).

3.4 TURBINE CASING OUTLET

Outlet of the turbine is a simple rectangular opening, at the bottom, more or less the size of the projected areas of the turbine.

3.5 LOAD CONTROLLER

This is an electronic device which automatically switches on or off a pre-requisite number of heators, in case the load is less than the power being generated, thus causing higher speeds of the rotor. No special devices are incorporated for overloading. The operator has to shut-off some of the load in case of overload, shut-off the plant entirely.

As stated earlier, the main advantage of this sytem and cross- flow turbines are the simplicity of the design which makes its local production possible. Also within the micro range, the efficiency curve off this turbine is pretty good and remains flat at higher discharges (Fig.3.5).

4. DISCUSSION

The Pakistan Council of Appropriate Technology has been engaged in the installation programme of micro-hydel plants since about 19 years it was observed initially, that the villagers and community leaders were reluctant to subscribe to these plants.

Fig.3.1. Assembled View of Cross-Flow Turbine and Nozzle.

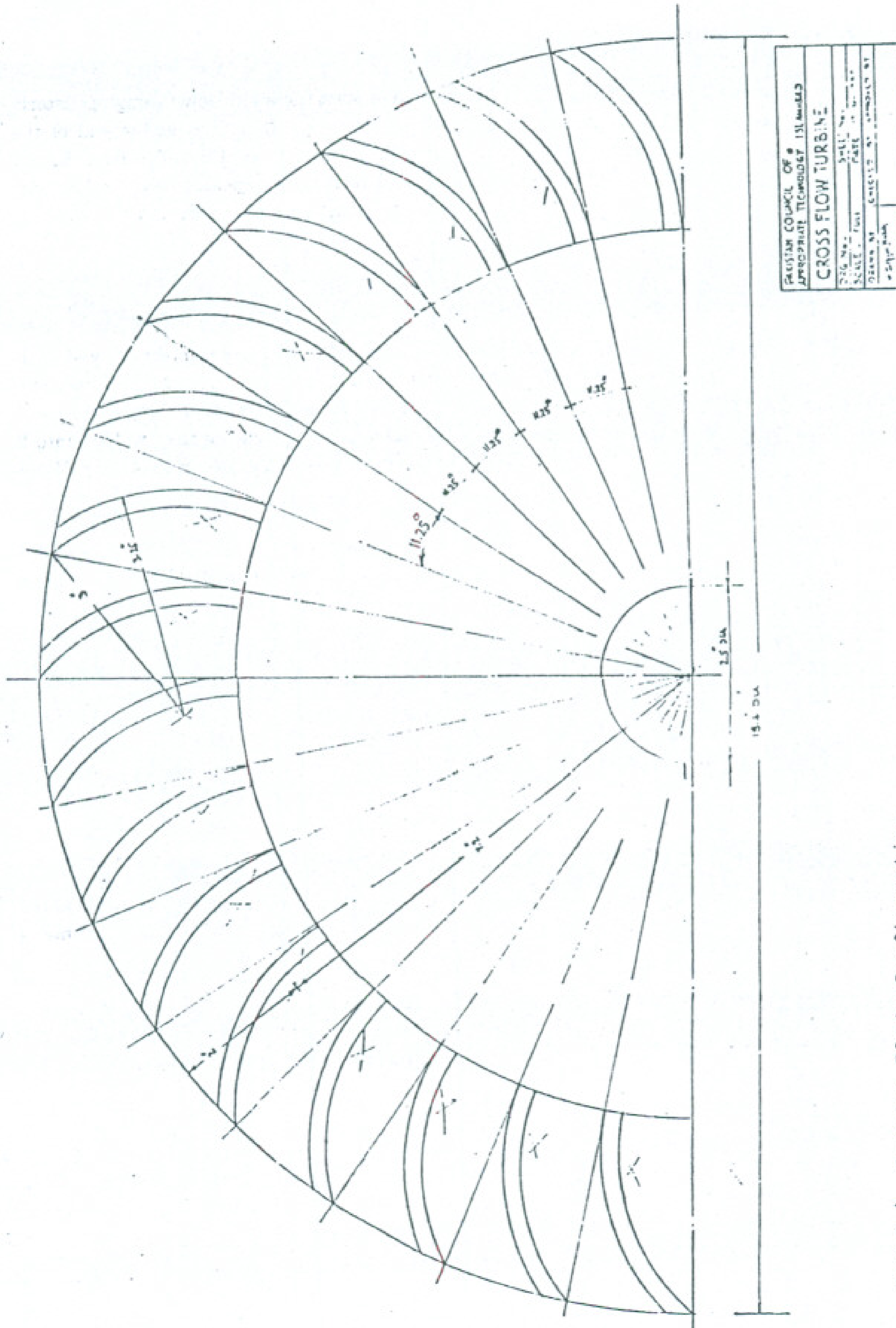

Fig.3.4. Turbine Blade Configuration.

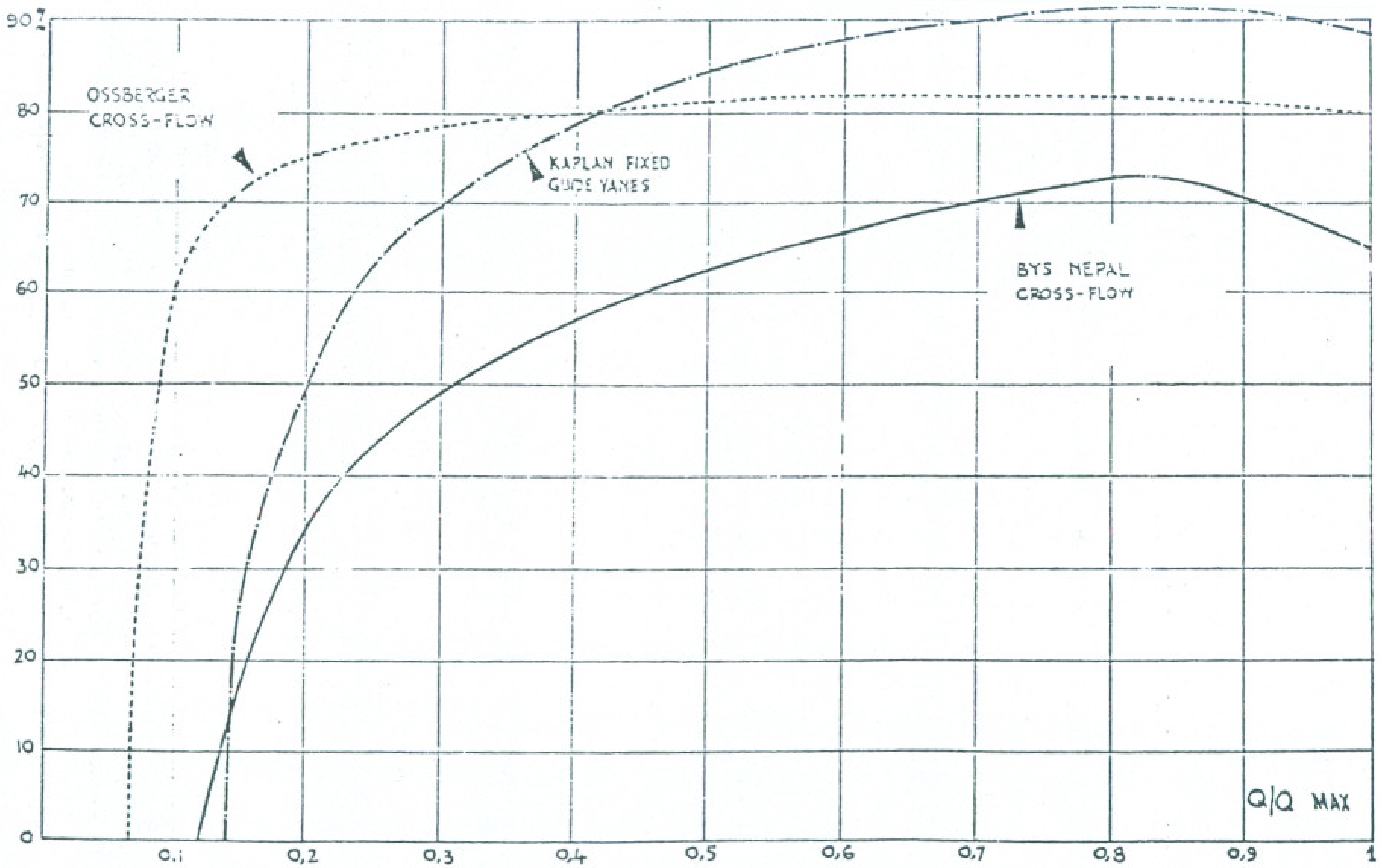

Fig.3.5. Efficiency Curves of Some Turbines.

They rather wanted that PCAT or any other agency may install the plants entirely on their own and operate them. Gradually, however, they realized the benefits of these plants and began to come forward requesting for installation and expressing willingness to contribute for it. The situation, at present, is that there are about 100 requests lying with the PCAT for these power plants where the villagers agree to pay most of the initial costs and operate them entirely on their own after completion. This attitude clearly shows the acceptance of a technology by the rural people and their realization that this was beneficial for them. Thus, they were willing to make some contribution to achieve this facility.

Apart from the supply of electricity for light at night, in some cases, the communities have installed other devices also, such as rice dehuskers, grain mills, etc. These appliances are of direct economical benefits to the communities. Also, in most cases, the idea of self-reliance and cooperation has evolved within the communities because they have to organize collection of money and proper utilization of electricity within their community. People have to act responsibility also. For example if people started using heators on a 5 or 10 KW plant, it is simply going to pack up and they are not going to be able to use it. This sense of responsible cooperation within the community is a very desirable omen and it negates observations of many other agencies that the poor, far-flug communities are usually lethargic and did not care for some new devices which may improve their living conditions. In many cases, it has also been observed that people have become more open towards other scientific appliances which previously they may have considered unnecessary or too expensive, or simply not for them. In quite a few cases, they have accepted with some contribution of their own, such other appliances as solar dehydrators, economical cook stoves, and so on. It is an experience of the PCAT that if such devices are demonstrated and disseminated intelligently, the villagers usually accept them. It may, however, be remembered that if any appliances are given entirely free, people may not realize their full potential, or care to obtain maximum benefit out of them. On the other hand, some contribution and involvement from them makes these appliances more valuable for them and they may take better care in their use and maintenance.

We in PCAT have witnessed an example of a major transformation in a particular community brought about by the installation of 2 micro-hydel stations. In village Bishband, District Swat, no road or even walk-path existed at the time of initial survey done by Dr. Abdullah, for about 4 miles, in that areas and they had to climb the mountaneous slopes to reach the potential site and the village. After the installation of 2 plants of about 5 KW capacity, the people of about 3 or 4 adjacent villages decided, that they did need a small road for their area and undertook the construction entirely on self-help basis. This road was completed some time ago and regularpick-up type transportwas playing to carry the agricultural products to the market as well as people from one place to another. During our last visit there it was found that the road has been widened.

It is expected that further enhancement of this programme as envisaged in the 7th Five Year Plan, and with possible assistance from International agencies, will bring about great socio-economic as well as technological changes in these areas which have been isolated and deprived of any development for such a long time.

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