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Directory
of sources of small hydroelectric turbines and packages

NRECA Small Decentralized Hydropower (SDH) Program

Directory of sources of small hydroelectric turbines and packages

Second edition

Allen R. Inversin

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Small Decentralized Hydropower (SDH) Program
International Programs Division

National Rural Electric Cooperative Association
1800 Massachusetts Avenue N.W.
Washington, D.C. 20036

This publication is one of a series that fosters the effective use of small decentralized hydro-electric power systems. This series is published by the Small Decentralized Hydropower (SDH) Program, International Programs Division, National Rural Electric Cooperative Association (NRECA). NRECA operates the SDH Program under the terms of Cooperative Agreement AID/DSAN-CA-0226 with the Office of Energy, Science and Technology Bureau, U.S. Agency for International Development.

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- providing training services in such topics as operation and maintenance, resource assessment, equipment fabrication, and institution building
- carrying out specialized services such as tours of U.S. manufacturing plants and small hydro sites and seminars on private sector involvement
- creating specialized products such as productive-use plans for energy from small decentralized hydropower.

For more information on the SDH Program, please contact:

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Scope of directory

This directory has been prepared to provide some basic information both on companies which market hydraulic turbines in the 1 kW - 1000 kW power range and on their product lines. An attempt has been made to include all packaged units which satisfy source requirements set by the U.S. Agency for International Development (see AID Handbook 1, Sup. B, Chapter 5). However, if the potential purchaser of a specific packaged unit containing some components made overseas is restricted by these requirements, it is advisable for him to verify that that unit does indeed satisfy these requirements.

Inclusion in this directory does not imply an endorsement of either the companies or their products. Some of those included have, through years of experience, built up a reputation for quality and with up-to-date design, test, and manufacturing facilities, continuing quality is probably assured. With the increasing worldwide interest in small hydropower, these companies and others, many very small, have moved in to fill the resultant demand. Prospective buyers must be alert to claims of, for example, high efficiency, unusual performance, durability, or low cost made by suppliers. Reputable suppliers will furnish lists of their past customers on request.

In addition to those companies included in this directory, a number of other companies are proposing to enter the field. Some are manufacturing standard designs while others are developing new designs (such as the Schneider Lift Translator Engine, the first prototype which was installed and is being tested at an irrigation canal drop in California). Because of the paucity of actual test and field experiences, these companies have not yet been included in this directory though they might well be included in updated editions. It is envisioned that this directory will be continually updated as more information on new companies and products becomes available.

Costs

The term "standardized packaged turbogenerating unit" conjures up the idea of pre-assembled units laid out on a shelf, each with a price tag attached, ready to be shipped out at a moment's notice. However, virtually every hydroelectric scheme is unique — many of the physical characteristics of the site, as well as the demands imposed on the system's operation and performance, are different. In meeting all these constraints through a "standardized package", a supplier can select from a wide range of generally standard components, some off-the-shelf, others designed but awaiting orders before fabrication. Packages with different components can have substantially different costs. For this reason, except in cases of specific turbines or well-defined packaged units, specific cost figures have been omitted in this directory. Though these would undoubtedly be of interest to the reader, any cost figures, beyond those described above, could easily misrepresent the actual equipment cost for a specific site.

In addition to further details on both the equipment available from, and the experience and qualifications of, prospective suppliers, more precise costings of equipment are clearly essential in order to decide among the equipment

available. However, for this purpose, it is best if complete specifications for a particular site(s) are furnished to potential suppliers who will then provide the specific cost figures needed.

However, several general comments can be made regarding trends in costs. One of the major factors which affects the final cost of turbogenerating equipment is the magnitude of the operating (net) head. For a given power output, as the available head increases, the required flow decreases. This then leads to a smaller turbine and a higher operating rpm, both of which contribute to reduced costs. As an example of this trend, one source[1] has computed the cost/kW under a range of heads for packaged units of several hundred kilowatts capacity from several manufacturers. As the operating head increased from 4 m to 15 m, it was found that costs decreased from the $500 - $1300/kW range to the $200 - $700/kW range. In addition to reduced equipment costs, the scale, complexity, and cost of civil works generally also decreases with increasing head. For these reasons, hydro sites with higher heads will have generally lower equipment and civil costs.

The capacity of the actual unit being considered is another factor affecting the final cost. Costs incurred in the manufacture of turbines do not rise in proportion to their capacity. In addition, the cost of the generator and governor for small units is nearly independent of capacity. Therefore, for a given operating head, the cost/kW generally decreases with increasing power outputs. For example, quotes from one small manufacturer of packaged impulse units for a specific site varied from $1500/kW for a 5 kW unit down to $300/kW for a 50 kW unit. For these reasons, if adequate water resources exist, it may be best to purchase sufficient excess generating capacity to cater to future needs. This is especially true if income-generating end-uses are to be included since these would increase the economic viability of such small schemes.

Cost reduction techniques

One principal method of cost reduction is to design the system so that a constant flow of water is consumed by the turbine. If this can be done, cost reductions are gained because:

(1) no adjustable flow-control devices (e.g., guide vanes, wicket gates, propeller runner blades, or needle valves) are required; and,

(2) no speed-control governors and hydraulic actuators for the above devices are then necessary.

A design to reduce costs can be accomplished in several ways. When it is possible to tie into a large existing grid, induction generators may be used. In such cases, governors and ancillary devices are not required anyway for speed or frequency control since the grid itself performs this function. On the other hand, in remote decentralized installations, synchronous generators are generally used. In conjunction with these generators, speed sensitive governors and flow-control devices have conventionally been required. These permit the turbine speed to be regulated by automatically matching the water power available to the turbine to

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1 "Report on Turbogenerating Equipment for Low Head Hydroelectric Developments", Stone & Webster Engineering Corp., April 1978

the varying power drawn from the turbine (due to varying electrical load). Only water which is required to meet the power demand at that time is used. The most efficient use of the water consumed by the generating plant can then be made. However, more recently, a reverse approach, whereby turbine speed is regulated by matching the power drawn from the turbine to the water power available to the turbine, has been adopted. In this case, a constant flow of water passes through the turbine and all flow-control devices are replaced by less costly electrical devices which maintain the power demand from the generator (and turbine) at a constant level to match the constant water power available to the turbine.

With small isolated schemes, where governors and actuators can contribute to a major portion of the overall cost of the equipment, a number of suppliers have adopted this option by using a less costly electronic device commonly called a load controller. This device can be inserted virtually anywhere in the electrical network and insures a constant electrical load on the turbogenerating unit to match the constant water power available. Any excess power available over that actually used by the customers is sensed electronically and dissipated in ballast resistors or the equivalent.

With its larger units, Neyrpic has taken a slightly different approach to maintaining constant load on its turbine. In this case, any unused (excess) power which is available from the turbine is sensed electronically but is dissipated through an eddy current brake which is an integral part of the generator drive shaft. Cooling water is circulated through this braking mechanism to remove any heat generated by the brake.

In applying this cost-reducing option for synchronous electricity generation, it must be kept in mind that the most efficient use of the water power available is not generally being made. A constant flow of water passes through the turbine irrespective of the electrical load. Any shortfall in user load over the water power available to the turbine is dissipated and potentially lost (though with proper design this power might be put to productive use). Therefore, though the total cost of equipment might be significantly less, especially in the smaller installations, the overall scheme might be less economical than an installation using conventional flow-control devices and a governor. Each installation must be considered on its own merits.

In all cases, a reliable device is necessary for both starting and stopping the unit. In general, to prevent runaway of the turbine, hydraulically-operated intake gates or valves are required to assure shutdown in the event of loss of load.

Information required to obtain quotes

In requesting price quotations from suppliers of hydraulic turbines and packaged units, it is important, when available and applicable, that as much of the following information as possible accompany each inquiry:

1. customer's name, address, and telephone number or cable address;

2. an indication of whether only an estimate is desired or whether a full detailed proposal or bid is required; and,

3. if possible, a map and/or sketch showing the layout of the proposed site. Drawings and photographs of existing structures and/or foundations are particularly important and useful.

In addition, for quotes on hydraulic turbines, the following information should be submitted to the supplier:

1. average gross head and/or net head available. For low-head sites, if the head varies noticeably with the flow, also include the minimum and maximum heads.

2. water flow available for the turbine. If virtually the entire stream is to be used, include a flow duration curve based on as many years of data as possible or, if unavailable, provide some indication of flow variation during a typical year.

3. total output power desired or needed. Indicate whether this value represents generator or turbine output. How many units are contemplated to produce this power?

4. type of machine to be driven? Is there a required rpm?

5. elevation of powerhouse site above sea level.

6. if water to the turbine is to be supplied by a penstock, actual or proposed length, internal diameter and material used in its construction.

7. if the powerhouse is already built, the distance from tailwater to the powerhouse floor (minimum, maximum and the average), flume and tailrace dimensions as well as water elevations.

8. accessibility of site by rail, truck, boat, air or on foot? What constraints might this place on the size of the equipment which can be transported to the site?

In addition to the above, for quotes on packaged units for electricity generation, the following would also be useful:

1. required electrical output (ac or dc, voltage, number of phases, frequency);

2. kind of operation envisioned (manual, semi-automatic, automatic, or remote control);

3. whether the plant is to operate separately or in conjunction with an existing power system? If the latter, give approximate installed capacity of the system.

4. whether a control panel and protective equipment including switchgear and metering cubicle are to be included? If so, their design requires a definition of transmission and distribution schemes. Unless specified, suppliers usually provide a standard system to comply with minimum standards.

Application charts

Accompanying the description of most of the manufacturers included in this directory is an application chart. This is included to provide the user with an idea of the range of power and head covered by their equipment. In the case of a few smaller companies, insufficient information is available to prepare such charts.

In these charts, the power refers to the mechanical power output of the turbine. In the power range of interest, the actual electrical power output varies from about 70% (for 1 kW units) to about 95% (for 1000 kW units) of this mechanical power output.

To determine the approximate flow (Q) needed by a turbine in order to produce the desired mechanical power (P) under a given net head (H), any of the following equations can be used:

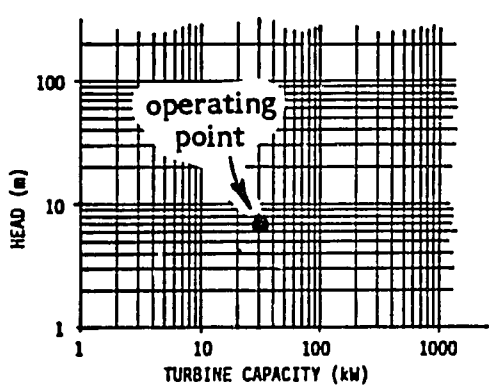
$$Q = \frac{P(kW)}{8\ H(m)} \quad m^3/sec$$

$$= \frac{130\ P(kW)}{H(m)} \quad litres/sec$$

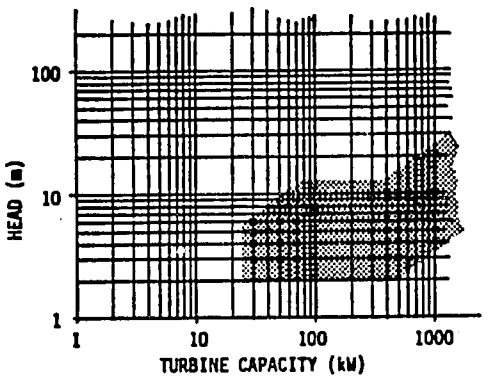
$$= \frac{15\ P(kW)}{H(ft)} \quad cusecs$$

A summary of all the application charts in this directory is included below to serve as a guide for directing the user of this directory to the manufacturers of equipment suitable for a particular site under consideration. By locating the point of operation for the particular site on the application chart, a brief review of these charts will indicate which manufacturers have suitable equipment available.

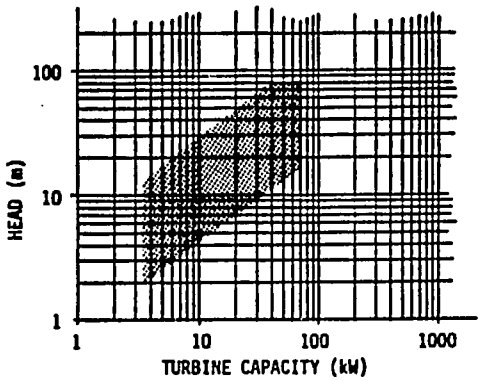
For example, if turbogenerating equipment is required for a site with a head of 7 m and a power output of 30 kW, the operating point would be located as shown at the right. By reviewing the application charts which follow, it is apparent that Allis-Chalmers, Leffel, and Ossberger/Stapenhorst could provide quotes for equipment suitable for that site.



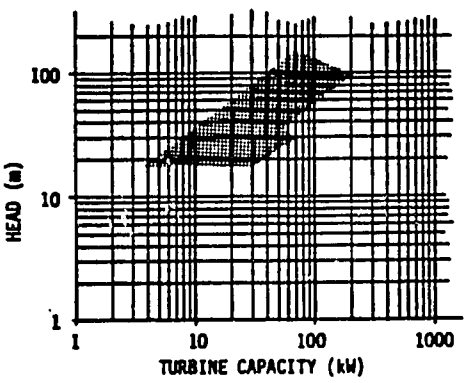
Summary of application charts



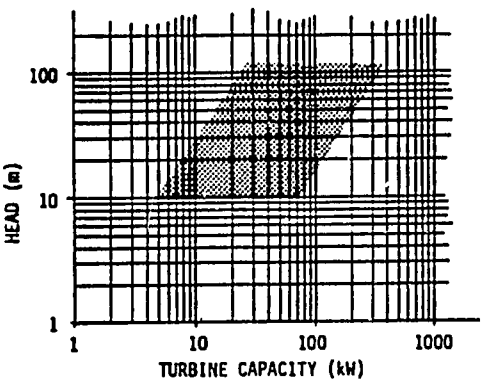
Allis-Chalmers (p. 1)



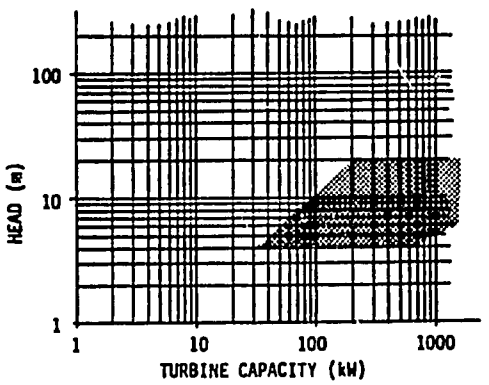
Balaju Yantra Shala (p. 5)



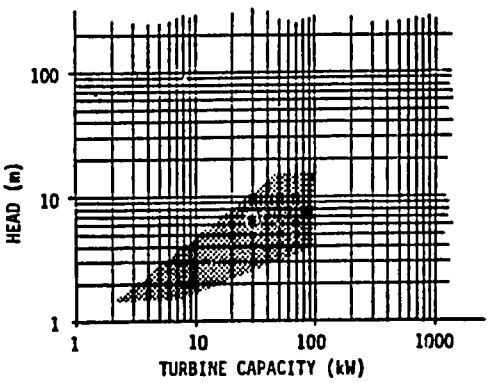
Cornell Pump (p. 12)



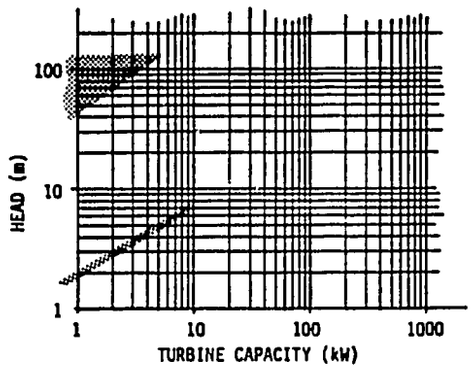
Gilkes/Border Contractors (p. 14)



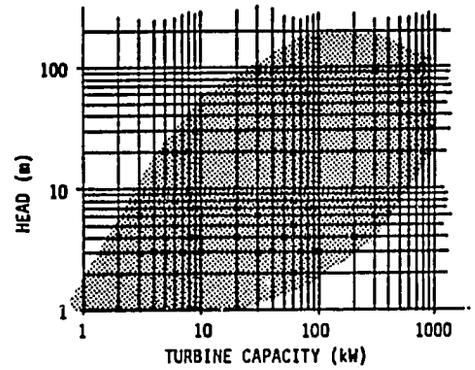
Hydro Energy Systems (p. 17)



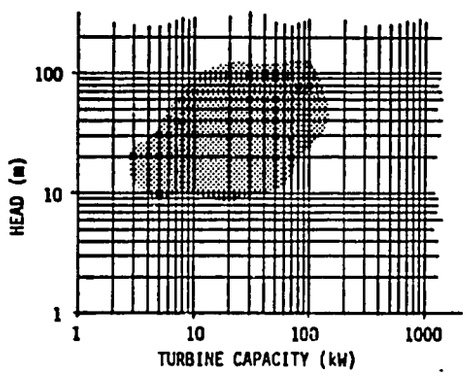
The James Leffel & Co. (p. 23)



Little Spokane Hydroelectric (p. 25)



Ossberger/Stapenhorst (p. 27)



Small Hydroelectric Systems
and Equipment (p. 30)

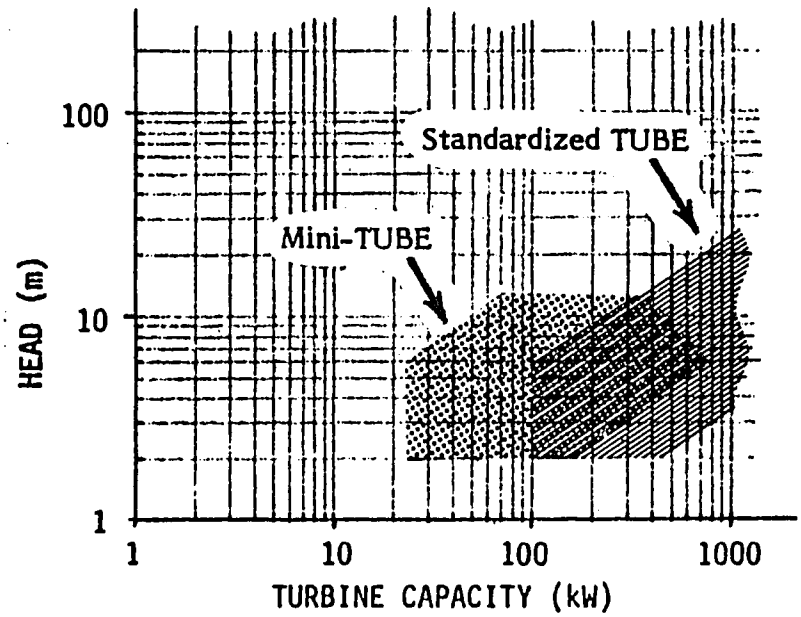
Manufacturers also included in this directory but without application charts are the following:

Butwal Engineering Works (p. 8)
Canyon Industries (p. 11)
Independent Power Developers (p. 21)
C.V. Sukaradja (p. 32)

ALLIS-CHALMERS CORPORATION

Hydro-Turbine Division
P.O. Box 712
York, Pennsylvania 17405

Tel: (717) 792-3511
Telex: 840435



Background

For a century, Allis-Chalmers has designed and manufactured all types of hydraulic turbines — impulse, Francis, propeller, and reversible pump-turbines. This major U.S. manufacturer also designs and fabricates all types of water-control equipment including spillway gates, inlet and control valves, free discharge and bypass valves, and centrifugal as well as axial-flow pumps. At its York plant, it has extensive design, model testing, and manufacturing facilities.

For several decades, Allis-Chalmers has been developing and manufacturing TUBE turbines and axial-flow (propeller) turbines with the generator located outside the water passage and connected to the turbine by a direct drive shaft or through a geared speed increaser. To more economically tap the low-head water resources in the 100 kW - 6000 kW power range, it has recently made available standardized TUBE turbine packages including horizontal and vertical shaft arrangements.

To more economically address the lower power range, Allis-Chalmers has fallen back on its pump and pump/turbine experience with axial-flow and centrifugal pumps. It is presently incorporating modifications in existing designs of standard commercial pumps. Low-head axial-flow turbines with an inclined shaft have been built and are operating successfully. These mini-TUBE turbine units are the first-phase approach to smaller low-head applications. For higher heads, centrifugal pumps may be recommended where there is a constant flow or where two units of unequal size can adequately meet variable flow conditions. The technology is available to modify standard commercial units to provide good efficiency. Model test data, based both on conventional pumps operated in the turbine mode as well as on reversible pump-turbines, provides a basis for modification recommendations.

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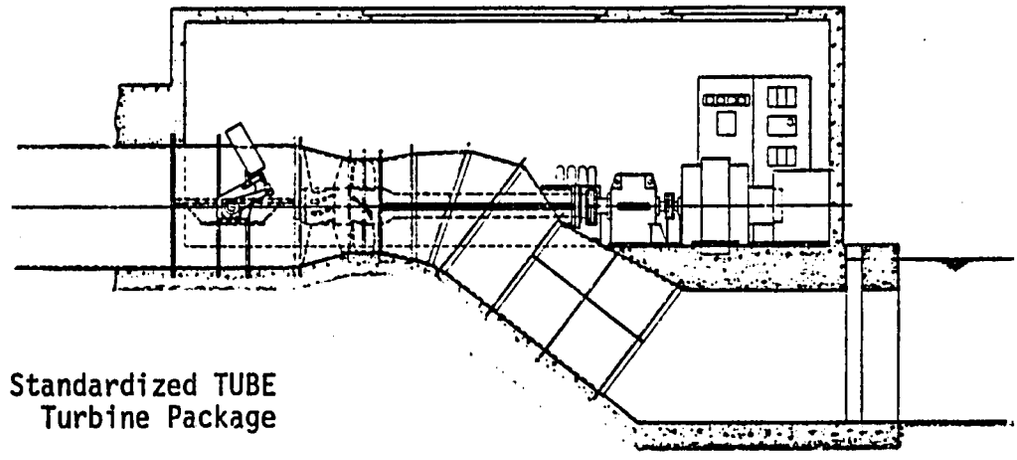
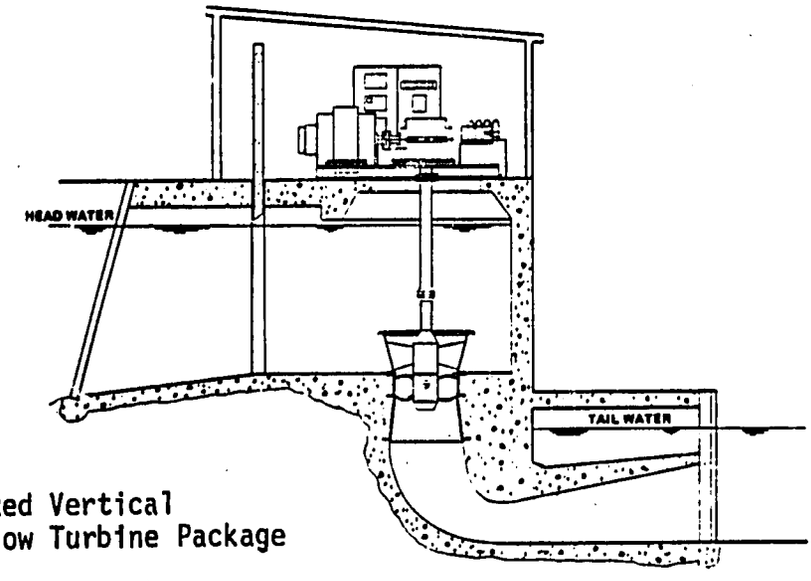
Equipment

1. **Standardized horizontal-shaft TUBE turbine** packages, as well as **standardized vertical-shaft axial-flow turbine** units are available in ten sizes from 100 kW - 6,000 kW. They are adaptable for upgrading existing low-head plants for making previously uneconomical sites attractive, or for new power



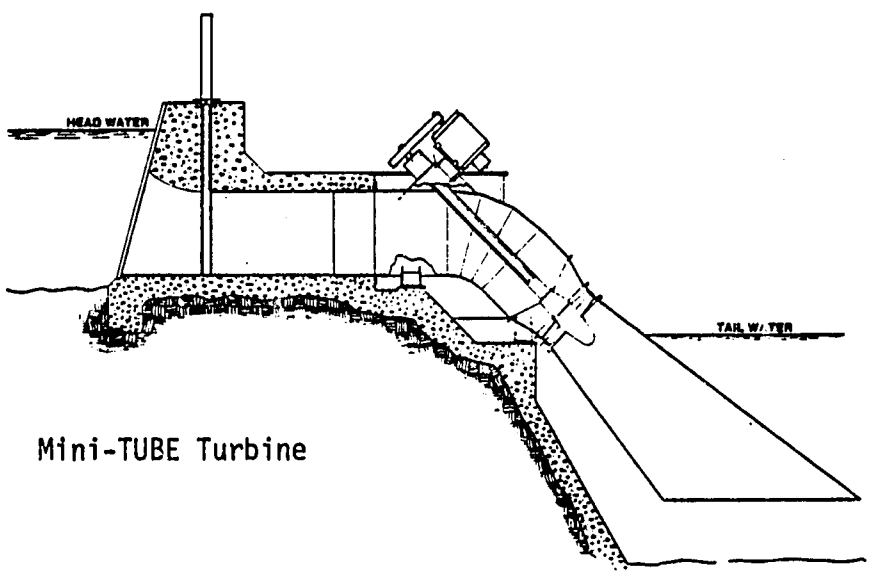
Standardized TUBE
Turbine Package

installations. These packages include the turbine water passageways (including draft tube) with intake gate or butterfly valves, fixed guide vanes, and fixed- or adjustable-blade turbine runner (with hydraulic controller for blade pitch control for the latter), geared speed increaser, generator, electrical controls and low voltage switchgear. They are available as complete packages. For installations overseas where local suppliers might furnish certain components, Allis-Chalmers can work with these suppliers to insure a properly integrated design. The lead time for units is approximately 9 - 12 months. The package can be extended to include the main power transformer, high voltage switch, and substation if desired.



Standardized Vertical
Axial Flow Turbine Package

2. The **mini-TUBE turbines,** with a power output in the range of 25 kW - 1,000 kW, are designed to be included in an economical and convenient package. Available in 12 runner diameters from 12 - 72 inches, the turbine package includes turbine water passageways and draft tube with fixed-blade propeller runner and guide vanes, generator with either belt or geared speed increaser and electrical control and switchgear. A butterfly valve with hydraulic operator is provided for units operating in the higher head range and where a penstock is required. With a short intake, a hydraulically operated gate will be more economical and is particularly applicable to the larger units at lower heads. This gate or valve controls turbine speed as the unit starts up and until it reaches the normal operating speed. A hydraulic power system is used to provide stored energy for tight shutoff and emergency closure. By designing a unit which can be bolted down and need not be set in concrete and by mounting the belt driven generator on the housing, foundation and building costs are significantly reduced. Aside from protecting the generating and control equipment from the weather, a building is virtually unnecessary. If a geared speed increaser is used, this as well as the generator would then have to be mounted on the concrete foundation.



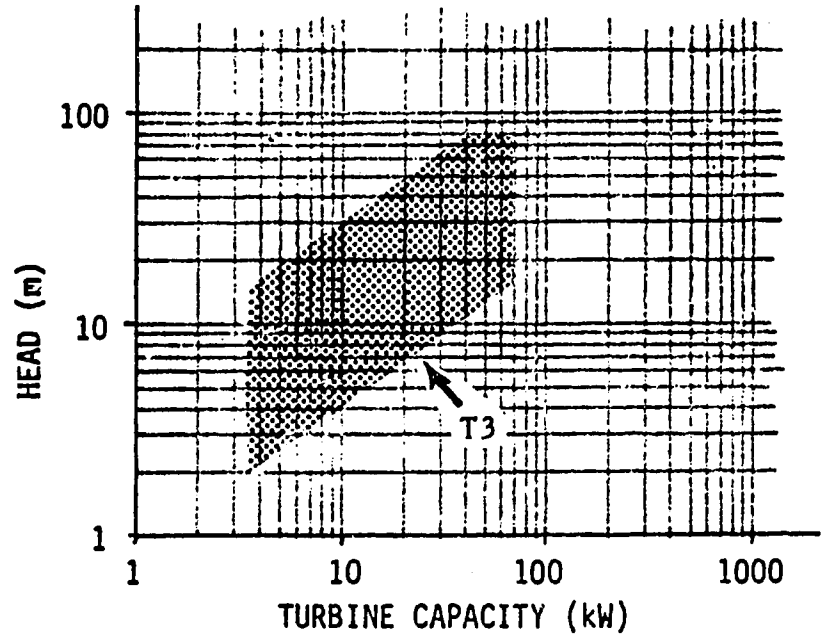
Mini-TUBE Turbine

3. A great variety of standard **centrifugal pumps** are also available for use as power generating units. These include both wet-pit and dry-pit designs as well as single-and multi-stage units and single as well as double-suction pump arrangements. Such units are available in an output range beginning at approximately 25 kW and have no specific size limitations at present. The technology for this use of pumps comes largely from the large number of reversible pump-turbines which have been designed and tested in the past. In addition, a number of units are in operation without modification and have been tested without modifications so that a basic reference has been established. Such equipment is presently being quoted on a selected basis.

BALAJU YANTRA SHALA (PVT.) LTD.

Post Box 209
Kathmandu, Nepal

Tel: 14809, 13379, 13296
Cable: BYS



Background

Balaju Yantra Shala (Pvt.) Ltd. is an organization initiated jointly by the Swiss Association for Technical Assistance (SATA) in Nepal and the Nepal Industrial Development Corporation (NIDC). It has a well-equipped mechanical workshop with modern machine tools obtained primarily from Switzerland. It has a staff of seven mechanical engineers and a well-qualified staff of about 200 machine tool operators. It also has a Mechanical Design and Drawing Section. Since its inception in 1960, it has been producing suspension bridge parts, big oil storage tanks, overhead water tanks and trestles, concrete mixers, mechanical equipment, spinning and weaving machines, steel structures for factories and buildings, and cross-flow turbines.

In 1973, a fabricated prototype of a cross-flow turbine was developed for BYS and since then, 33 such units have been installed in Nepal. These are primarily used for agro-processing though some are used for electricity generation and lift irrigation. A later version was developed and tested in Switzerland and brought

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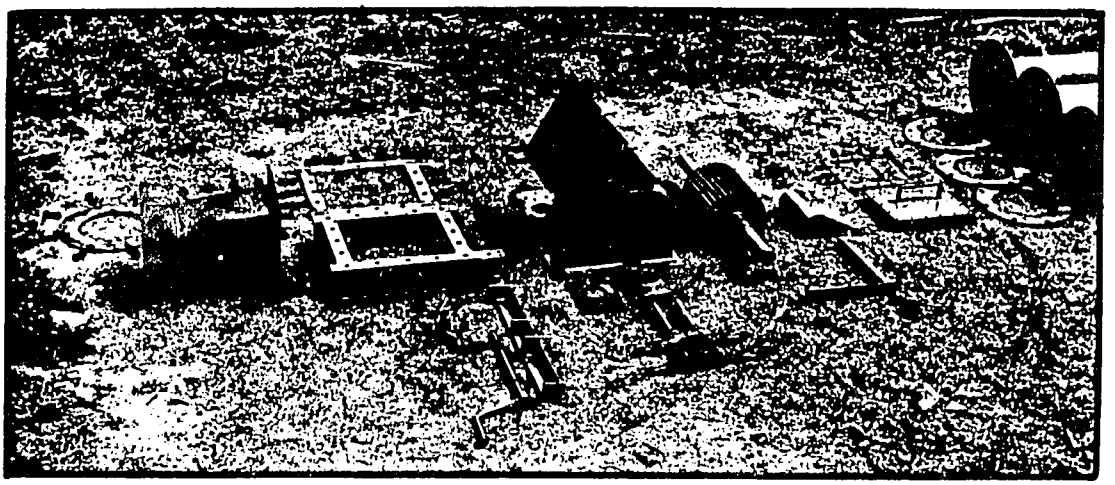
into production at the end of 1980. In the following nine months, 12 such units were sold and installed, including three for electrification schemes.

Equipment

Turbine T3 is a **cross-flow turbine** of fully welded construction. In addition to the turbine and housing, it includes (1) a guide vane which can be used to regulate the flow into the turbine either manually or hydraulically, (2) an adapter between the penstock and the rectangular turbine inlet, and (3) a draft tube, if required.

To facilitate transporting this unit on foot into remote areas, units are fabricated to permit carrying individual parts to the site where they can then be assembled. Assembling the unit with bolts also permits ease in repair or replacement of individual parts if necessary.



To cover a wide range of heads and flows, the cross-flow turbine T3 is available in 11 standardized widths. Because it has a smaller diameter than the original design, higher speeds are possible. These range from about 300 - 1700 rpm depending on the head at the site. Less gearing up is therefore required if electricity is to be generated. Efficiency of the unit averages about 70%.

Ex-factory prices for turbine T3 range from $650/kW at a very low head (2 m), to $200/kW at medium heads (20 m), and down to $110/kW at high heads (80 m).

For the generation of electricity, hand regulation of the turbine is possible. In addition, through research done in Switzerland, BYS has available a mechanical, water-hydraulic proportional-type governor with speed regulation of ± 5-10%, adequate for most situations. Water, under the head available at the installation, is the working fluid and there is, therefore, no need for a pump. Research was also initiated in Switzerland on a electronic load controller and work to simplify the design and use locally available Indian components is being done by Butwal Engineering Works (Pvt.) Ltd. (Nepal).

BUTWAL ENGINEERING WORKS (PVT.) LTD.

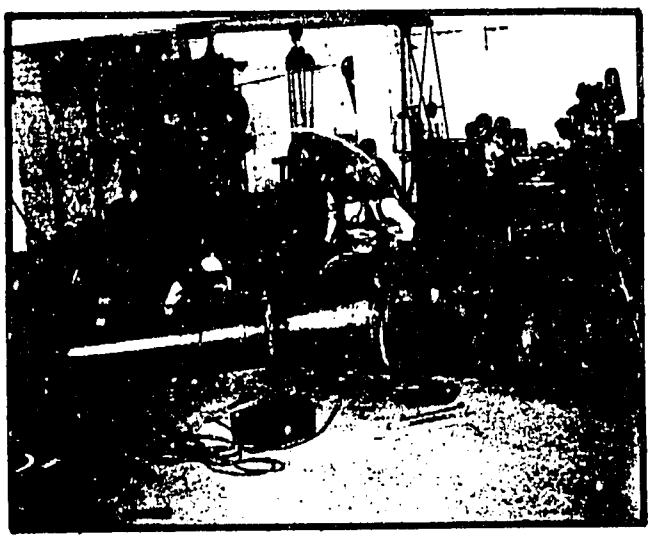
Post Box 1
Butwal, Lumbini Zone
Nepal

Cable: BEW

Background

In 1963, the United Mission to Nepal (UMN), in cooperation with the Department of Cottage Industries, started the Butwal Technical Institute. The mechanical workshop of BTI became in 1977 a private limited company, Butwal Engineering Works (BEW), controlled by BTI. It has one of the best equipped mechanical workshops in the country, with mechanical tools to handle a wide range of tasks.

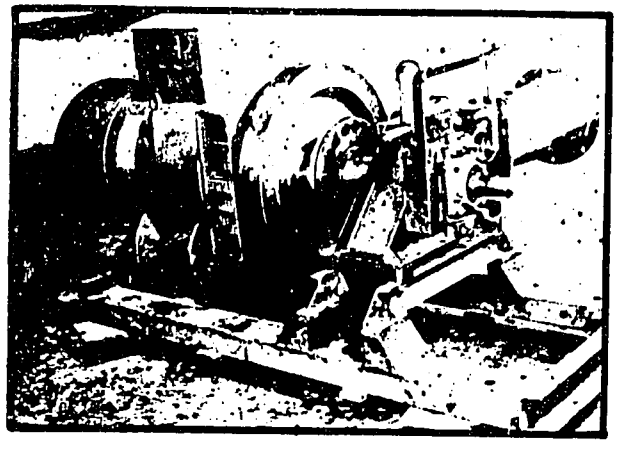
BEW has a staff of four engineers, seven supervisors, and about 25 machine tool operators. In addition to its workshop, it has a mechanical design section and a well-equipped site for testing its turbines and other hydraulic equipment. It fabricates a variety of products, including suspension bridges, trans-mission towers, irrigation gates, water and fuel tanks, penstock pipes, and cross-flow turbines. BEW originally fabricated a high-head Pelton unit. Shortly thereafter, when it became apparent that, in Nepal, lower head sites were found more frequently and integrated better with the existing irrigation networks which were often found near hydropower installations, BEW switched over to a cross-flow turbine design more suitable for lower heads.



In cooperation with BEW, Development and Consulting Services (DCS), another UMN enterprise, handles the installation of BEW turbines in the field. In the last four years, it has installed 58 of their turbines. It also participates in research on other equipment which can be utilized in conjunction with micro-hydro installations. These include (1) a mechanically-driven air heater for drying of agricultural produce (with 10 kW and 25 kW units already having been built by BEW), (2) rice processing equipment, and (3) storage cookers which more efficiently use of the capacity of small hydroelectric plants for cooking. With the assistance from the Swiss Association for Technical Assistance (SATA) and the Centre for Electronics Design Technology (CEDT) of Bangalore, India, efforts are underway to simplify an electronic load controller, originally designed in Switzerland, to permit local assembly using Indian components.

Equipment

Fully welded **cross-flow turbines** of two diameters are available. Type 405 has a 400 mm diameter runner and a nozzle 50 mm across. A more recent design, Type 205, has half that diameter which is more appropriate since it results in lower overall size and turbine cost and increased shaft speed. These turbines come in ten standardized widths to cater to the power required or flow available at a specific site. Ex-factory prices for turbines range from $120/kW to $200/kW depending on head.



BEW has developed a hydraulic governor suitable for small turbines and several are being tested in the field. In addition, an electronic load controller is under development. These units may be commercially available shortly.

CANYON INDUSTRIES

5346 Mosquito Lake Road
Deming, Washington 98244

Tel: (206) 592-5552

Background

Canyon Industries represents a small group which recently entered the field primarily with very small units. It has recently made several units in the range up to 20 kW and also rehabilitates used hydroelectric machinery.

Equipment

Canyon Industries manufactures both cross-flow and Pelton runners. The latter can be integrally cast to any of eight sizes or custom designed with individual buckets.

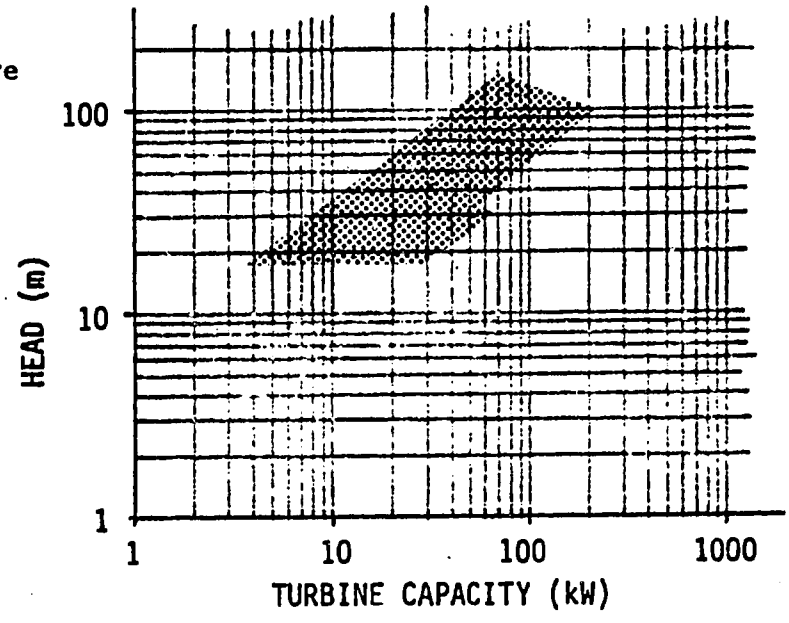
Either individual turbine units or complete systems, which include the turbine, generator, and electronic controller, are available. Typical costs for its systems are:

Capacity	Cost/kW
15 kW to 50 kW	About $600/kW
5 kW to 15 kW	About $800/kW
Under 5 kW	$1000 - $1500/kW

CORNELL PUMP CO.

2323 S.E. Harvester Drive
Portland, Oregon 97222

Tel: (503) 653-0330
Cable: CORNELL PLT



Background

Cornell Pump Company has been manufacturing pumps and related products since 1946. Its current line of pumps, in the range of 1 - 200 horsepower, is used for a variety of purposes including irrigation, food product handling, commercial refrigerant circulation, domestic and industrial sewage handling, and industrial water and waste handling.

Based on its experience with irrigation projects, Cornell observed that diesel generation units were supplying power for irrigation equipment at an ever-increasing operating cost. Yet, at a number of sites, available irrigation water had surplus head and energy which had to be dissipated across an orifice or valve. To harness this energy, Cornell decided to modify its standard pumps as reversible pump-turbines to drive small generating units.

In October, 1981, Cornell put its first unit into operation in Oregon where it harnesses the energy available as irrigation water drops 150 meters from an upper to a lower canal. During the months when surplus water is available, it generates up to about 170 kW into the local grid.

Equipment

Cornell **reversible pump-turbines** are modifications of its end-suction, single-stage centrifugal pumps. Standard units are constructed of cast iron and bronze though special units are made of a variety of materials.

Cornell can provide a complete turbogenerating package with controls. For isolated systems in the lower power range (5 kW - 20 kW), it would generally supply a synchronous generator with its own load controller. For larger systems,

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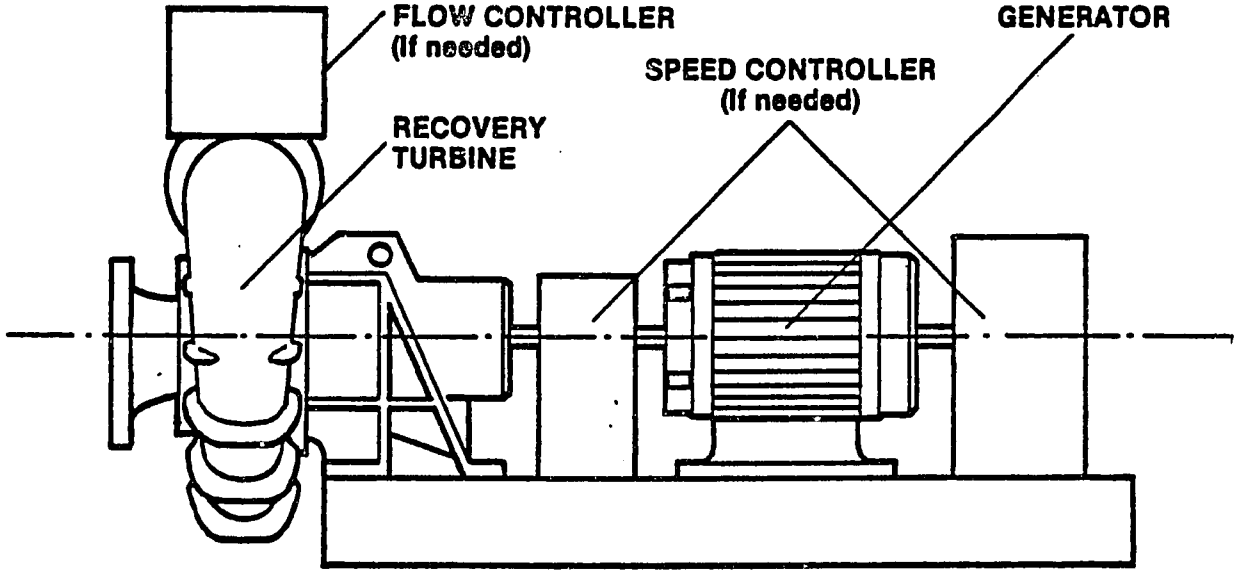
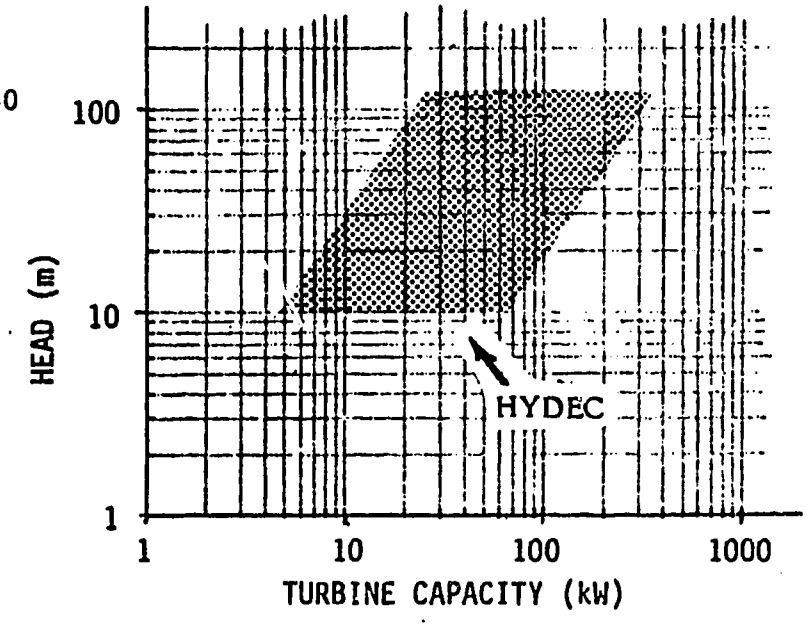
it would proposes induction generation, with appropriate controls, into the local grid. Prices for these packaged units range from $1,000 - $1,200/kW in the 10 kW - 15 kW power range to under $500/kW for units over 100 kW.



GILKES/BORDER CONTRACTORS, INC.

4600 Shipyard Road
Blaine, Washington 98230

Tel: (206) 332-5545



Background

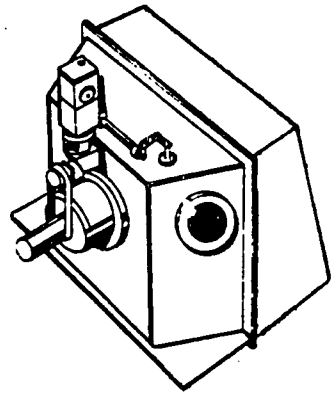
Gilbert Gilkes & Gordon is an English firm which has manufactured water turbines and pumps for over a century. Manufacturing Francis as well as Pelton and Turgo impulse runners, its equipment covers a wide range, from fractional kilowatt units to the 10 MW range. A large number of its turbines have been installed overseas.

Border Contractors Inc. is the sole representative of Gilkes in the United States. At present, the turbine runner, cast housings if necessary, and some specialized components are imported from England. Fabricated housings, generators, governing equipment, and other components are either fabricated by Border Contractors according to Gilkes engineering drawings or else purchased locally.

Equipment

1. The **Hydec** is Gilkes' answer to demand for a small standard turbine for use under medium and high heads. It incorporates a single or twin jet Turgo runner with a stainless steel deflector for each jet. Usually the twin jet

HYDEC Turbine
with Governor



models are equipped with only one needle valve which permits control over the quantity of water used by the unit. Turbine speed is regulated by means of a Woodward governor which controls the deflector(s) and thereby controls the portion of water actually available to the runner. The Hydec is available in four sizes with outputs ranging from 5 kW under a 10 m head to 300 kW under a 90 m head.

A packaged unit includes the Hydec with governor, generator, belt gearing (if necessary), butterfly valve, and inlet pipework between the butterfly valve and nozzle(s).

The cost of such a packaged unit, with Woodward governor but without generator, ranges from $270/kW for a high head (80 m) and power (300 kW) up to $5,400/kW for a low head (10 m) and power (6 kW). As is often the case, cost can be reduced by appropriate design. At the high end of the cost/kW range, for example, the governor, which could under certain conditions be omitted, accounts for about 20% of the cost. A further reduction in cost might, for example, be affected by eliminating the relatively costly needle valve.

The Turgo runner, manufactured only by Gilkes, has all the advantages of a Pelton runner but in addition, for a given head and power requirement, it can have a smaller diameter and, therefore, can attain a higher speed than a Pelton runner. This can reduce or eliminate the need for gearing between the generator and turbine.

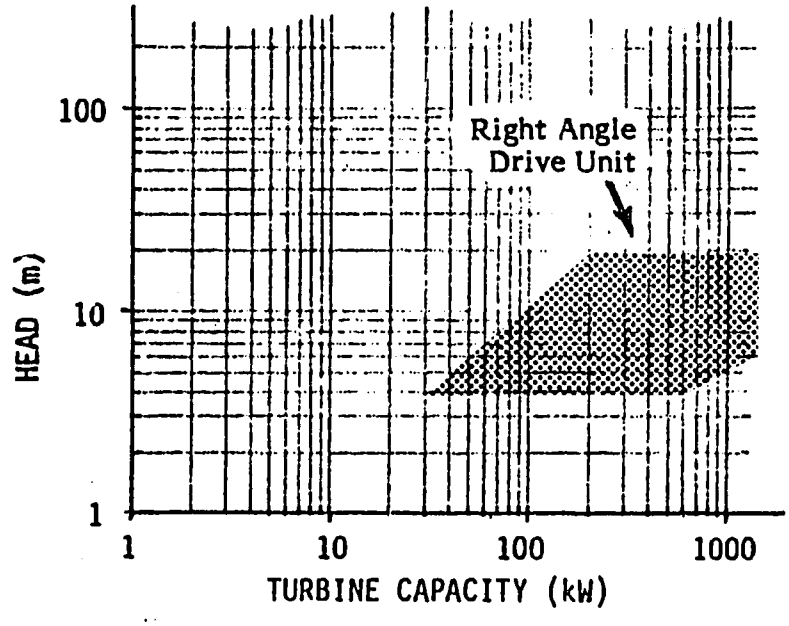
2. Though Gilkes makes spiral cased, horizontal **Francis turbines** specifically for small outputs (up to 100 kW) under heads ranging from 8 - 60 meters, the unit is cast in England and the final package probably would not qualify as American-made. However one standard, low-head Francis package is being developed which would qualify. With fixed vanes, it can operate under a head in the range 2 - 12 m with an output power up to about 50 kW (at maximum head). Further details should be available shortly.

   A recent quote for a 15 kW unit operating on a 38' head at 1200 rpm, complete with synchronous generator, voltage regulator, and electric load controller was $18,000.

HYDRO ENERGY SYSTEMS, INC.

Two World Trade Center
New York, NY 10048

Tel: (212) 466-1404
Telex: 645430



Background

Hydro Energy Systems, Inc. is a new corporate organization involved in the application, sales, manufacture, and service of low-head hydraulic turbines. It is the exclusive U.S. licensee of Neyrpic's standardized low-head product line. It is presently finalizing arrangements for local manufacturing facilities and has set late 1981 as the target date to initiate manufacture of the Right Angle Drive and tubular units. Local manufacture of its bulb units will follow.

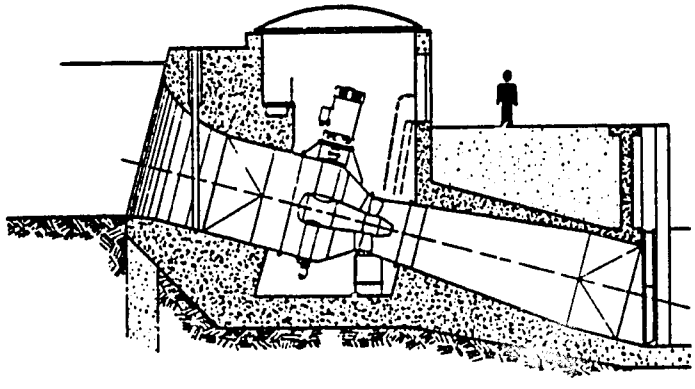
Equipment

Hydro Energy Systems offers three types of pre-engineered low-head units, each designed for specific site conditions. Local manufacture will begin with the Right Angle Drive and tubular units.

1. The **Right Angle Drive unit** covers the 100 kW - 1500 kW range with seven runner diameters. It is designed to operate under heads of from 3 - 20 m. The major advantage of this unit is its very compact design which minimizes the size and cost of civil works. The generator is mounted on the turbine housing and no generator foundation is therefore necessary. The factory assembled package means faster and less costly field installations and is suited to isolated locations due to simplified construction. Current delivery of the entire package, including generators and controls, is 12 months.

   The design includes fixed-pitch runner blades and guide vanes with an integrated right angle drive and speed increaser. Although use of such fixed-pitch units have conventionally been restricted to induction generation into a main grid, Neyrpic has engineered a device which permits the use of this Right Angle Drive unit in remote areas, away from the grid, to generate synchronously up to 1000 kW. If less electrical power is consumed than the design power available from the generator, the excess power is sensed electronically and dissipated by means of an eddy current brake on the

Right Angle
Drive Unit



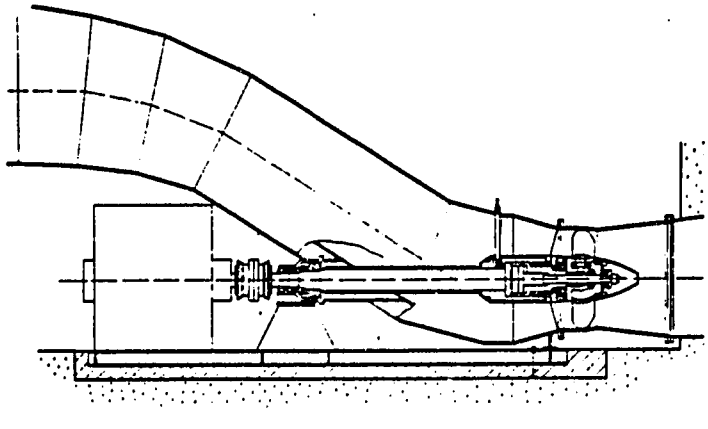
generator shaft. Excess heat generated in the process is dissipated by circulating cooling water. In this manner, the potential power available from the water is always matched to the total power consumed (by both the end-use consumer and the brake) and the runner speed is maintained constant.

All auxiliary items such as lube oil pumps are directly driven by the main shaft. The entire package can therefore be designed for isolated locations and minimum maintenance.

The general cost of the complete package, including generator, controls and eddy current brake, will range from $1500/kW for the 100 kW size to $500/kW for the 1000 kW size. But actual equipment cost is also strongly affected by the available head. For example, the cost of a standard 500 kW package without an eddy current brake ranges from $1000/kW under the minimum of 3 m down to $300/kW under the maximum head of 20 m.

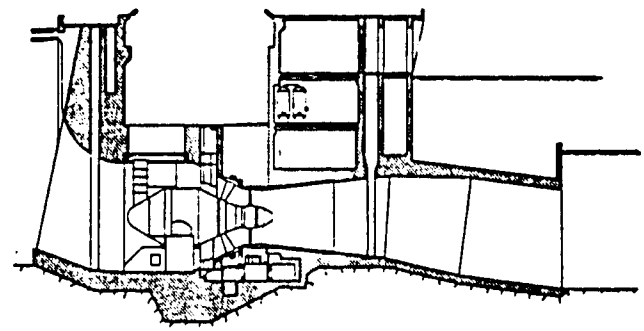
2. The standard **tubular unit** will be available in four standardized horizontal arrangements for heads of 3 - 20 m and outputs of 500 kW - 5000 kW and features an upstream elbow design for better efficiency and cavitation characteristics. Application of tubular turbines is most commonly found for "run of the river" sites, in combination with penstock arrangement.

Tubular Unit



3. The standard **bulb unit** is designed for the 500 kW - 5000 kW output range with heads of 3 - 20 m. The standard bulb will be available in seven different runner diameters. While bulb turbines are generally more expensive than other hydraulic turbines, their compact design and straight-through configuration provide numerous advantages particularly in civil works areas, such as less excavation, lower superstructures, and reduced plant width. In many applications, the resulting savings more than offset the higher cost of the turbine. In addition, the compact design characteristics of bulb units with their rational layout of flow passages can provide better performance under selected site conditions.

Bulb Unit



INDEPENDENT POWER DEVELOPERS, INC.

Route 3, Box 174H
Sandpoint, Idaho 83864

Tel: (208) 263-2166

Background

IPD, a relatively recent entry in the field of micro-hydro units, was initially involved primarily with the generation of dc, storage in battery banks, and inversion to ac where required. While this line of equipment is still available, IPD has in the last several years become more involved in ac generation. Aside from the generator, all the necessary equipment is fabricated by IPD.

Equipment

IPD uses propeller, cross-flow, and Pelton runners under heads ranging from 3 - 400 m at fixed flows to cover the lower portion of the power range. The units are generally directly coupled to the alternator, but with the cross-flow runner, a geared speed increaser is often necessary.

IPD is solely involved in the sale of complete packaged units including turbine, generator, and load controller. Package costs are in the following ranges:

Turbine type	Operating head	Cost/kW
propeller	3 m to 30 m	$1800 - $2500
cross-flow	30 m to 70 m	$1300 - $2000
Pelton	70 m to 400 m	$ 800 - $1500

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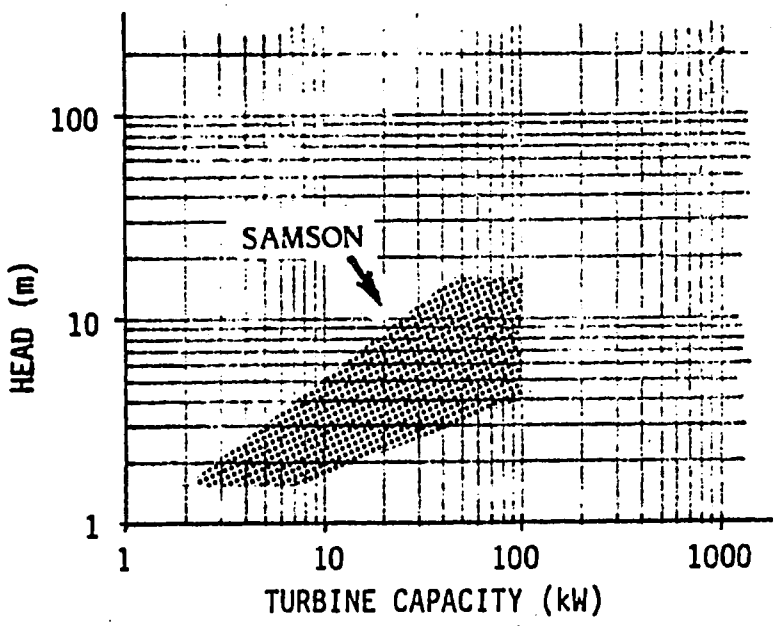
THE JAMES LEFFEL & CO.

426 East Street
Springfield, Ohio 45501

Tel: (513) 323-6431
Telex: 205419



Background

Leffel manufactures Francis, propeller, and Pelton turbines covering a wide range of power outputs as well as additional components for hydroelectric schemes, including penstocks, trashracks, and head gates. Leffel installs new units, repairs and overhauls old turbines, and rehabilitates existing sites.

In addition to generating electrical power, a number of Leffel turbines have been installed to provide direct motive power to pumps, factory equipment, and paper, textile, flour, and feed mills. In all, over 10,000 Leffel turbines have been installed in the U.S. since 1862 and several hundred more have been installed overseas.

In October of 1979, The James Leffel & Co. affiliated with Tampella, a Finnish manufacturer of large-scale waterpower equipment for over 100 years. As a consequence, the turbogenerating equipment manufactured by Tampella in Tampere, Finland, complements Leffel turbines to cover virtually the entire power range.

Equipment

1. Given appropriate site and flow conditions, Leffel's **Samson (Francis) turbines**, with nine standard runner sizes, cover the "micro" range of hydro turbines (up to 100 kW). These are installed in a vertical configuration, either directly in an open flume or in a steel pressure flume, with either manual control or automatic governing.

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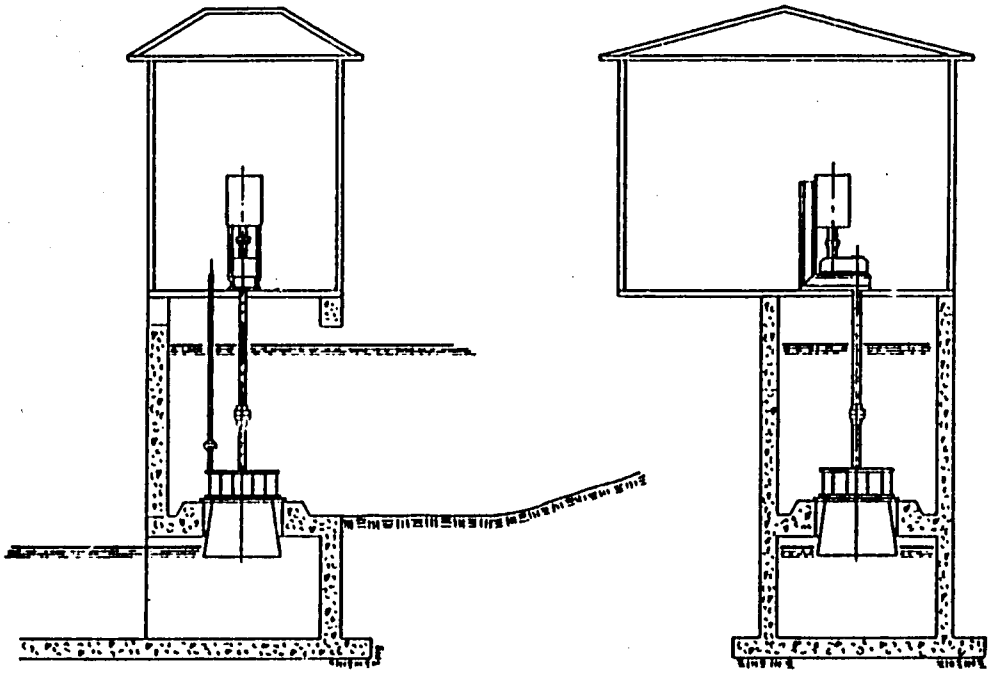


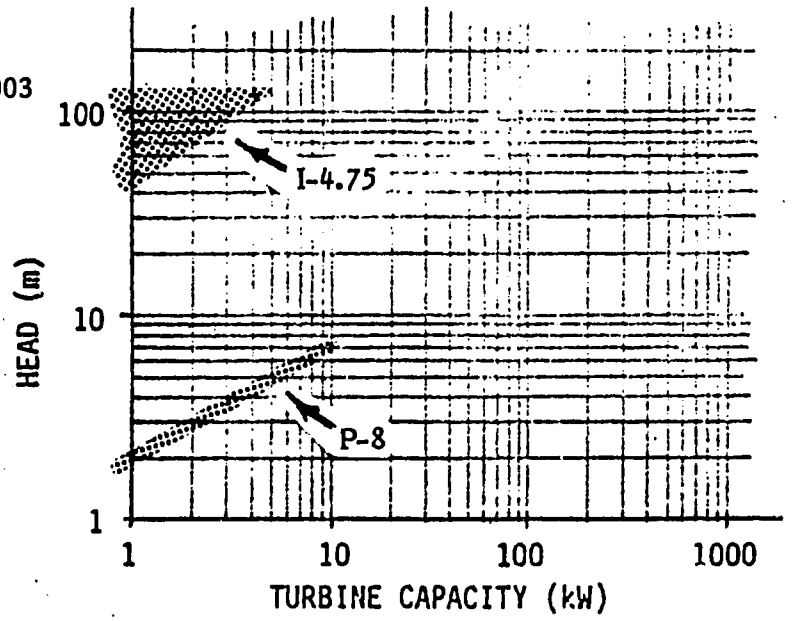
Leffel SAMSON Turbine

2. In addition to the Samson units, Leffel manufactures spiral cased **Francis turbines, Pelton, propeller, tubular, and bulb turbines.** Propeller units may be either fixed or adjustable blade, in vertical or horizontal configurations, with fixed or adjustable wicket gate mechanisms.

LITTLE SPOKANE HYDROELECTRIC

P.O. Box 82
Chattaroy, Washington 99003
U.S.A.

Tel: (509) 238-6810



Background

Little Spokane Hydroelectric was formed in 1978 as a manufacturer of small-scale hydroelectric equipment. A complete range of activities, from pattern making through to turbine testing, is possible at its facilities. This small company is unique in that the power used to manufacture the equipment (except for casting) is produced at its own low-head site. Little Spokane Hydro has been involved in over 20 small-scale hydro projects. Little Spokane is also currently under contract with the U.S. Department of Energy to develop a simpler blade adjustment mechanism for Kaplan-type turbines.

Equipment

Little Spokane Hydro has available two small standard units and can supply larger equipment on a quote basis. These larger units include both Pelton and axial-flow units.

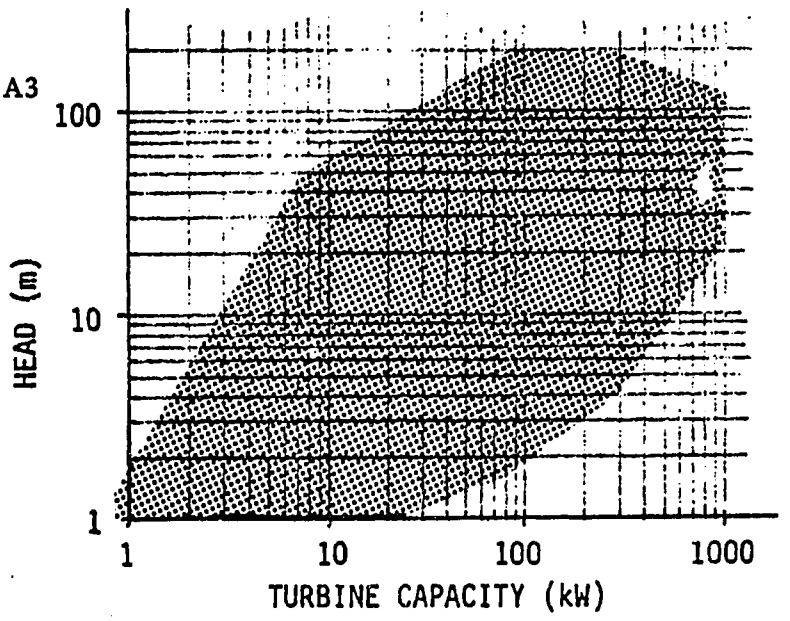
1.Of its two standard units, one is a standardized low-head **axial-flow turbine** (Model P-8) which operates under a head of 2 - 8 m, with a corresponding output of 600 - 10 kW. This is a bronze propeller runner in a cast aluminum housing which couples directly onto a standard 10" flange. This unit can be supplied as is or as a complete generating system engineered to specific site conditions. The cost of the turbine only is about $2,300.

2.Also available is a small **Pelton** package (Model I-4.75) for dc generation which operates under heads of 15 - 120 m with corresponding outputs of 100 W to approximately 2 kW (with one nozzle). Provision is made for including up to four nozzles. It is constructed with a bronze runner, a cast aluminum housing, and is supplied with a heavy-duty dc brushless alternator in a range of voltages. Cost of the basic package is about $1800.

OSSBERGER/F.W.E. STAPENHORST, INC.

F.W.E. Stapenhorst, Inc.
285 Labrosse Avenue
Pointe Claire, Quebec H9R 1A3

Tel: (514) 695-2044



Background

Ossberger-Turbinenfabrik is an exception among the major hydraulic turbine manufacturers. For over half a century, it has concentrated solely on the research and development of single type of turbine, the Michell (Banki) cross-flow turbine, with power outputs below 1000 kW. It is the only major manufacturer of this type of turbine in the world. Ossberger turbines are serving small isolated systems in remote areas in many parts of the world, with a substantial number of its units under 75 kW.

F.W.E. Stapenhorst, Inc. is the sole representative for Ossberger in North America and is restricted to supplying only U.S. funded projects. Though the cross-flow turbine, housing, and guide vanes are manufactured in Germany, the generator, governor, electric controls, and other components can be made in the U.S. to Ossberger specifications. Its complete packaged units may, therefore, satisfy U.S. source requirements.

Equipment

A significant advantage of the **cross-flow turbine** manufactured by Ossberger is its relatively high efficiency (80% - 85%) over a wide range of head and flows variations. By manipulating two simple guide vanes, its efficiency remains flat from full flow down to about 1/4 of that flow. Up to ± 20% variation in head results in no significant changes in efficiency. Only the Kaplan or variable-pitch propeller turbine can approach this level of efficiency over a wide range of flow conditions at low or medium heads (at the cost of substantially more complexity). On the other hand, it must be recalled that with isolated run-of-the-river schemes, efficient use of the available water may not be important. The possibility of high efficiency with off-peak loads available with the cross-flow turbines might therefore be of no consequence in such schemes.

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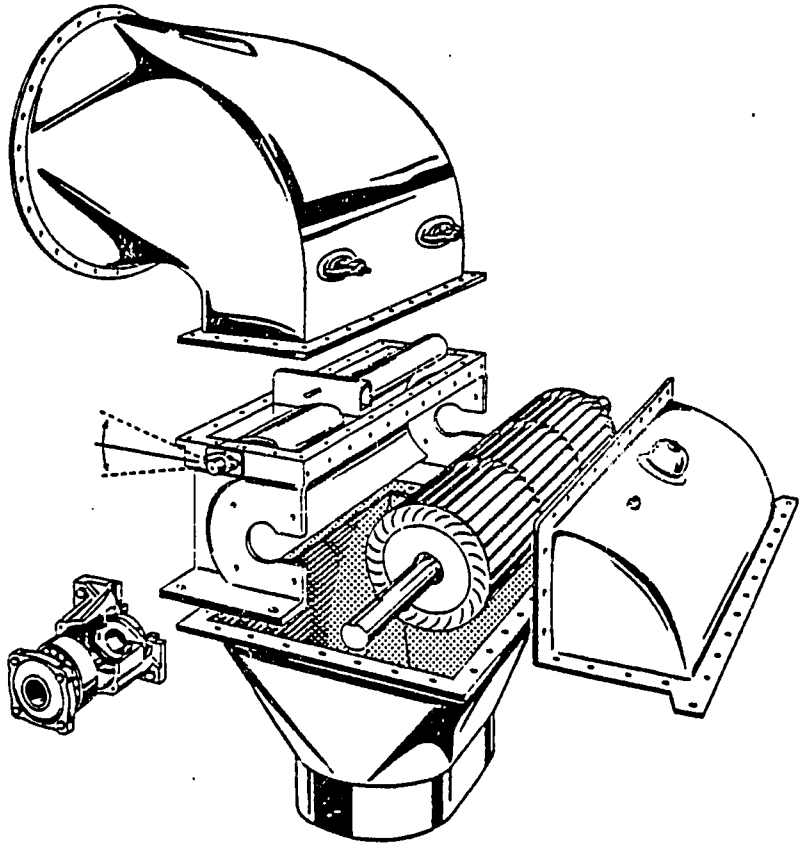
In addition to the turbine housing with draft tube and guide vanes, generating sets include standard governor, speed increaser, generator, and transition piece between penstock and turbine. The turbine is completely assembled and mounted on a frame ready to be bolted to the floor. The draft tube and transition piece are

Ossberger Turbine



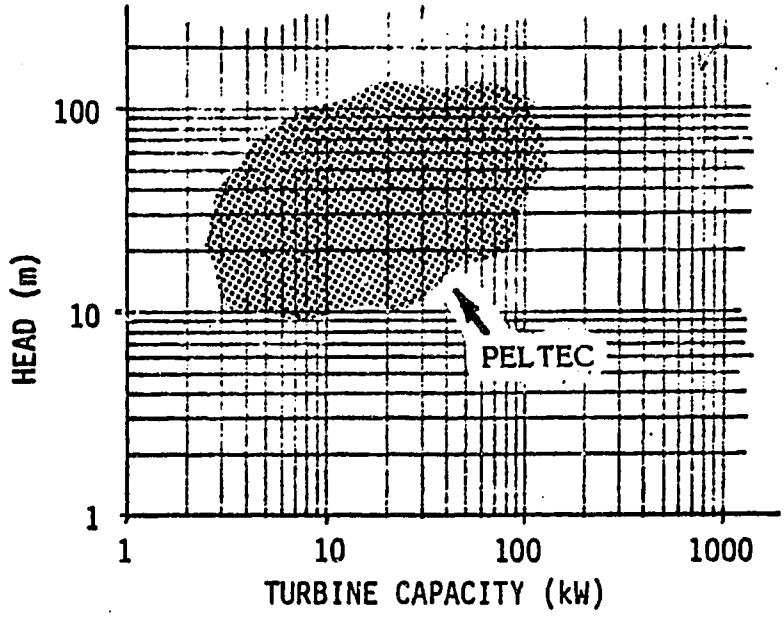
bolted to the assembly at the time of installation. For generating sets up to about 75 kW, the complete unit including the generator is mounted on a common frame to facilitate installation.

Small standardized units, UNIVERSAL Types A and B, for low flows and heads and power outputs of 1 kW - 9 kW are available with either manual control or governor. However, even a complete package probably does not contain sufficient U.S. made components (depending on the final configuration) to satisfy U.S. source requirements.

SMALL HYDROELECTRIC SYSTEMS AND EQUIPMENT

5141 Wickersham Street
Acme, Washington 98220

Tel: (206) 595-2312



Background

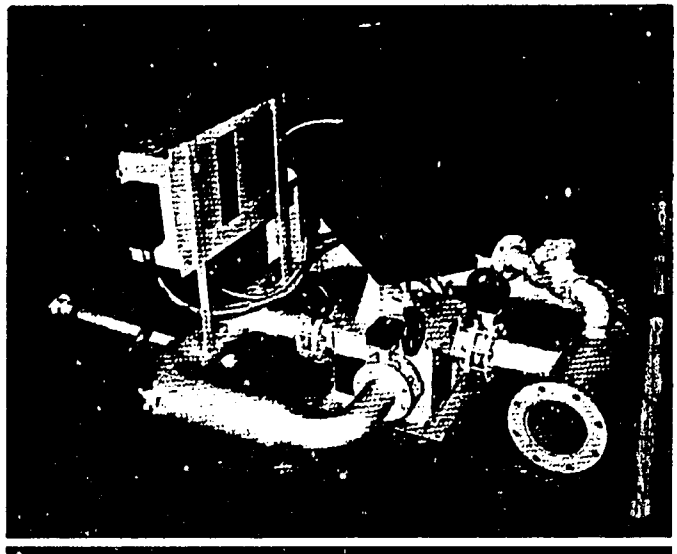
One of the several groups to recently enter into the manufacturing of small hydroelectric units, Small Hydroelectric Systems and Equipment now specializes in Pelton turbines with runners cast, after its own design, in stainless steel, bronze, or other metals. All aspects of the fabrication of its units, except the pouring of the runners, is done in its new facilities. Peltech units with capacities of up through 100 kW have been manufactured to date.

Equipment

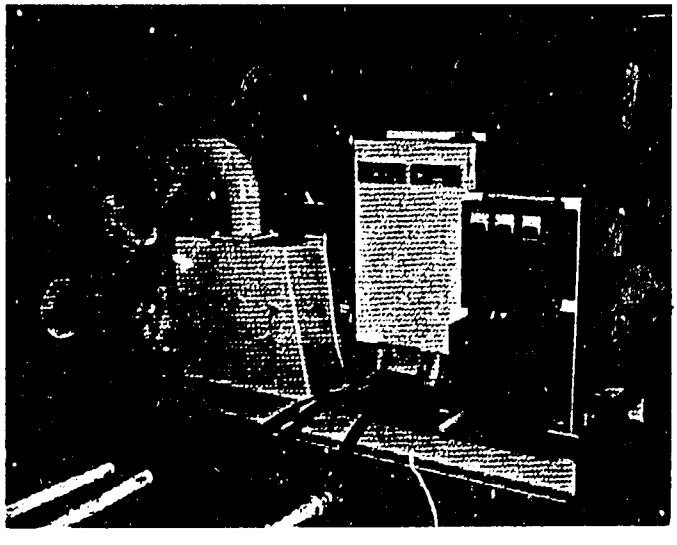
SHSE has available its **Peltech** units, either single or double jet, horizontal axis, or up to six jets, vertical axis Pelton turbines. The runner is available in four pitch diameters. Though spear valves can be incorporated in these units, they may not be necessary depending on site requirements. Even without spear valves, some flow control can be exercised by closing individual nozzles; further control can be accomplished through adjustment of deflectors. Peltech units can be furnished with either a hand wheel for manual control, a Woodward governor activating deflectors, or a load controller designed by Energy Independence Research (EIR). The alternator is mounted on a common frame with the turbine.

Cost of specific hardware is available on demand. As an example, the cost of a Peltech turbine with 9 3/4" stainless steel runner with housing and one to four fixed nozzles (depending on flow available and/or power required), but without alternator and governing or controlling devices, ranges from about $1600/kW for a low-head (20 m), low-flow (single nozzle with 4 kW output) turbine down to below $200/kW for a higher head (60 m), higher flow (four nozzles with 70 kW output) turbine.

In addition to complete units, Pelton runner castings are sold as cast or machined. Basic drawings are available for its Peltech units.



Vertical axis
Peltech, 4-jet



Horizontal axis
Peltech, 2-jet

C.V. SUKARADJA

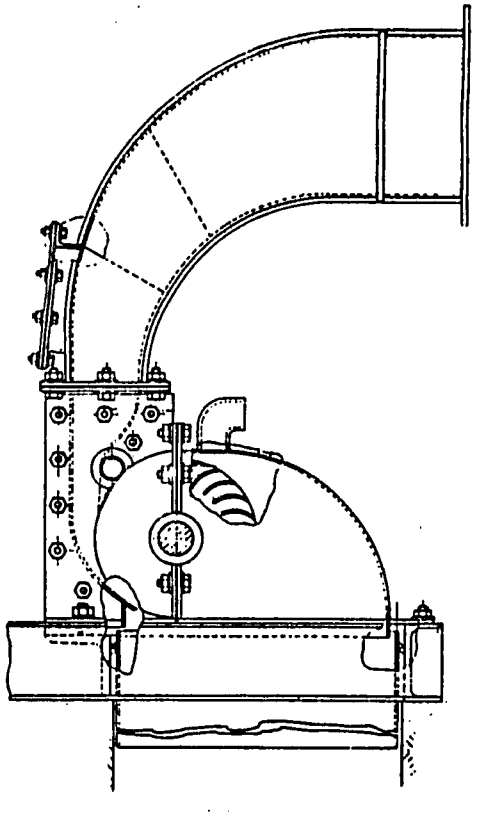
Jl. Kom. Ud. Supadio (Jatayu) 98
Bandung, Indonesia

Tel: (022) 615885, 611637

Background

C.V. Sukaradja, a metal workshop and engineering firm established in 1961, manufactures various kinds of machines and equipment needed by local industries.

Sukaradja is manufacturing cross-flow turbines in the 5 - 50 kW range. Its design was researched and developed in 1977 with the assistance of Dutch engineers within a framework of intergovernmental cooperation. Sukaradja makes all components for the turbine. The generator, electric controls, and other components are either assembled in Indonesia under license from Japan or imported from overseas. It is currently involved in the manufacture of a turbine of 400 kW capacity.



Equipment

Output from the cross-flow turbine manufactured by Sukaradja is controlled manually by use of a guide vane. Its units are operating under heads of 5 - 50 m and are coupled by belts to the alternator. Efficiencies range from 65 - 70%.

Complete packaged units, including turbine, generator, and load controller, are available. For turbines in the 5 - 50 kW range, the cost is about $400/kW.