7 SITE SURVEYING

7.1 Power from a stream

The amount of power that can be provided by a stream depends on two things. These are called the *head* and the *flow.*

1)_The *head,* measured in metres (m), is the vertical drop from the top of the penstock to the bottom. The greater this drop, the greater the power and the higher the speed of the turbine. It is important not to confuse this height with the penstock (or stream) length.

2) The *flow,* measured in litres per second (l/s), is the amount of water which flows past you in one second when you stand by the stream.

Hydro-Power is calculated by multiplying the *head* and *flow* by the force of gravity. The unit of power is the Watt (W). 1000 Watts = 1 kilowatt (kW). Since the force of gravity is fairly constant (9.81m/s^2), the formula for Hydro Power can be written as follows:

Hydro Power (W) =head (m) x flow (l/s) x 9.81

Example Calculate the power in a stream

The maximum head of a stream on a farm in Western Nepal is 70 meters. The flow that has been measured is 5 litres per second. What hydro power is available in this stream?

Answer: Power = head x flow x gravity
= 70 x 5 x 9.81
= 3433 W or **3.4 kW**

It is important that the head is carefully measured. In some places the flow is clearly more than is needed. If this is true then accurate flow measurements are not required. If there is doubt about any of the calculations then the measurements should be repeated. It is better to underestimate the head and flow rather than to overestimate them.

7.2 Obtaining the Necessary Equipment.

A variety of equipment to help determine the head and flow is discussed in this section. Some methods require practice in order to be used accurately. Methods have also been included which involve no specialist equipment or training enabling anyone to be able to estimate the power.

For head measurement, the water-filled tube method is the lowest cost though time consuming. Use of digital altimeters and Abney Levels has also been described. Where available, these methods can provide a relatively quick and accurate alternative if used correctly. Digital altimeters are becoming more widespread and lower in cost though a quality one cost about $200.

The flow measurement techniques described are the bucket method and the float method. The float method is much less accurate but very easy to perform. Use of the digital conductivity meter in what is called the 'salt gulp' technique of flow measurement has also been included. At many sites this method is much more practical and accurate than the others. Like the digital altimeter, conductivity meters are gradually becoming more widely available and have a similar cost.

7.3 Measuring the Head

The techniques, summarised in Table 7-1, differ in terms of cost, complexity, and accuracy. Generally, the lower the head, the more critical the accuracy of the measurement.

The head should be measured at the most likely place for the penstock. This means that the site layout will have been studied and possible places for the power house and forebay tank will be under consideration. Don't forget, keep the penstock as short as possible to obtain the required head. The head required for a pico hydro project like the ones described in this manual (medium to high head) will need be at least 20 metres and ideally 50 metres or more.

	Method	Cost	Accuracy	Time	Difficulty	Equipment Required	No. of People
1	**Water-filled plastic tube**	Low ($20)	Accurate with practice	Takes time (3-6hrs)	Easy to learn	Plastic tube, tape measure, wooden pegs, notebook and pencil	2 or more
2	**Altimeter**	Medium / High. ($200 each) Borrow or hire if possible	+/-1m to +/-5m depending on model (greater accuracy is possible using 2 altimeters)	quickest method (less than 1hr)	No skill required	Digital altimeter, wooden pegs, notebook and pencil	1 (though better with 2)
3	**Abney Level**	Quite low. Borrow or hire if possible	Accurate with practice	Quite slow (up to 2hrs depending on experience)	Practice required	Abney Level, long tape measure, two sticks (1.5m), pegs, notebook and pencil	2

Table 7-1 A comparison of methods to measure Head in metres

Water-filled Tube

This is the cheapest method of head measurement to learn. No specialist equipment is required. A piece of clear, plastic tube, about 20 metres long with a diameter of 10 or 12 mm, is the main piece of apparatus.

Fill the tube with water so that when the two ends are held together, the water level is about 30cm from the top. The water inside the tube will always find the same level on either side. A plastic funnel will help to pour in the water. Bubbles in the tube should be avoided as they can cause inaccurate readings. They should be removed where possible by allowing them to rise out of the tube (very small bubbles don't matter).
At least two people are required for this method but more can help with taking measurements and recording the results.

Procedure

Step 1: One person holds each end of the tube and does not allow the water to spill out. Begin by matching the water level in the tube to the expected water level of the forebay tank which should be marked by a stick. Your assistant should remain still, holding their end of the tube at this point. Meanwhile, move downhill carefully holding your thumb over the end of the tube as you go so that the water doesn't spill out. Once your eye level is approximately the same as the expected water level in the forebay, raise the tube to head height and take your thumb off the end.. Adjust your position as necessary so that the water level in the tube matches exactly your eye level and the expected level in the forebay. Record that one reading has been taken and stand still.

Step 2: The assistant now moves downhill past your position keeping the water in the tube by holding a thumb over the end. As they walk further down, lower your end of the tube until the water in your end is at the level of the soles of your shoes. The assistant stops walking downhill when the water reaches eye level. Record that a second reading has been taken

Step 3: The process is repeated until one side of the tube is held in the expected location of the turbine. The number of reading taken are then totalled up. This is multiplied by the average height (to eye level) in metres of the two people who took the measurements. to give the total head. The procedure should be repeated two or three times until you are sure that the head measurement is accurate. Good marking at the forebay site and the powerhouse position enable the same section of hillside to be measured again. If the head is more than required then an intermediate position, can be found. The distance between the two marker points should be measured to decide the length of penstock required.

A variation of this method is to seal one end of the tube with a pressure gauge. The pressure at each measuring point is recorded and the sum of the total pressures can be used to calculate the overall head. The pressure gauge must be calibrated before use so that the readings are trustworthy. A tall building an long tape measure can be used for calibration.

Digital Altimeters

Figure 7-1 Head measurement using a digital altimeter in Kenya

Digital altimeters are the most convenient way to measure the head at a site. Height is calculated using changes in air pressure. All that the user has to do is to record one reading at the proposed forebay location and one at the site of the turbine in order to determine the head. The second reading should be taken as quickly as possible to prevent atmospheric changes in pressure (changing weather) from affecting the readings.

The best way to remove weather effects is by using two identical altimeters and to take measurements at the same time. One altimeter remains in the same position, either at the top or the bottom of the slope to check the effects of changing weather. The other is used to calculate head. Meanwhile any changes in head caused by atmospheric conditions are noted and then adjustments can be made to the final figure. It is easy to repeat the test several times in order to check the head. If the altimeters can be zeroed, zero both at the same time. Agree the time required for the person who carries the second altimeter to move to their new position. Using watches take the new readings on both altimeters at the same time. The two readings can be subtracted to give the head. An accuracy of at least +/- 5m is expected with digital altimeters although +/- 1m should be possible with some.

The Abney Level.

The Abney Level (or Clinometer) is a hand held sighting meter. It requires skill to use but once mastered can measure heads with an accuracy of +/- 5%.

With this method, the angle of the slope is measured. The linear distance is also measured and using simple trigonometry, the height difference between two points is calculated. When these are added together the total head is obtained.

Procedure for head measurement using an Abney level

Step 1: Two posts are needed which are 1.5 to 1.6 metres in length or the distance from ground to eye level, (they must be the same but their exact length is not important). The first is held at the proposed location of the turbine and the second about 30m towards the intake. A clear line of site is necessary so this may affect the route taken. A brightly coloured ribbon or similar object is useful to identify the top of the sighting post

Step 2: The distance between the top of the two posts is measured and recorded (distance d). Some Abney levels have a built-in range finder and this can be used instead of a tape measure.

Step 2: The angle between the tops of the two siting posts is carefully measured using the level and recorded. Both posts should be held straight with the level resting on top of one.

Step 3: The process is repeated up the hill until the proposed intake level is reached.

Step 4: The heights between each pair of points are calculated using the sine rule and added together to give the total head.

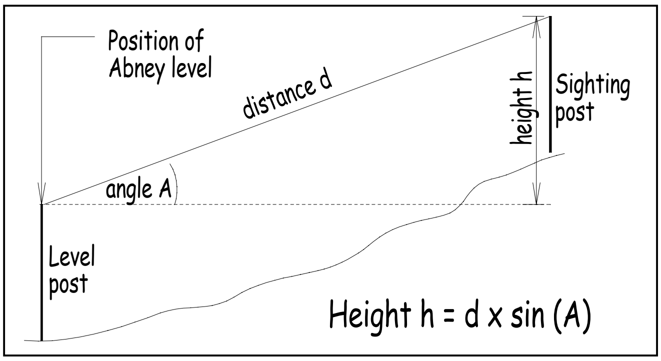


Figure 7-2 Calculation of the height between two points using an Abney Level

	Method	Cost	Accuracy	Difficulty	Time	Equipment required	Number of people
1	**Bucket Method (only suitable for flows less than about 10 l/s)**	Negligible	Reasonable / poor depending on method / experience	Not difficult	10 minutes + time to block stream if required	Bucket and stopwatch	2
2	**Float Method**	Negligible	Poor although reasonable accuracy in smooth parallel-sided channels	Not Difficult	30 minutes	A float (piece of wood), tape measure, stopwatch	2
3	**Salt Gulp Analysis**	High ($200). Borrow / hire a meter	Medium to high accuracy with practice (±5%)	Requires care to perform	1 hour	Conductivity metre, Salt weighed into bags, bucket, calculator	1 or more

Table 7-3 Suitable methods of measuring small flows (<50l/s)

Figure 7-3 Head measurement using an Abney Level in Nepal

Station No.	Distance D	Angle A	D x sin(A)
1	31.5 m	14°30′	7.89 m
2	29.0 m	7°15′	3.66 m
11	23.1 m	10°20′	4.14 m
		Total head	57 metres

Table 7-2 Using an Abney level, the distances and angles are recorded at several points between the turbine and intake position so that the total head can be calculated as shown above.

7.4 Measuring the Flow

The accuracy to which the flow needs to be measured depends on the site. A demand survey and estimates of the head help to determine the required flow. In many cases, the flow available will be more than is needed for the scheme, since the flows for pico hydro are small. The most critical time of year is towards the end of the dry season when rain has not fallen for some time. This is the best time to measure the flow. Local people will be able to say if the water level in the stream is typical for that time of year and help the surveyor estimate the flow throughout the year. Three methods of flow measurement are explained which are particularly suitable for the measurement of small flows (less than 50 litres per second) The methods are summarised in Table 7-3.

The Bucket Method

A simple method of finding small flows (up to about 10 l/s) is to use a bucket and a watch. In fact any large, waterproof, container is suitable, providing that you can first find its volume in litres. A 15litre bucket is suitable for the smallest flows (3 litres per second or less) and larger ones for bigger flows.

STEP 1: Find the volume of the bucket (if unmarked).

Take a smaller container with a known volume. A one litre water bottle is a good example. Fill the bucket with water using the smaller container and count how many litres you have added. Mark the level in the bucket clearly when the maximum number of complete litres has been added.

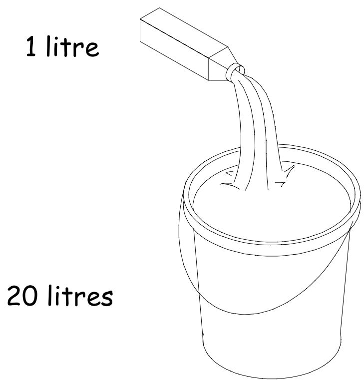
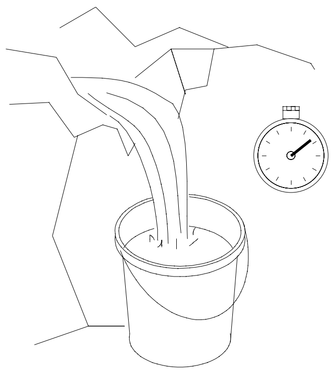


Figure 7-4 Use a small container of known volume to find the volume of a larger one.

STEP 2: Find a place to measure the flow.
This can be difficult. You need to find a method of directing the water in the stream into the bucket. It is important that as little as possible escapes. If some does escape, estimate a percentage and add on to the measured flow.
STEP 3: Take the measurements.
Using a stopwatch or ordinary watch with a second hand, record how long the bucket takes to fill to the marked level. Repeat this at least 3 times and average the results. If you find that the bucket fills in less than 5 seconds, your results will not be very accurate. For more accuracy it is better to use the largest container which you can find or try another method of measuring the flow.
STEP 4: Work out the flow in litres per second.
If the bucket holds 15 litres and takes 8 seconds to fill then the flow is 15/8 l/s or 1.87 litres per second

Suggestions of methods to divert water into the flow measuring container

1. Natural Waterfall



2. Build a weir from available materials and use a wooden channel, a corrugated sheet or a piece of stem from a banana plant to channel the water

3. Build a simple weir and use a piece of pipe

The Float Method.

It works well in canals or channels. It can also be used in rivers and streams although with less accuracy Two pieces of information are needed to calculate the flow by this method. The first is the **cross-sectional area** of the water flowing in the stream or channel. The second is the **speed** that the water is flowing. This is measured using a float and timing its travel between two points a known distance apart.

Procedure
STEP 1: Find the cross-sectional area (CSA).
The difficulty of measuring the cross-sectional area depends on the type of flow under consideration. Estimating the CSA in a smooth-sided channel is much easier than in a shallow, rocky stream.

To estimate the area at a particular point, measure the width and then take depth measurements at regular intervals across the flow. Plot the depth measurements on squared paper as shown in Figure 7-5. Join them up with straight lines to the width that is marked along one axis to create an enclosed area. The area can be estimated by counting the number of squares that are enclosed. Multiply the number of squares by the area which one square represents in m^2. Repeat these measurements in the middle and at the other end of the length over which the float is being timed (approximately 10 metres). Three values of the CSA will allow an average to be calculated.

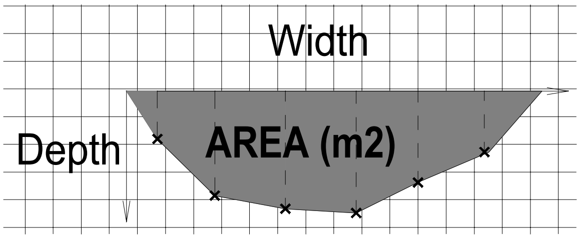


Figure 7-5 Squared paper can be used to help estimate the cross-sectional area

STEP 2: Measure the speed of the flow (surface velocity).
A length (L) of 10 metres between the marking points should be sufficient. Begin to time the float when it passes the first marker and stop as soon as it passes the second. Repeat at least three times for consistent results. For the test, choose the straightest section of stream with the most even cross-sectional area.

STEP 3: Calculate the flow in litres per second
The flow is the product of the average stream area and the average velocity (or average speed) of the flow: Since the water moves more quickly on the surface than in other parts of the stream, an additional factor must be introduced which takes this difference into account. The difference between the surface velocity and the average stream velocity depends on the type of stream. Guideline "velocity correction factors" are given below. The table also gives an indication of the accuracy that can be expected.

Type of stream	Velocity correction factor	Accuracy
A rectangular channel with smooth sides and bed	0.85	Good
A deep, slow moving stream	0.75	Reasonable
A small stream with a smooth bed	0.65	Poor
A quick, turbulent stream	0.45	Very poor
A very shallow, rocky stream	0.25	Very poor

The equation to calculate the flow is:

$$Q = A_{ave} \times V_{surface} \times \text{Correction Factor}$$

where
Q= Flow rate (m^3/s)
A_{ave}= Average cross-sectional area (m^2)
$V_{surface}$= Surface velocity (m/s)

Divide the answer by 1000 for a flow rate in litres per second. Clearly, the accuracy of the float method is limited because of the requirement for correction factors and the difficulty of measuring the cross-sectional area of many streams.

Example Calculate the Flow using the Float Method

What is the flow in a small channel where the following information has been obtained?
1) The water in the channel is 25 cm deep, the sides of the channel are approximately square and the width is 40 cm. The side are quite smooth
2) When a stick was floated down a 20m section of the channel it took a) 36 b) 40 and c) 44 seconds

Answer:
(i) Cross sectional area of the water in the channel
= 0.25 x 0.4
= **0.1 m^2**
(ii) Average time taken
= (36+40+44)/3
= **40 seconds**
Average surface velocity
= 20metres/40seconds
= **0.5 m/s**

(iii) Correction Factor for a smooth channel
= 0.85
(iv) **Flow = Area x velocity x correction factor**
= 0.1 x 0.5 x 0.85
= **0.0425 m^3/s**
The flow in litres per second
= 0.0425 x 1000
= **42.5 litres per second**.

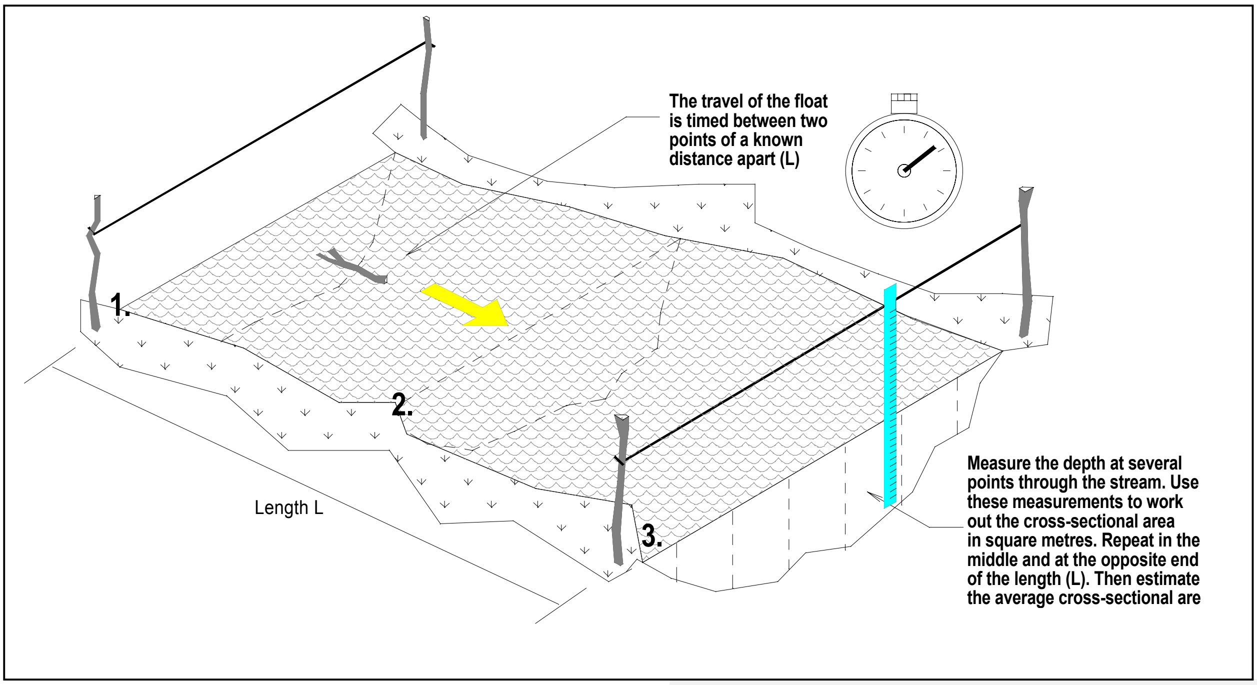


Figure 7-6 The float method of flow measurement

The Salt Gulp Method

This method requires more complicated calculations than the others but is easier to carry out. With some practice however, it can be the most convenient, rapid and accurate method of measuring flow in a stream.

A portable digital conductivity meter and some means of accurately weighing salt are required. Digital conductivity meters are becoming more widespread and it is hoped that they will eventually be available in all areas where pico hydro development is taking place. Access to a computer is useful. A spreadsheet allows the results to be rapidly converted into a flow rate. Otherwise a calculator and graph paper are required to calculate the results.

Figure 7-7 Portable conductivity meter and carefully weighed bags of salt

This method is accurate to within 5% if performed carefully. It relies on the fact that the conductivity of water in a stream will rise when salt is added. The flow rate is determined by measuring the speed and concentration of a cloud of salty water as it passes downstream.

Procedure:

STEP 1: Add the salt solution to the stream
A known mass of salt is mixed with some water in a bucket until fully dissolved. The amount of water in the bucket doesn't matter but once the salt has been added then the water must not be spilt. Record the mass of salt added, to the nearest gram. All the salt water solution is then tipped into the stream. The mass of salt used depends on the size of the flow. As a rough estimate, use approximately 25g of salt for every 5 litres per second of flow (the flow will have to be guessed on the first occasion).

STEP 2: Record the conductivity change downstream. The conductivity meter probe is placed in a swiftly moving area of flow, 25 to 30 metres downstream of where the salt solution is added. The normal conductivity level of the water is recorded. This is called background conductivity. As soon as the conductivity readings begin to climb, record them every 5 seconds. This will usually happen 2 or 3 minutes after the salt water has been tipped in upstream. If, within 15 minutes, the conductivity has not reached at least twice the background level, then the procedure must be repeated with a greater quantity of salt. Readings continue to be recorded every five seconds until the conductivity has returned to its background level. This will normally be after a further 10 to 15 minutes. If possible select a scale on the meter that is just sufficient for the maximum conductivity to be read. This may mean loss of the first set of results.

The meter readings are typically given in micro Siemens (μS) which are units of conductivity ($ohms^{-1} \times 10^{-6}$).

STEP 4:Plot a graph of changing salt concentration against time

These readings should be plotted on squared paper as a graph of conductivity against time. The shape of the graph allows the results to be evaluated. A smooth curve with a peak value at least twice the level of the background conductivity, indicates that the procedure has been successful. If the curve is badly skewed or the readings are uneven then the procedure will need to be repeated.

STEP 5: Calculate the area under the curve

The area under the curve must be established in order to calculate the flow rate. This is done either by counting the squares underneath the curve or by summing the results using a spreadsheet. If you count the squares then the axis scale must be taken into account.

STEP 6: Calculate the flow rate

The equation for calculating the flow rate is as follows:

$$Q = \frac{M \times k^{-1}}{A}$$

where:
Q = flow rate (l/s)
M = mass of salt (mg)
k^{-1}= conversion factor ($ohm^{-1}/mg\ l^{-1}$)
A= area under curve ($s \times 10^{-6} \times ohm^{-1}$)

The conductivity is converted into salt concentration by multiplying by a conversion factor that takes water temperature into account. The conversion factor, k^{-1} has units $ohm^{-1}/mg\ l^{-1}$ and assuming a water temperature of 22°C, the value of k^{-1}= 2.04.

Note: The mass of salt must be converted to milligrams (grams x 10^3) before being used in the equation.

Salt Gulp Flow Measurement

Location:	Thulo Phako, Basantapur, Eastern Nepal	
Date:	20th May 1998	
Time:	7.30 am	
Water Temperature:	22	°C
Net Head:	50	metres
Mass of salt used :	25000	milligrames
Background Conductivity	29.2	microSiemens
Time period between results	5	Seconds
Conversion Factor k	2.04	ohm-1/mg l-1

Flow Rate = mass of salt in mg x factor k / area under curve
Area under curve = Total of condutivity change x time period

Area under curve =	10698	
Flow Rate =	4.77	litres per second

Power Available = Flow Rate x Head x Gravity

Power Available =	2338	watts

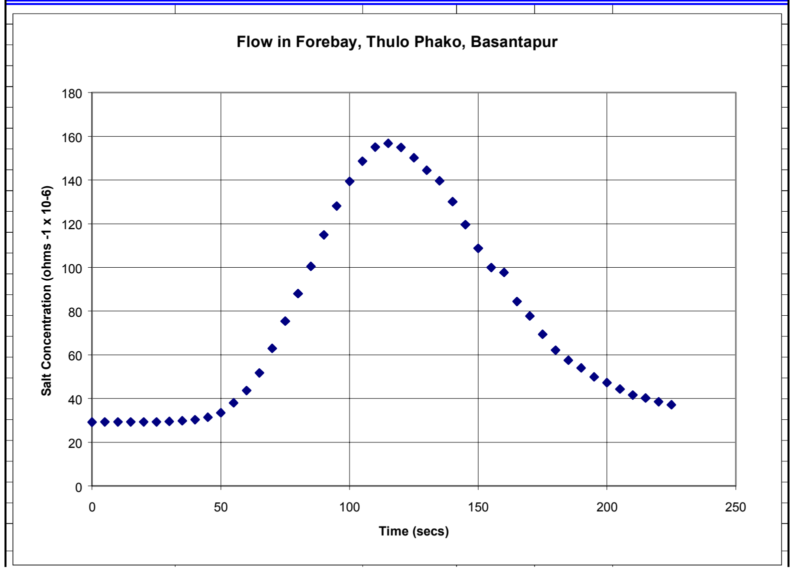


Figure 7-8 Results from the 'salt gulp' method of flow measurement can be analysed quickly using a spreadsheet.

Time (seconds)	Conductivity Reading Ohm^{-1} x 10^{-6}	Conductivity Increase Ohm^{-1} x 10^{-6}	Time (seconds)	Conductivity Reading Ohm^{-1} x 10^{-6}	Conductivity Change Ohm^{-1} x 10^{-6}
0	29.2	0	230	36.2	7
5	29.3	0.1	235	35.1	5.9
10	29.3	0.1	240	34.3	5.1
15	29.3	0.1	245	33.8	4.6
20	29.3	0.1	250	33.3	4.1
25	29.3	0.1	255	32.9	3.7
30	29.5	0.3	260	32.5	3.3
35	29.8	0.6	265	32.3	3.1
40	30.3	1.1	270	31.8	2.6
45	31.5	2.3	275	31.6	2.4
50	33.5	4.3	280	31.4	2.2
55	38	8.8	285	31.3	2.1
60	43.7	14.5	290	31.2	2
65	51.7	22.5	295	31.1	1.9
70	62.9	33.7	300	31	1.8
75	75.4	46.2	305	31	1.8
80	88	58.8	310	29.9	0.7
85	100.5	71.3	315	29.9	0.7
90	114.9	85.7	320	29.8	0.6
95	128.1	98.9	325	29.8	0.6
100	139.4	110.2	330	29.8	0.6
105	148.6	119.4	335	29.7	0.5
110	155.1	125.9	340	29.7	0.5
115	156.8	127.6	345	29.7	0.5
120	154.9	125.7	350	29.6	0.4
125	150.2	121	355	29.6	0.4
130	144.4	115.2	360	29.6	0.4
135	139.6	110.4	365	29.6	0.4
140	130.1	100.9	370	29.5	0.3
145	119.6	90.4	375	29.5	0.3
150	108.8	79.6	380	29.5	0.3
155	100	70.8	385	29.4	0.2
160	97.7	68.5	390	29.4	0.2
165	84.4	55.2	395	29.4	0.2
170	77.8	48.6	400	29.4	0.2
175	69.4	40.2	405	29.4	0.2
180	62.1	32.9	410	29.3	0.1
185	57.5	28.3	415	29.3	0.1
190	54	24.8	420	29.3	0.1
195	49.9	20.7	425	29.3	0.1
200	47.3	18.1	430	29.3	0.1
205	44.3	15.1	435	29.3	0.1
210	41.6	12.4	440	29.3	0.1
215	40.2	11	445	29.3	0.1
220	38.5	9.3		**Total**	**2140**
225	37.1	7.9			

8 PICO HYDRO DESIGNS

8.1 The 'Pico Power Pack'

The 'Pico Power Pack' is a new design of pico hydro-power system. It is low cost, reliable and suitable for electrification of remote villages. For information on how to manufacture this design, a complimentary publication entitled "The Pico Power Pack - Design and Manufacture" has been prepared.

8.2 Inspiration for the 'Pico Power Pack'

The Peltric Set: Different pico hydro systems have been developed in several countries to help solve the growing demand for rural electrification of remote communities. The Peltric Set and FDTA pico hydros in particular provided the inspiration behind the development of the 'Pico Power Pack.' The 'Peltric Set' was developed at Kathmandu Metal Industry in Nepal and is shown in Figure 8-1. A vertically mounted induction generator is directly coupled to a Pelton turbine. The turbine casing also forms the base for the generator which makes the design simple and economical with material. AC electricity is generated which means that the power can be distributed economically over hundreds of metres. There are approximately 500 units of this type electrifying villages in Nepal at the present time.

Figure 8-1 The 'Peltric Set' has provided many rural villages with an economical electricity supply in Nepal

Low Cost DC System: A different system has been designed at FDTA (Fundacion Desarollo de Technologias Appropriadas) in Colombia, South America. The turbine runner is also a small Pelton wheel but a 12V DC car or truck alternator is used as a generator. The turbine is coupled to the alternator using a pulley belt and mounted on a simple steel-angle frame that is easy to manufacture. An installation of this design in shown in Figure 8-2. Since the turbine shaft is horizontal, it is also possible to run other machines with hydro-power in addition to the generator. This design has been used to provide the energy source for a mechanical refrigerator, for example. No extra control system is required other than the voltage regulator which is already included with the alternator. Since DC (direct current) is generated, no frequency regulation is required but the electricity must be used close to or at the powerhouse.

Figure 8-2 A Colombian manufacturer (right) installs a DC pico hydro system.

The pico power pack combines the low-cost steel-angle base and horizontal shaft of the Colombian alternator unit with the simple design of a Pelton turbine directly driving an induction motor used with the Peltric Set. The three designs are compared in Table 8-1.

Figure 8-3 Installed Pico Power Pack

Type of Pico Hydro System	Type of electricity Produced	Amount of power generated	Number of houses which can be electrified	Possibility for using mechanical power	Easy access to nozzle and turbine	Cost
Peltric Set	AC	500-5000W	1 to 300	No	No	Low Cost
Colombian Alternator System	DC	50 - 500 W	1 or 2	Yes	Yes	Very Low Cost
Pico Power Pack	AC	500-5000W	1 to 300	Yes	Yes	Low Cost

Table 8-1 This table compares three designs of pico hydro system

The 'Pico Power Pack' components are shown in Figure 8-4. The generator is mounted horizontally on a steel angle base frame. Since AC (Alternating Current) is generated, the system is suitable for electrifying houses that are up to one kilometre away from the powerhouse, like with the 'Peltric Set'. The removable case makes it easy to inspect the turbine and the nozzle and to clean them when necessary.

The generator shaft is extended at the opposite end from where the turbine is attached. This allows a pulley to be fitted. Small machines such as mills, grinding wheels or saws can be driven with a pulley. In this way, the hydro-power can be used for a wider range of productive purposes. The extra money made through running a small business using pico hydro-power, makes it easier to repay the cost of the scheme.

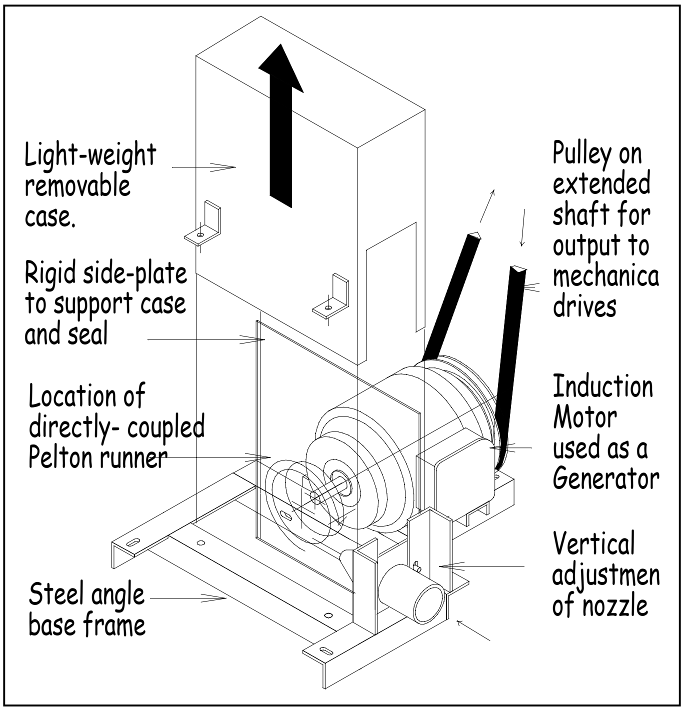


Figure 8-4 The Pico Power Pack generates AC electricity and allows mechanical equipment to be driven.

Table 8-2 Suitability of different turbine designs for pico hydro

Turbine Name	Head Range	Cost for 5kW	Maintenance	Damage by Silt
Pelton	Medium and high	Low	Simple and robust so low maintenance	Little effect from silt
Cross Flow (Michel-Banki)	Medium and low	Low / Medium	More turbine maintenance required than Pelton	Little effect from silt
Turgo	Medium and high	Medium - more complex than pelton	Low maintenance	Little effect from silt
Propeller	Low	Low / Medium	More maintenance required than Pelton	More problems with silt over time
Pump-as-Turbine	Medium and low	Low	More maintenance required than Pelton	More problems with silt over time
Francis	Medium	High - uneconomic at 5 kW	More complicated to maintain	Not for use with heavily silt-laden water

8.3 The Turbine

This is the part of the system which harnesses the hydro power and turns it into mechanical (rotating) power. Several different designs of turbine have been developed. Some of their characteristics are compared in Table 8-2. The type of turbine that is used in the Pico Power Pack is the Pelton wheel.

The Pelton Turbine

The Pelton turbine runner is used for many small-scale hydro power systems if the head is more than 20 metres. It is relatively low cost to manufacture but tough enough to last a long time. The case and nozzle are also simple to build and even a very small Pelton turbine can work very efficiently converting most of the hydraulic power into mechanical power to turn the generator.

Figure 8-5 Locally Manufactured Pelton p.c.d.180 mm (Sri Lanka)

How It works

A Pelton turbine has one or more nozzles that direct pressurised jets of water onto specially shaped buckets that are fixed to a wheel. The buckets absorb the force of the water jet and push the wheel round at high speed, often at 1500 revolutions per minute. The bucket shape is designed to divide the jet into two halves and then to deflect the water away smoothly to stop it interfering with the jet or with the other buckets. A cut-away section allows the next bucket to move further round into position while the first is still in contact with the jet.

The correct size of Pelton Turbine Runner

The size of a Pelton wheel or 'runner' is measured using the 'pitch circle diameter' (p.c.d.). This is twice the distance from the centre of the jet to the centre of the runner.

The size of the turbine runner for a pico hydro system is usually no more than 200mm p.c.d.. This distance is used because this is the place where the jet strikes the buckets and determines how fast the runner rotates.

The smaller the runner becomes the faster it will rotate. This means that direct coupling to the shaft of the generator is possible. This reduces the cost of the parts and makes the system simple to install as pulleys and belts are not required.

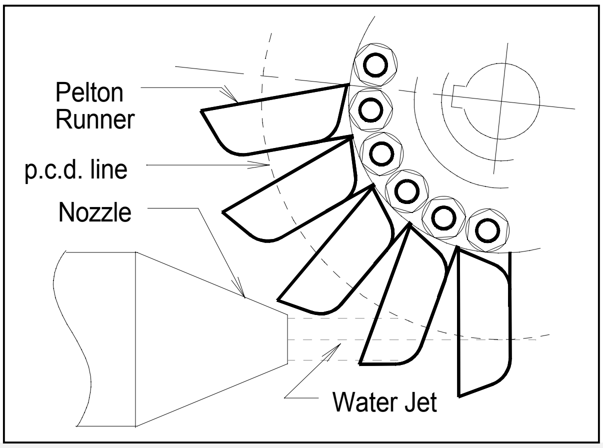


Figure 8-6 The Nozzle directs the water jet on to the p.c.d. line of the turbine runner

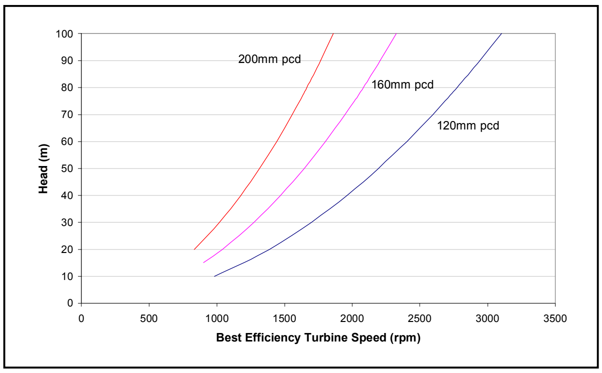


Figure 8-7 Graph showing the operating range of three Pelton runner diameters