PowerSpout Low Head Turbine

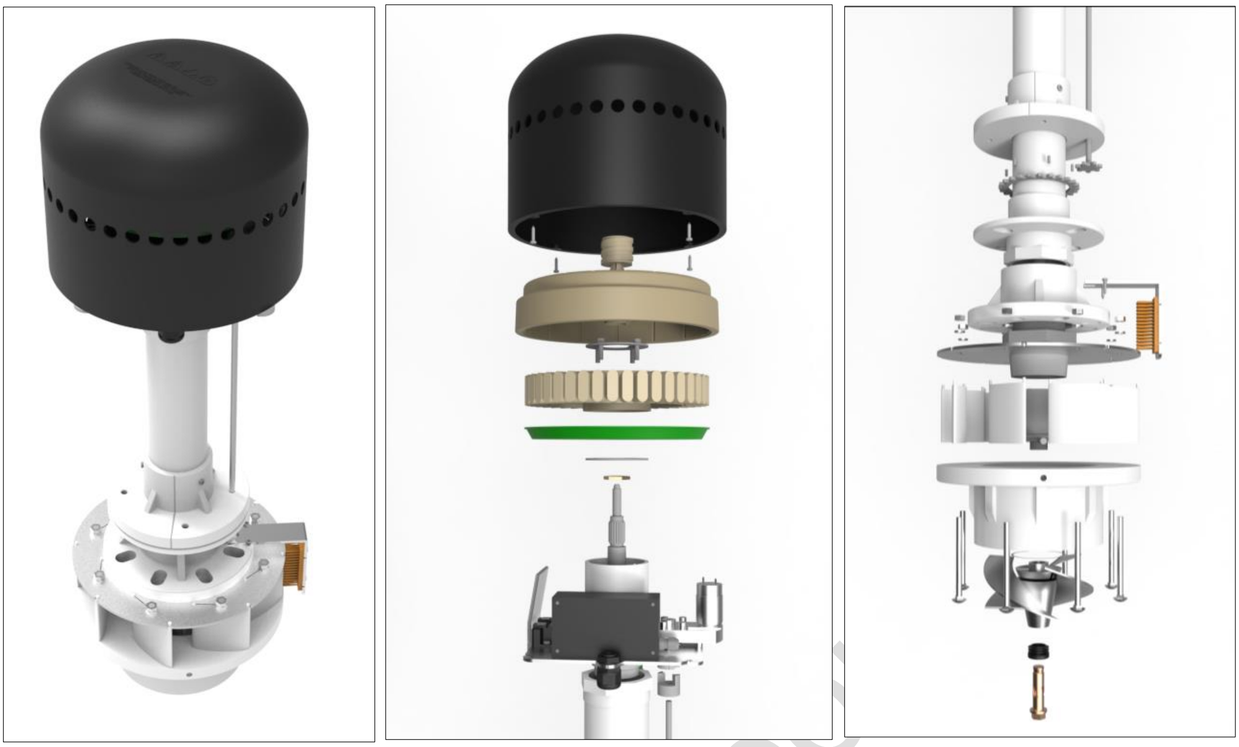
Variants LH and LH Pro
(LH-mini due soon)

Installation Manual
(Low Head 1600 W maximum output/unit)



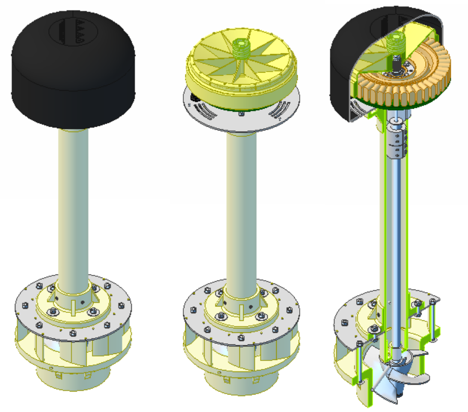


December 2015



Domestic install picture

Please read this manual carefully before beginning installation



Above: PowerSpout LH – basic model – for MPPT regulators and grid-tied inverters

PowerSpout LH **Pro**
premium model with auto-cleaner
Also for MPPT regulators and grid-tied inverters

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Revisions history
1. Original document released February 2012
2. Updated Nov 2015 by HP & ML
3. Warranty info removed to PS all Warranty & terms Nov 15

PowerSpout Contact details

Web: www.powerspout.com

If you cannot find the answers to your questions about our product, renewable energy systems, or your site's potential in this document or on our website at www.powerspout.com, please visit www.powerspout.com/faq and submit a question. We will answer this as quickly as possible, and you will be notified by email when this occurs.

PowerSpout is a product proudly designed and manufactured by:

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If you need to contact EcoInnovation by phone then email first via our web site and check the local time in NZ if calling from overseas. Business hours are 9:00am to 5:00pm weekdays only. EcoInnovation is closed for up to 3 weeks over the Christmas break from 24th December.

Table of Contents

1. Turbine identification and Safety information

1.1. Use of links in this document

To avoid issues with broken links when doing future updates, all linked documents show the file name but take you to our Document Index file which we always keep up to date with links to the most recent editions of our documents. These are stored in a public Google Drive folder. You will need to have a Google Drive account to view these documents in the shared public drive.

1.2. Turbine serial numbers

As of September 2013 all turbines have identification plates and serial numbers.

PowerSpout WATER GOES IN POWER COMES OUT

Read manual	IP24 ingress IK10 impact RoHS
Model type: PLT, TRG, LH, LH Pro	Rated Power: Watts
Serial number:	Rated Amps Short circuit Amps
Rated speed: rpm Maximum rpm 3000	Head: m (x10 kPA) Flow: l/s
Rated volts loaded: DC	New Zealand – country of origin Mass: < 25 kg
Rated volts unloaded: DC	Date manufactured:
Protective class I - earth connection required	Possible residual voltages - always check first
Klampit 75 120 240 not fitted	Capacitor discharge time mins (if fitted)
Annual inspection needed refer to manual	Guarantee 2 3 5 10 years

For example:
You might see 100-7S-2P-S HP F 3061 A as the serial number.

This means you have a 100 series stator, connected 7 Series and 2 Parallel fingers per phase, High Power rotor upgrade, Filter installed for conducted emission compliance, invoice number 3061 and other identical units were supplied at the same time labeled A, B, C, D etc.

If you ever need to query an installation or order spares for a product take a picture of the identification plate and forward it with your query. The generator code is also engraved on the back of the PMA stator.

1.3. Safety

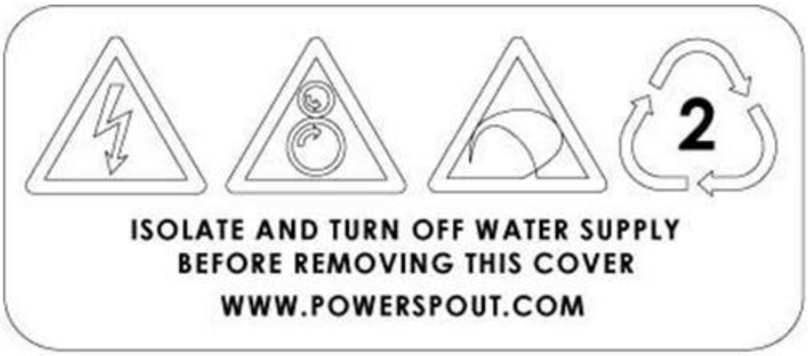
We have tried to ensure you can install and operate your PowerSpout with little or no damage to you, others or your environment. You can also contribute to this by ensuring you are aware of the potential hazards that exist when dealing with moving parts, electricity, access to your hydro site, water, and taking steps to help others recognize and avoid such hazards.

1.3.1. Service in situ

PowerSpout do not support in-situ servicing (with the exception of frequent manual re-greasing), as the risks of injury are much higher than at ground level on a workbench. The turbine should be removed to the workshop for servicing. The site access must be suitable for safe removal and replacement of the turbine.

1.3.2. Top cap safety warnings

The top lid of both the LH and LH Pro forms part of an electrical enclosure and carries the following warning signs. There are both rotational and electrical hazards present. Turbines must be turned off and unplugged (or breaker turned off) prior to removing this cover.



- Electrical hazard
- Rotating machinery hazard
- Made in New Zealand identification
- Recycling identification

Once the turbine has been commissioned, all fairings must be in place and secured with the supplied fixings. This precaution ensures that children cannot remove the covers and be exposed to a rotational hazard.

It is possible for a child to insert a hand through the guide vanes, which would result in serious hand injury. The installer must make provisions to ensure this cannot happen such as:

- Grate over the top of the turbines that is locked in place, extending 600 mm each side to ensure a child cannot reach under and touch the blades.

The turbine installer must ensure that the turbine is mounted such that children cannot reach up under the turbine and be able to touch the spinning blade.

1.3.3. Grid (power network) connections

All PowerSpout LH variants can be grid-tied (no batteries required) this option suits clients that are already connected to the grid and have a good water resource close by.

The **PS all Install Manual** shows the system configuration for a grid tied PowerSpout using a grid-tied inverter. Not all grid-tied inverter are suitable for hydro connection so contact PowerSpout for a list of approved inverters that can be used.

WARNING
Operating voltage within a PowerSpout LH Pro is normally around 180-200 V DC when grid connected. Open circuit voltages can be as high as 400 V DC and is much more dangerous than the 230 V AC found in many European countries and must only be installed or serviced by persons trained in electrical work.

Please ensure you use a registered electrical worker who is familiar with this type of equipment and voltages.

2. Introduction

Congratulations on your choice of PowerSpout LH. This ingenious little device correctly installed and maintained will give you years of trouble free generation, avoiding the need for expensive generators or power bills. Not only does the PowerSpout LH give you renewable energy; it is also made of predominately recycled materials, making it one of the most eco-friendly generators available on the global market.

PowerSpout LH turbines have been shown to achieve over 60% efficiency and can generate up to 1.6 kW on a suitable site; with multiple units the output can rise up to 16 kilowatts (kW).

2.1. Other documents you will need

This manual does not cover the associated electrical system since this has much in common with other PowerSpout turbines. Be sure to read the **PS all Install Manual** and any **PS MPPT** documents that are relevant to your system. For maintenance and assembly of the LH, please read the **PS LH Service Manual**. Keep records in the **PS all Maintenance Log**. Warranty information for all PowerSpout products can be found in **PS all Warranty & Terms.**

2.2. How does the LH turbine actually work?

The PowerSpout LH is a propeller type turbine. This type gives the maximum shaft rpm from the lowest head of water. The propeller is completely submerged in water (unlike the pelton and turgo turbines that run in air, driven by a jet of water).

The Powerspout LH propeller is situated at the **top end** of a tube that connects two bodies of water. The head of pressure on the propeller is actually created by the suction effect of water in the draft tube **below** the turbine. It is important that this tube is full of water, so both the turbine at the top, and the mouth of the tube at the bottom must be completely submerged in water.

The drive shaft connects the propeller to an alternator above the water level, which produces electricity. The current is rectified within the unit to DC suitable for a Maximum Power Point Tracking battery charge controller or a grid-tied inverter, just like a modern solar PV array. Contrary to popular myth, DC is more efficient than AC for transmission of power in cables.

One advantage of situating it at the top of the draft tube is that the PowerSpout LH turbine is very unlikely to suffer flooding at times of exceptionally high rainfall. The rising water level in the tailrace will however reduce the operating head, and therefore the power output (Watts).

2.3. Versions of the PowerSpout LH

There are two different versions of the PowerSpout LH available to suit different situations. These are briefly described in Table 1. Details of flow rates, generator types and generation potential on different sites are provided in Table 6. Your PowerSpout LH will be configured for the flow rate you provide. The flow rate can drop to half the design (maximum) flow and the unit will still run, but produce less than half the power.

Table 1. Different versions of PowerSpout LH

	PowerSpout Low Head version	
Features	**LH**	**LH Pro**
Automatic guide vane cleaner	no	yes
Propeller cutter bar/cleaner	yes	yes
Maximum voltage (Voc) (depends on generator type and regulator fitted)	Approximately 150, 250, 400	Approximately 150, 250, 400
Typical MPP cable voltage (depends on generator type and regulator fitted)	Approximately 70, 120, 200	Approximately 70, 120, 200

2.4. Guide vane cleaner

An automatic guide vane cleaner is installed in the LH Pro. This is invaluable in situations where the water has a high leaf litter burden. It is also advisable in situations where the installation is checked infrequently. Submerging your intake filter in a deep, calm pond can help to reduce the need for a cleaner. Turbines not fitted with a cleaner will need regular manual cleaning or there will be significant loss in performance over time. On our test site manual cleaning was needed every 6 hours for the LH turbine but the LH Pro ran without any need for cleaning provided larger sticks were prevented from entering by the installation by a suitable screen.

Where an automatic cleaner is used, a grate to stop twigs is still needed or the cleaner can get jammed as shown below. This does not damage the power supply or drive motor, as it senses the overload caused by the jam and pulses the motor until the jam is manually removed. Remember; **never** clean a jammed cleaner with the turbine running as the cleaner could start rotating without warning, trapping your fingers.

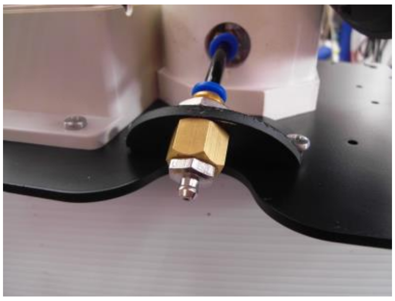
Litter will build up on the outside guide vanes quickly needing regular manual cleaning (LH)

Stick jammed in automatic cleaner (LH Pro)
Please note rotation is now anti-clockwise to reduce jamming risk.

2.5. Planning your installation

Before commencing the installation process you should have selected the appropriate components and consulted your local regulations concerning use of water and undertaking electrical work. This manual and the others linked to above include information and links to relevant tools to facilitate this process. It should take no more than one day for a person to install a PowerSpout LH once flume, pipework and earthworks have been completed.

This manual will help guide you through PowerSpout LH site preparation, and the installation process to ensure it is installed correctly and runs efficiently. There is a section on commissioning the turbine. It is essential to check that the turbine will not produce a voltage that could damage your electronic equipment. Be sure to carefully follow the commissioning procedure before connecting any external circuit.



Remember to grease your new PowerSpout LH

Advice is also provided on basic maintenance to ensure safe and reliable supply of power for years to come. Do remember that regular maintenance is important. Please also read the latest edition of the **PS LH Service Manual** Grease the bearings (20 ml grease) prior to first use and thereafter according to the appropriate schedule (5ml grease).

- Every 6 months for generation up to 600 W.
- Every 3 months for generation up to 1500 W.

If you have an automatic grease canister then do not forget to replace this every 12 months.

Keep records in the **PS all Maintenance Log.** In the event of any warranty claim we will need to see this log.

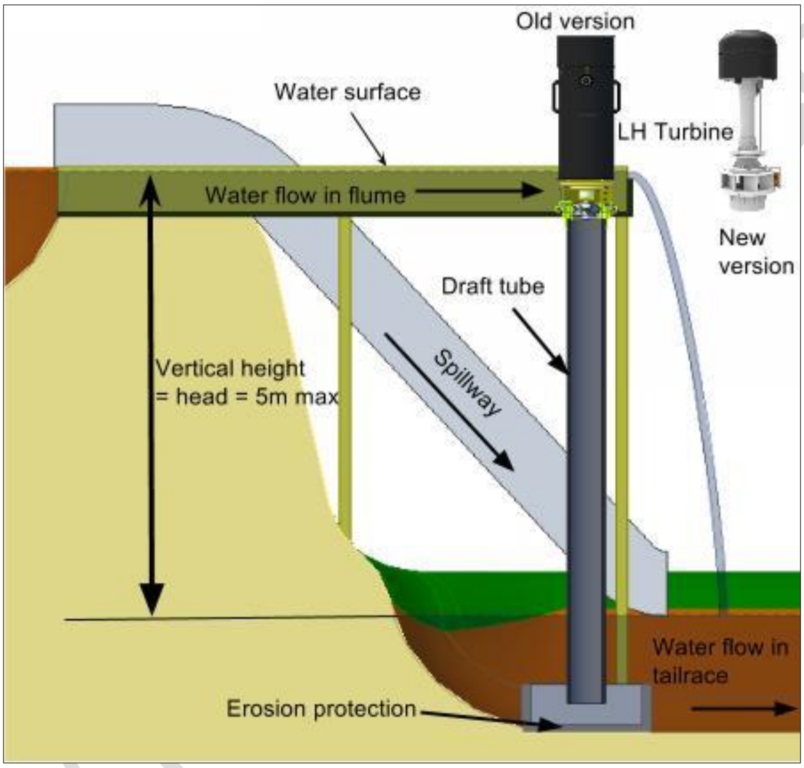
Videos to introduce PowerSpout and demonstrate PowerSpout assembly and bearing replacement are available via www.powerspout.com and in our Document Index. A video on the history of the Smart Drive generator over the last 20 years may interest many customers.

3. Where and how to site the turbine

A PowerSpout LH turbine is more likely to be closer to your home than a PowerSpout PLT or TRG. LH turbines will be installed on larger streams which tend to meander down valley bottoms where homes are typically closer. PowerSpout LH turbines are best employed by locating a part of the river that drops 2-5 m quickly (over a set of rapids).

3.1. How to assess the potential of your site

The generation capacity of your site is determined by the water supply, primarily by the vertical distance the water falls (head) and how much water flows in a given time (flow rate). Please note that the "head" for the LH is the drop in height between the water surface **at the turbine** and the water surface at the tailrace.



A rough estimate of generation potential for all PowerSpout turbines can be calculated as follows:

Generation (Watts) = head (metres) x flow (litres per second) x 5
Generation (Watts) = head (feet) x flow (gallons per minute) / 10

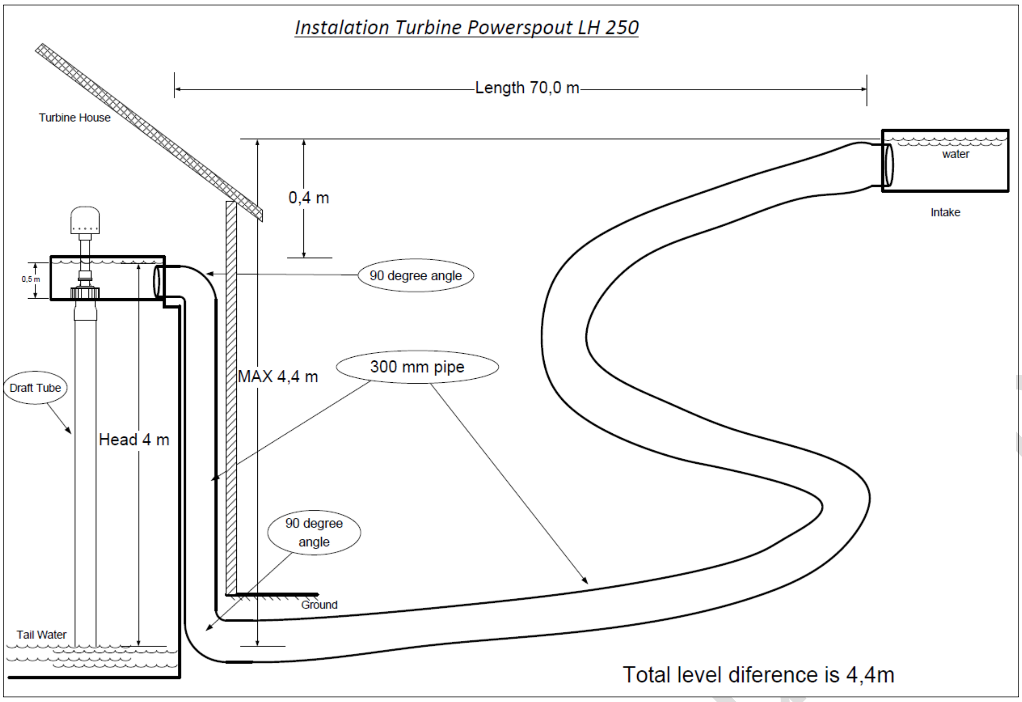
Please refer to the **PS all Calculator Manual** for more information. Use the Advanced Calculator tool to enter the details of your site and discover exactly what is possible.

The calculator will specify how many turbines you need to use all of the flow you are reporting. The HP (high power) option will be automatically selected if it is appropriate for your site (above 3.6 m head). If you need an HP upgrade you will see the “HP” appear in the SD code e.g. 60dcHP-3s-4p-delta (provisional). All this means is that the turbine price will be a little more (US$299) in order to allow you to access the available power.

3.2. Pipes and Flumes

Water must be extracted from its normal course by an intake and brought to the turbine via a flume or a pipe. Here are two examples of flumes:

It is also possible to use a large diameter pipe, which is normally straight, but could dip to follow the surface of the terrain, and rise to feed the turbine header tank.



When entering the Head in the calculator, use the vertical height measurement in the diagram above **between the water surfaces at the turbine location**. Any extra head or "fall" needed for the supply pipe or channel is not to be included in this figure. The calculator will also help you to size the flume or pipe large enough to carry the required flow of water. You need to allow for some fall between the intake and the turbine so that the correct flow can reach the turbine and submerge it to the desired level. See Section 4 for more detailed guidance.

3.3. "In Pipe" turbine coming soon

Powerspout have developed and are testing an "in pipe" version of the LH turbine that uses "positive head" from a feeder pipe in addition to the "negative head" of the draft pipe.

The main features are:

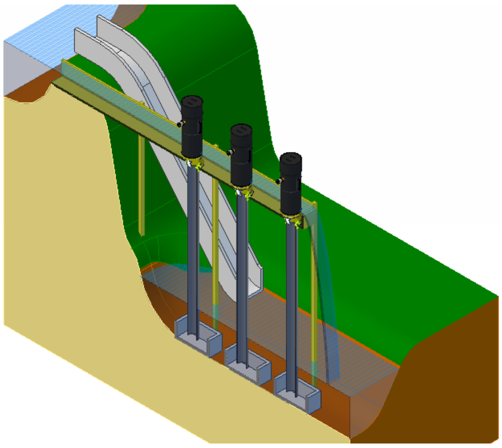
- Same top end as LH and TRG products
- Common propeller & driveshaft
- Positive head - bolt to PVC flange
- Negative head - glue to the PVC expansion adaptor
- Debris cutter included above blade
- 150mm inspection/cleaning opening
- Maximum power 1.6kW
- Maximum positive head = 6m (minimum 1m)
- Maximum negative head = 4m (minimum 1m)
- Flow range = 20-50 lps
- Automatic grease canister included
- Ceramic face seal and ceramic bearings (production version only)
- Efficiency data – awaiting R&D test results

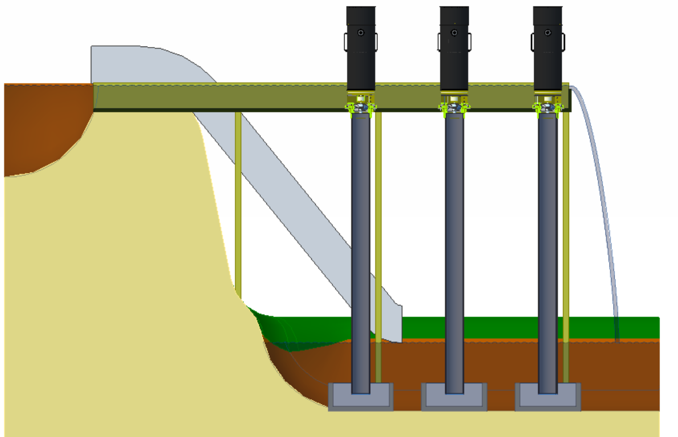
As these turbines can operate on +ive and –ive head, it will operate at up to 10m total head and up to 1.6kW each.

3.4. LH-mini coming soon

PowerSpout have developed and are testing a smaller LH turbine that uses a 100mm propeller instead of the 154mm used on LH turbine. We expect this will operate in the 10-20 l/s flow range. The LH was designed for the 25-50 l/s flow range. We hope this will be ready early 2016.

3.5. Multi-turbine sites





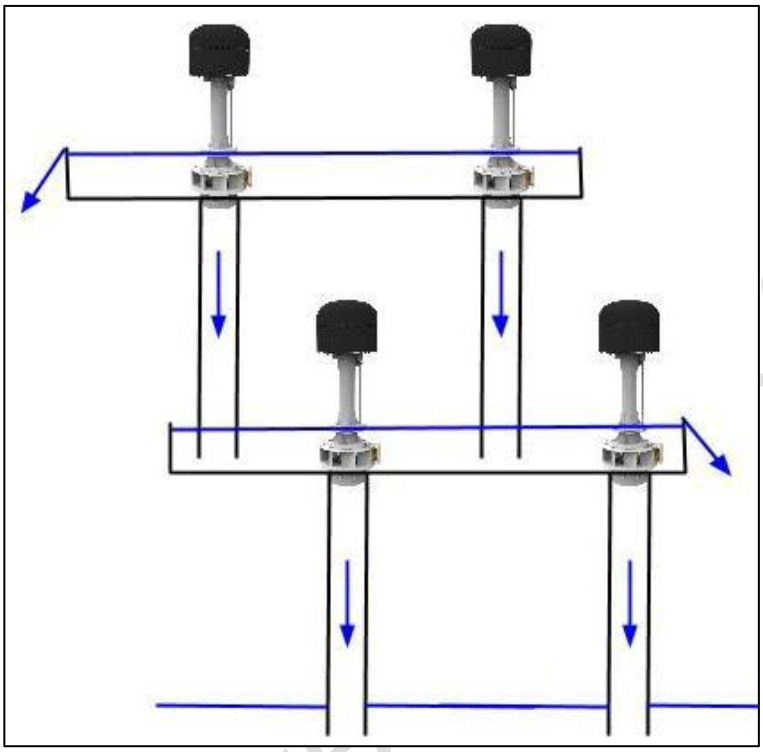
Turbines can be added together as shown. The flume needs to be made larger and stronger and the DC output cable can be combined via a DC fused combiner box into a common supply cable to your MPPT regulator. Some large MPPT regulators can handle 3-4.5 kW of input power per unit. Make sure your MPPT regulator is large enough to handle all the power with a 10% margin.

If your river tends to dry up in summer you simply remove a turbine and block off the draft tube opening.

The document PS LH Case Study provides valuable additional insight into the issues of installing multiple turbines.

3.6. Too much head

If the head exceeds the 5 metre maximum head for the PowerSpout LH then you could also consider using the PowerSpout TRG turbine(s), or you could stack LH turbines vertically as shown schematically below, so that the water is used twice. One advantage of the using the LH turbines rather than the Turgo is that the LH can be more easily positioned above flood levels.



3.7. Too little flow

Most sites will have considerable variation in flow. LH turbines can only run over a maximum 2:1 variations in flow rate ie it can tolerate a reduction in the flow rate to half the design (maximum) flow. While it will still run, it will produce less than half the power because the head and the turbine efficiency will also have dropped a little.

For example, if a turbine is designed to generate 1000 W with 50 l/s and the water flow drops to 25 l/s it will generate approximately:

25/50 x 1000 x 0.9 = 450 W

Once flow drops below 50% the MPPT tracker cannot slow the blade sufficiently and air will get drawn in. This means the vacuum will be lost and generation will be minimal if any at all (10-50 Watts).

Operation at low flow may produce some rasping noises due to air vortices.

Also there is likely to be much more rapid wear on the shaft and its bush since these are lubricated by water. Operating the LH below <50% of the design flow can result in the lower nylon bearing melting due to lack of cooling and lubrication. PowerSpout have an upgrade to a PTFE lower bush that will increase the resilience in low flow situations that can occur if the intake grate gets partially blocked with debris.

If the turbine stops then it is unlikely to re-start, as debris tends to accumulate. It may be preferable to remove the turbine from site. It can easily be lifted out of the draft tube.

If there are multiple turbines operating then the best strategy for low flow is to remove some turbines and blank off the draft tube mouths. The remaining turbines will make better use of the remaining flow. Or you can drop a piece of 300-400mm PVC tube over the turbine to blank off it intake openings (you will need a waterproof connector such as an MC4 on your power cable to do this).

3.8. Siting your PowerSpout LH turbine

Some tips for locating a good site for your turbine include:

- Choose a place that is accessible. If necessary make steps and put in rope handrails to ensure that your turbine can be accessed safely.
- Choose a site where the river drops 2 - 5 m quickly (over a set of rapids).
- Hydro turbines do make some noise, so keep them at least 30 m from your home. LH turbines are much quieter than Pelton or Turgo turbines.
- Ensure turbine is mounted above maximum river flood level.
- Place it reasonably close to your battery bank, or the point of grid connection, although the cable is not such a major expense with modern, higher voltage operation.

LH turbines operate with a cable voltage in the range 70-120V DC. Turbine sites up to 1,000 m away are often economically viable using 2-core aluminium cable. EcoInnovation holds considerable stocks of cable at very good prices for our NZ customers

For longer high power cable runs, 200-400V operation is possible. Please contact PowerSpout for more detailed advice for such sites.

3.8.1. Cable sizing

The Advanced Calculator tool on the www.powerspout.com web site will work out the cable size for you for a given % loss or the % loss for a given cable size.

Try to keep losses as low as possible, particularly if you have limited hydro generation and need all the power you can get. A loss of 5% in cables is normal. Cables with losses greater than 10% should only be used in cases where the cable cost is very significant in the total equipment cost and/or where you can generate plenty of power (more than needed).

3.9. Water diversion and return

Micro-hydro systems may potentially affect:

- Plants and fish in the water.
- Plants and animals beside the water.
- Stream banks and surrounding land.

You must check with your local authorities to see if you need to obtain consent either to build any structures or to take/return water from a waterway. The impact of your system on stream ecology will usually be considered during this process. EcoInnovation have some consent application examples for NZ that we can email you that might help in your application.

Diverting less than 50% of the minimum seasonal flow rate in your water source means there is no impediment to fish moving up or down stream and hence gives aquatic life a better chance to survive.

Natural waterfalls and steep rapids often prevent the free upstream movement of aquatic life, as such turbines that exploit natural waterfalls may take more water and do not need to provide fish passage.

Where the fall is engineered from pipes or timber flume the natural bed of the river becomes the best fish pass possible, but you must leave some water remaining in the riverbed.

You should take care to ensure that the exhaust water from the turbine can return to the river without scouring the bank or bed of your waterway. Where the exhaust water from the draft tube impacts the river bed, line the river bed with timber/concrete. (This is illustrated later in the manual).

Numerous studies have shown that small fish can pass through Kaplan/Propeller turbines unharmed. Kill rates typically range from under 5% to approximately 20% if instantaneous pressure changes are less than 4m.

It is not possible to completely screen small fish from entering the LH turbine. If you did the screen would block very quickly stopping any generation. In some countries authorities insist on intake screens of 1-3mm in size. In such cases you will have to install an automatic screen cleaner. PowerSpout are working on such a cleaner, that we hope to have available in late 2016.

4. Site civil works and water management

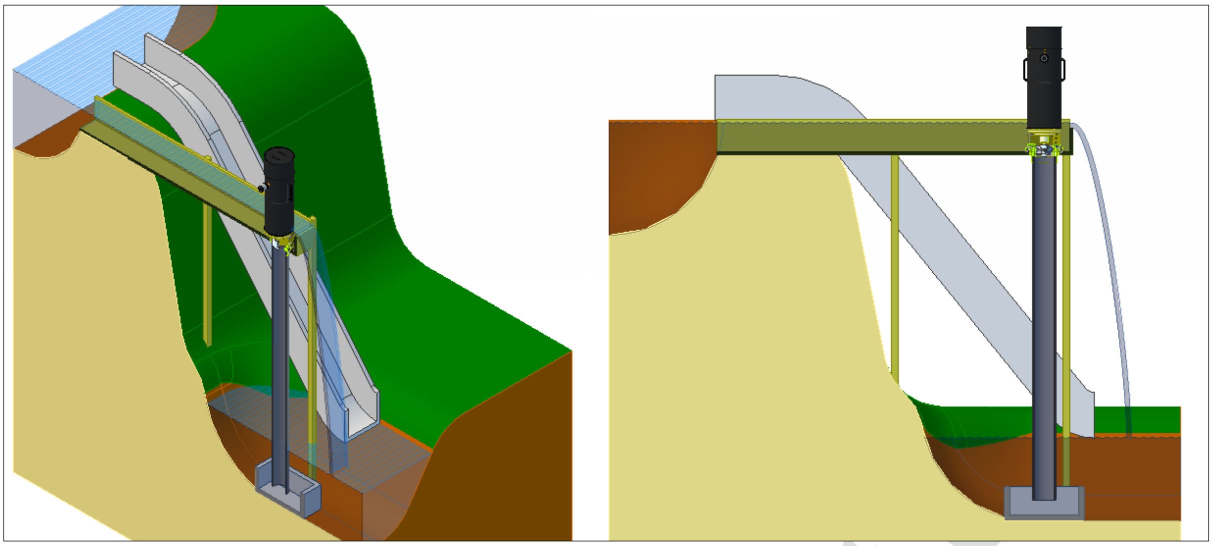


Figure 1. Typical installation of LH turbines

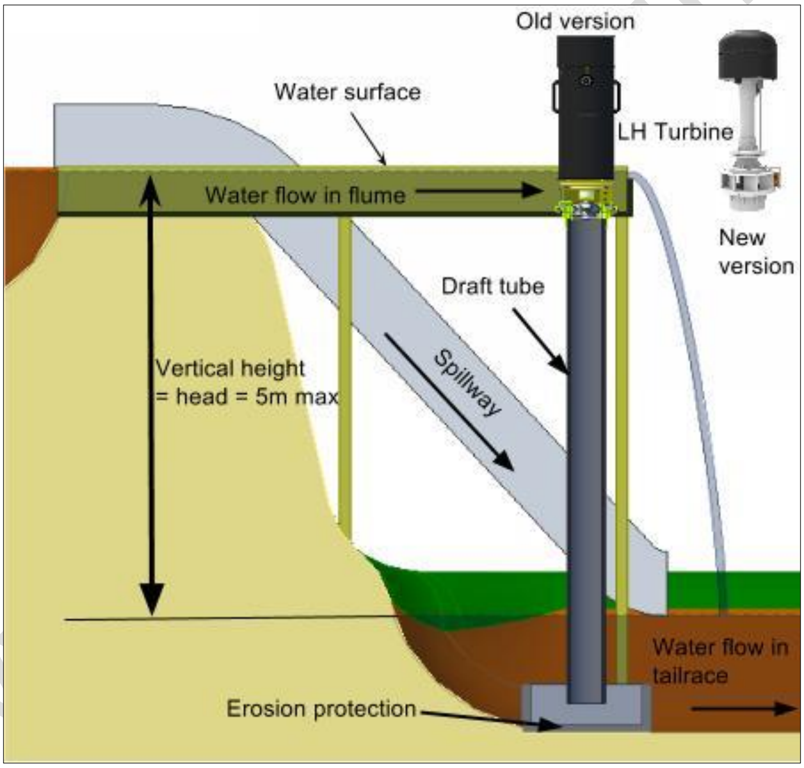


Figure 1 illustrates:

- Timber flume (normally plastic-lined) to supply water and attain the fall needed
- Intake overflow path (spillway) for excess water and fish pass
- PowerSpout LH Pro turbine (<u>with old-style long fairing no longer made</u>)
- Vertical draft tube
- Erosion protection at the end of the draft tube
- Spillway bypass for flood flows - could be the natural riverbed or an engineered structure or both.

4.1. Intake

Water intake pipes capable of 50 l/s and more can be dangerous and easily capable of sucking a small child into them which could be fatal. Open timber flumes are safer in this regard but good signage and protection are essential, even on private lands. Intakes need to be protected by metal rails to ensure such accidents do not happen.

Many Low Head turbines are installed on the overflow of small lakes or dams and may only operate during the wetter months, with solar PV providing the power during the sunny months. Installation on dams and lakes is generally easier as the maximum flood height is often much less.

Avoid the many streams (e.g. in New Zealand) that increase 3-6 m in height in extreme floods. Maximum flood height should be less than 50-75% of the draft tube height.

4.1.1. Advice on fixing a flume to the top of a waterfall

Where you have a natural set of rapids in a stream you generally have a hard rock riverbed to work from. You can connect the flume into the bed of the river at the top of the falls during periods of very low river flows and/or by using sand bags to divert the flowing water around the work site. This is normally done with a combination of rock anchors and concrete. Advice on site from an experienced engineer is often helpful and well worth the consultation fees.

Protection from floods needs to be carefully considered on a site-by-site basis. The main ways to minimise flood risks include:

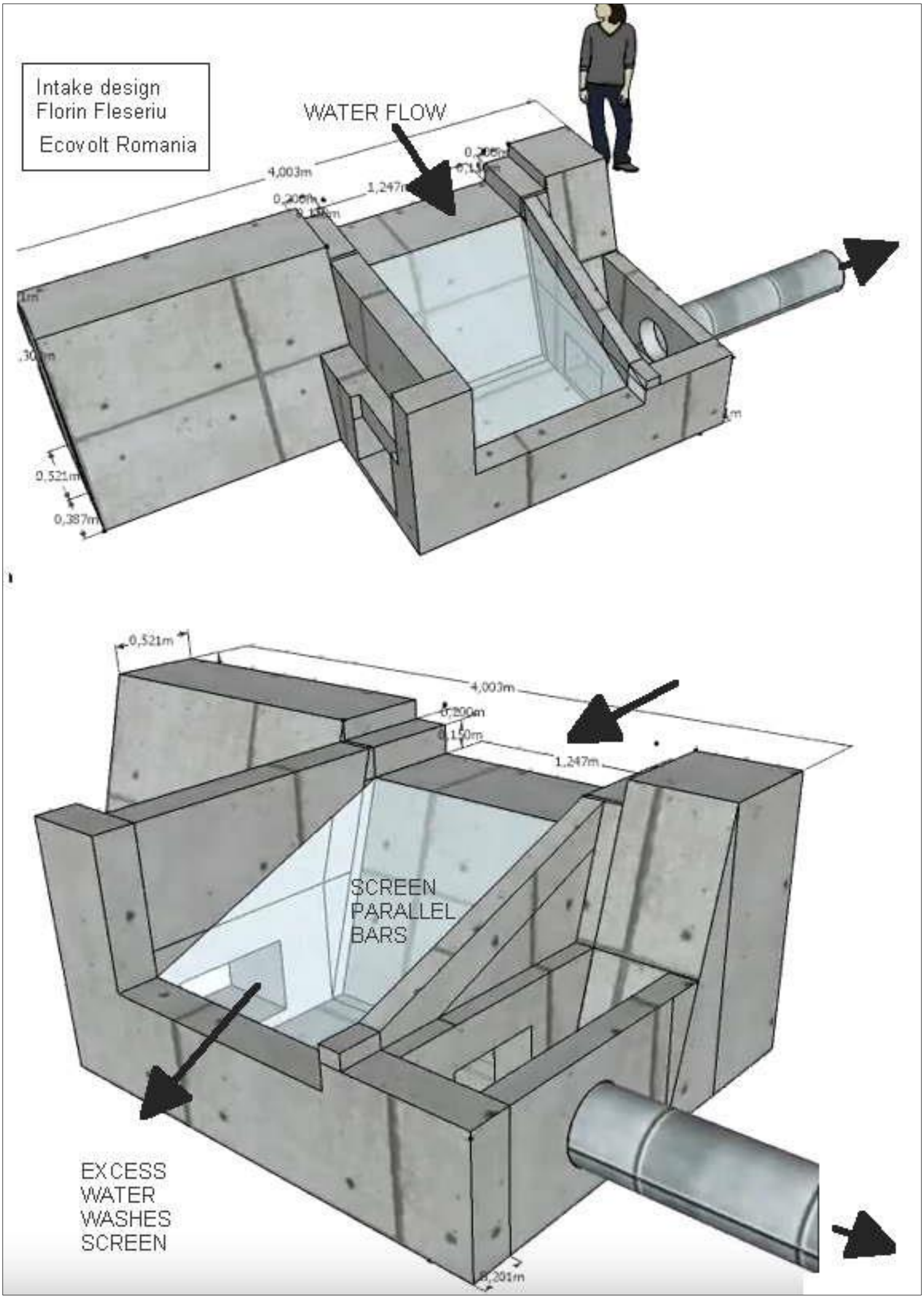
- Understand the flooding risks at your site by asking the locals and being observant during heavy rains.
- Have the take off to one side of the river.
- Do not restrict the flood path with the intake point of your take off, as this would increase the flood height.
- Use plenty of steel and concrete as needed.
- Seek professional advice, particularly on difficult sites.
- Always do a 1st rate job. Do not cut costs or you will regret it.
- Inspect the site after flood events and repair any damage as soon as possible.

The above is easier said than done and the task should not be underestimated. Many sites for Low Head turbines already exist, such as abandoned water wheel sites. Such sites may already have water being diverted into a channel or flume. It is likely that abandoned waterwheel site or sites that have natural falls will be the main application for the LH turbine.

4.1.2. Diversion structures (weirs)

Below are some drawings of a weir intake feeding a pipe. Water flows over the lowest part of the weir crest and into the intake chamber through a screen or trash rack. Overflow water helps to remove debris from the screen. In times of flood the level rises and a much wider crest is available for overflow. The weir also needs wing walls that are high enough to prevent floodwaters from washing out the banks on either side.

Note the access for cleaning/scouring sediment, and the opportunities for flow control gates on both sides of the central chamber. The penstock (pipe) is on the right. If the mouth of this pipe is to be closed with a sluice gate then you must fit a vent pipe on the penstock. This would be a vertical branch that rises above the intake water level.


Intake design
Florin Fleseriu
Ecovolt Romania
WATER FLOW
4,003m
1,247m
0,521m
0,387m
SCREEN
PARALLEL
BARS
EXCESS
WATER
WASHES
SCREEN

4.1.3. Dams and ponds

Damming a large body of water will not increase the head or the maximum output power of the turbine. Nor is it likely to offer energy storage that can run the LH turbine for more than a few hours (unless very large). Building a dam is unlikely to be cost-effective and may have unacceptable impact on local life-forms. But if you have other reasons for constructing a dam, or for diverting water into a pond, then there will be no problem in taking water from this source.

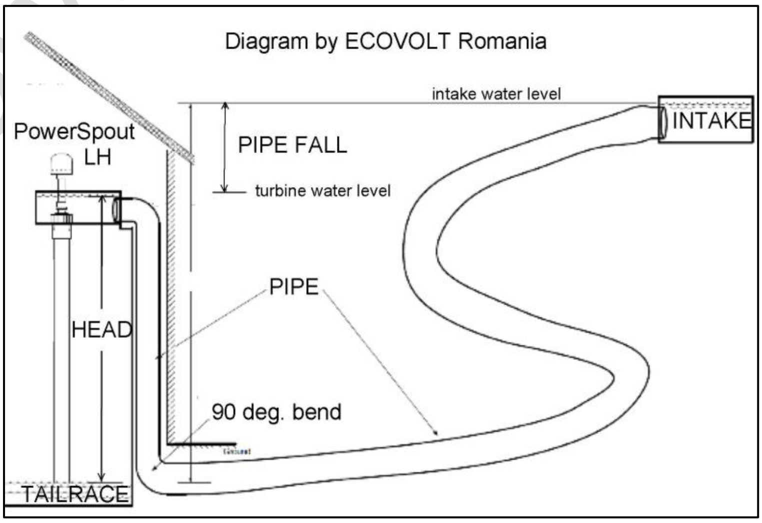
There is some benefit in using a large, static body of water. Floating debris will float and overflow. Heavier debris will sink. By using a submerged intake you will have very few problems of blocked filter screens with a pond intake. Make arrangements to clean the screen with a long handled brush. Vent the pipe so that a blocked screen cannot create a vacuum. If the mouth of this pipe is to be closed with a sluice gate then you must fit a vent pipe on the penstock below this gate or valve.

The filter mesh or screen should be deep below the water surface **at all times** so as to avoid sucking in floating debris. The slow movement of water will help to prevent the screen from blocking so that it rarely needs cleaning. The pipe mouth can be below the level of the turbine in some cases. Provided the water level is high enough in the pond you will still get enough flow.

4.2. Flume, channel or pipe penstock

4.2.1. Pipe fall

A large pipe, channel or flume will be needed to carry the very large volume of water (litres per second) from the intake to the turbine. We call this the penstock. Some head will be lost in the penstock. This is referred to in the Advanced Calculator as "pipe fall". Pipe fall is the **difference in height between the water surface** at the pipe or flume mouth and the water surface at the turbine. Any slope in the pipe itself may affect how full the pipe is (by bringing it above the surfaces in question) but if the pipe is full then any slope will have no effect on the "pipe fall" or the flow rate.



Much depends on setting the water levels at the intake and at the turbine correctly. If the "pipe fall" is insufficient then you will never get enough flow. You would need to use a larger pipe, raise the intake level or lower the turbine level.

If the fall is excessive then you may need to take steps to limit the flow velocity. The preferred solution to excessive flow would be to raise the water level at the turbine, as this increases the head, but it may not be practicable to do this without overloading the supporting structure with the weight of water. Making the water deeper might also necessitate mounting the turbine on a plinth, or draft tube extension. For more insight please read the **PS LH Case Study April 14**.

The Advanced Calculator tool will help you to design your flume or choose a suitable size of pipe and prevent disappointment. Or you can do your own calculations. Note that **the Calculator assumes a partially full pipe**. A full pipe will deliver a higher flow rate (litres per second). A partially full pipe will deliver less flow, but the water is likely to arrive at high velocity and if the pipe is above water it will cause considerable mixing of air.

4.2.2. Water depth in pipe

The Calculator specifies the water depth in the pipe. The assumption here is that the pipe mouth is at the surface of the intake (as would be the case with a flume or open channel). The advantage of installing a pipe at this height would be a reduction in weight, assuming that the pipe must be supported on legs like a flume. Such a pipe must be carefully graded for constant slope.

The disadvantages are:

- The pipe needs more fall to deliver the flow, so more head is lost in this way.
- The velocity of the water is higher and you will get turbulence and mixing of air bubbles.

Where a pipe can be laid on or under the ground for support it will be preferable to keep the pipe well below the water surface at both ends of the penstock. Usually a pipe will slope downward but it may bottom out and rise again to feed the turbine. If for any reason the pipe has a high spot between the intake and the turbine then this must be vented with a vertical branch pipe to allow any trapped air to escape.

4.2.3. Penstock gradient

A shallow penstock gradient (say 1000:1 or one mm per metre run) between intake and turbine water levels is desirable to maximise turbine head and to minimise flow velocity. But you will find that it requires a larger pipe or flume which will be more expensive and heavier to support. The final design will take into account many factors including the available head and site details. It is not necessary to use the default pipe fall in the Advanced Calculator (0.1 metre). In fact this much fall in a 20 metre run will produce a high water velocity that must be mitigated by the construction of a very large tank at the turbine.

4.2.4. Flow rates in open flumes

The tables below provide examples of the flow rate in flumes and pipes with rectangular and circular cross-sections respectively. In each case there is a slight slope with a fall of 1mm per metre (1,000 mm) of watercourse. As mentioned above, there is no advantage to running a pipe partially full unless the weight is an issue (supported on legs).

The minimum dimensions of the side of the flume should be no less than 450mm wide and 400mm high to enable sufficient room to install a single turbine.

Table 2. Flow rate (l/s) for different rectangle flumes with a fall of 1 in 1000

Water Depth (m)	Width of flume (m)			
	0.45	0.6	0.75	0.9
0.2	63	92	122	152
0.3	108	161	215	272
0.4	156	234	317	405
0.5	-	311	425	545

Table 3. Flow rate (l/s) for different pipes with a fall of 1 in 1000

Water Depth (m)	Pipe Diameter (m)			
	0.3	0.4	0.5	0.6
0.2	31	43	52	60
0.3	40	78	104	126
0.4	-	86	152	198
0.5	-	-	155	256

4.2.5. Constructing Flumes

See section 5 for details of how we constructed our flume. If you are installing a flume at a site with natural rapids to attain a vertical fall you need to give due regard to the following:

- Flume size and fall
- Flume entry height
- Mechanism for limiting flow in flume (normally end and side flume overspill is employed)
- Mechanism to stop the flow of water
- Flume attachment at water take-off point
- Flume strength/design and support (often on rammed timber or steel posts)
- Flume lateral and longitudinal stability: you have many tonnes of top weight and good support is needed to prevent flume from falling over
- Flume strength/integrity in floods
- Screen to catch larger debris (sticks and twigs) in a position that can be easily cleaned. A finer intake screen is needed for the LH turbine without automatic cleaner.
- Designed to deter children from accessing or playing on it
- Safe and restricted access to the turbines for service and cleaning
- Large “danger” warning sign and physical barrier in the river before the intake so recreational river users do not get drawn into the intake

4.3. Turbine header tank

Where the water is brought to the turbine (or turbines) via a flume it would be normal to simply install the turbine(s) in the bed of the flume at its lower end as described in the next section (5). Where the penstock is a pipe then you will need to install a tank at a suitable elevation relative to the intake water level. The draft tube is installed in the floor of the tank and the turbine sits on top this tube.

4.3.1. Water level in the tank

The permissible range of water level at the turbine is 200-450mm. When designing the overflow, 300-350 depth is a good target to aim for. Water level here will determine the "pipe fall" and hence the maximum flow rate and water velocity. It would be helpful if the overflow level were made adjustable so as to fine-tune the flow rate. Excessive overflow may cause erosion and be detrimental to the flow in the diverted watercourse. It is also likely to cause air mixing. If air finds its way into the draft tube then the suction head will be diminished and the output will suffer.

It may be difficult to estimate the flow rate in a large pipe completely full of water, using the calculator. But pipe fall and flow calculations are important. Do not forget to make allowance for any tight elbow bends in the pipe as their influence can be significant in short penstocks.

4.3.2. Overflow

The overflow can be a simple notch in the tank wall so that surplus water cascades out and drops to the ground. In this case you will need to take care to avoid erosion. Alternatively you could fit another vertical pipe rising through the floor, with its mouth inside the tank at overflow level. Bear in mind that the overflow will set the water depth in the tank and thereby the maximum flow.

4.3.3. Tank size

For a single turbine the minimum size of tank would be approximately one square metre of surface area with walls 500 mm high. For example a section of flume 2.5 m long and 450 mm wide and 450 mm deep (based on the flume dimensions in Section 5) would be suitable. If the penstock is a pipe then this should be installed at a low level, for example at the bottom of the furthest wall from the turbine or entering the tank from below, at the far end of the tank. The reason for installing the pipe at low level is to make sure it is full of slowly moving water rather than having a shallow jet of high velocity water that disturbs the water in your tank.

4.4. Draft tube

Normally the draft tube will be vertical so as to minimise its length. The bottom end must be submerged at all times in the tailrace. During startup the draft tube gradually fills with water as air bubbles exit the bottom end. Once full it creates a suction head that drives the turbine runner. It is important to seal it so that no air can leak into the draft tube, as air bubbles will expand and reduce the weight of water pulling the suction head. See Section 5.4 below for a full description of how to install a vertical draft tube.

Sizing a vertical draft tube

PowerSpout Low Head turbines have been designed to use 200 or 250 mm OD thin wall (4-5 mm) PVC pipes for the draft tube. These pipes are commonly used for storm water, wastewater and culvert pipes in metric countries. Hence these are not supplied with the turbines. A 200 mm PVC pipe flange is supplied with each turbine and a 200-250 mm pipe adaptor and pipe joining sleeve can be supplied for an extra charge.

Draft tubes with over 4m head should have at least 6mm PVC wall thickness. We have observed 1 site where the daft tube collapsed due to the partial vacuum internally,

Once the length of the draft tube gets longer than 2.6m we recommend that you install the larger 250mm size. The larger pipe will give better results at all sites, but is more costly to do. The larger diameter slows the water, so there is less kinetic energy lost in the exhaust flow. For example, a 2.6 m head site using 200 mm OD vertical draft tube can generate >524 W from 40 l/s, with about 40 W (7%) lost to the kinetic flow needed for the exhaust water to exit the flume pipe. If a 250 mm OD pipe is installed then this loss reduces to 16 W (3%) and generation will increase to >548 W (a saving of 24 W = 210 kWh/year).

4.4.1. Draft sizes in the USA and countries that use schedule 40 PVC pipe

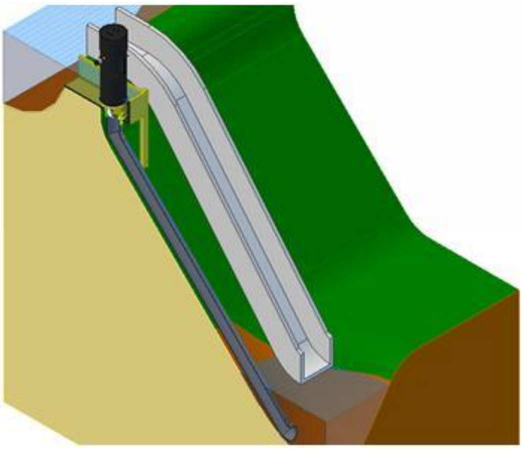
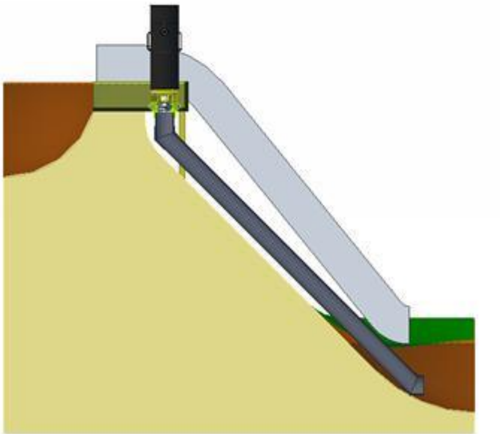
Metric OD pipe sizes are not commonly available in the USA so ‘schedule 40’ PVC pipe should be used. The 8” PVC pipe has an ID in the flared glue end of 219 mm. The 200 mm standard pipe flange supplied with the turbine we can machine to 219 mm OD (200mm ID) for these parts to glue together.

If the larger draft tube is needed then the OD of the 200-250 mm pipe adaptor is 273 mm and a flared end 10” pipe is also 273 OD, so these parts will glue together well.

Clients using schedule 40 pipe should advise the pipe ID and OD of both the flared and non-flared pipe ends when placing their order, so we can ensure that the pipe flange sent is a good fit.

Schedule 40 PVC pipe sizes				
Nominal pipe size Inches	O.D. Inches	O.D. mm	I.D. Inches	ID mm
8	8.63	219.08	7.94	201.73
10	10.75	273.05	9.98	253.39

4.4.2. Angled draft tube sites

The above illustrates another possible install situation. If an angled draft tube is used then it is longer and therefore has a greater friction loss. The output power can still be estimated from performance table 6.

At our test site we installed an angled drive tube (as shown) to test the concept. This comprised 8m of 250mm pipe and 2 x 90 degree bends as shown.

This was tested at 3.3m of head and produced 560 W. The flow was reduced due to the extra pipe friction.

On a straight pipe the turbine produces 760 W at 45 l/s. So the difference is 200W. As the angled draft tube is much longer and the bends are equivalent to about 10m of pipe we have less generation due to:

- Reduced flow rate in the pipe
- Increased pipe friction losses
- Losses due to the water exit velocity

If you need to use an angled pipe instead of a flume and vertical draft tube then you should:

- Increase the pipe to the next size up
- Keep the pipe as short as possible
- Have large radius "swept" bends and as few as possible
- Allow for some power loss
- Allow for the fact less water will be used

Angled draft tubes should not be used on heads above 4m without seeking our advice first.

If you do the above, your output power is likely to be 20-25% less, and flow rate 10-15% less than the tables indicate.

You may also find that the turbine will not self-start, and you may need to flick the magnetic rotor by hand to get it going. Be sure to replace the protective fairing afterwards. This is because the longer pipe is harder to fill with water so the negative pressure takes time to build. The stationary propeller inhibits the flow, so a flick of the magnetic rotor by hand helps ensure start-up. Or you can simply tilt the turbine and allow water to rush into the draft tube.

4.4.3. Does a draft tube need to be tapered?

Some suppliers of propeller turbines do supply a gradual tapering draft tube. These are very costly to freight around the world. There is some benefit in a tapering draft tube but it is small and PowerSpout LH turbines still produce more power from the flow despite the use of a parallel-sided draft tube. This is the reason we tend to use a larger draft tube size than our competitors.

4.5. Tailrace

The foot of the draft tube(s) must be submerged in the tailrace. Factors to consider include the following:

- Allow sufficient clearance below the pipe mouth so that water can escape (100 mm)
- The bed may need to be lined with concrete to prevent widespread erosion.
- In dry weather you will need a small weir or lip on the tailrace to retain water level above the pipe end. Check the end of the pipe is at least 200mm under the water line.
- In wet weather or floods it is important to make sure the tailrace area is open and well drained, because a rise in water level at the tail race will reduce the suction head and hence the power output.

5. Making a flume – guidance notes only

Reducing waste is always good, so planning your flume to use standard local timber sizes is an important part of good planning. What follows is an example that uses standard materials and produces almost no waste.

In NZ treated pine that has an off ground life >50 years is common. Materials used for garden and landscaping are often a few grades lower than construction premium grade and cost effective. In NZ this is often referred to as fencing grade.

Common fence materials you can buy in NZ include:

- 100x 50 mm x 4.8m long fence rails
- 75 x 50 mm x 4.8m long fence rails
- 50 x 50 mm x 1.2m long fence battens
- 150x 25 mm x 4.8m long boards
- 100 x100 mm post in a range of standard lengths every 600mm up to 3.6m

Always bolt joints with M12 galvanised bolts and 50x50mm square washer; nails are only to hold the material in place while you bolt it.

For a cost effective flume construction set your support posts every 2.4m and 450mm apart from inside edges. Riverbeds are often muddy and difficult to work in. We drove 75mm hot dipped galvanised pipes into the bank until they would go no further. This is hard demanding work only to be done by the physically fit and strong.

We then bolted the timber post to the pipes and straightened them up. By adjusting the length of the pipe we were able to get 3.6m height using only standard posts without any need to cut them.

Bolt horizontal 100 x 50 members between each post pair to support the bottom flume boards. Make sure you allow for a very small fall, and get your heights correct.

You will be using 150mm boards (3 wide) to line the bottom of the flume and 3 on each side to give a 450 x 450mm flume section. Stagger the joins every 2.4m so that the joins in neighbouring boards do not line up.

Cut your fence battens in half and every 600mm join the 3 x 150x 25mm boards together using 60-75mm long stainless steel screws.

The flume bottom will be very springy at this stage (do not walk on it yet).

Bolt the side boards in place staggering the joins as before. Using 60-75 mm long stainless steel screws, attach the outer edges of the bottom boards to the side boards every 100 mm to make a beam.

Then join all the side boards together every 600 mm with the battens as before. You can now walk along the flume safely.

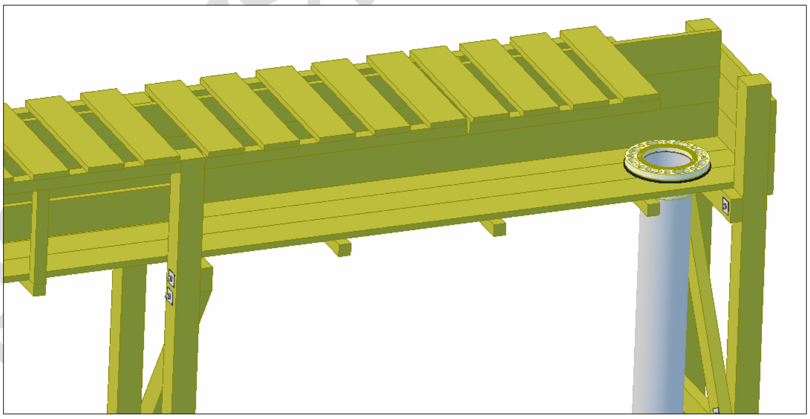
The diagonal braces shown are to provide lateral (sideways) restraint, but this may not be sufficient with posts bolted to pipes (consult local engineers). Lateral restraint can be increased by using screw ground anchors and guy cables to the top on the posts and tightening on opposing sides.

You will also need to provide longitudinal restraint. Bolting diagonal 100x50 opposing timbers between the sets of vertical post will suffice or you can use ground anchors and cables as mentioned before.

The end result needs to be a strong structure that can convey the water and bear the weight of several workers without any tendency to sway.

You can now attached thick UV stable plastic sheet and hold in place thin 10x30mm timber battens which will ensure your flume does not leak.

The last task is to make some firmly fitting board walk sections; these are made from the 50x50 mm battens and 150 x 50 mm boards previously shown. These should be screwed in place at each corner so that if you stand on the edge and it will not flip.



5.1. Getting access to your turbines

As your turbines might be 2-5 m in the air on top of a flume, you need a safe way to access them. This is best done by using the flume as a walkway. Walking in the water is dangerous as it will get slippery over time and there is a risk of a slipping accident. Also your electrician will not be too happy standing in water with all his test meters.

Removable board walks, about 1.2 m long and up to 500 mm wide, are the way to do it safely. How to do this cost effectively is covered in the guide to flume construction above.

Many jurisdictions around the world require that any fall greater than 1m has a 1 m high handrail around it and vertical members with a gap no more than 100 mm. As children are excluded from the site the need for verticals <100mm gap may not be needed.

Building a handrail may not be practical. The use of a safety harness and provision of strong clip on points may be a better way to comply with local safety regulations. We all recognise you can fall off a 3m waterfall and kill yourself, but as soon as you install a platform it needs to be safe for the people allowed to use it. Visitors (invited or not) to your property will be attracted to man-made structures and they have the right to expect them to be safe, even if they have not been invited to try them out.

For the above reason we can only offer guidance notes. You **must seek local advice** and comply with local building codes for any construction you may undertake. A building permit may be required.

Our guidance notes may not be acceptable in many highly regulated jurisdictions. Remember safety first!

This picture (with an older style LH turbine) shows a clip over flume boardwalk so the turbine can be accessed by walking along the top of the flume.

The position of the walkway board up against the turbine body ensures children cannot reach under and touch the turbine blades.

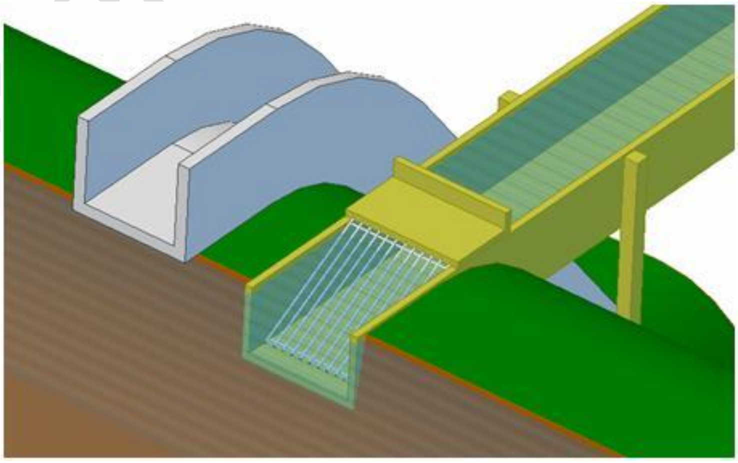
There is no handrail shown. Fall protection while on the boardwalk is provided via a harness and secure clip on points. Access to the boardwalk is prevented by a locked barrier 1.2m high and a 'Danger Keep Out' sign.

5.2. Making an intake strainer

Angled bars will stop and collect larger debris. The flowing water will tend to push rubbish up onto the flat surface where it is more easily cleaned away.

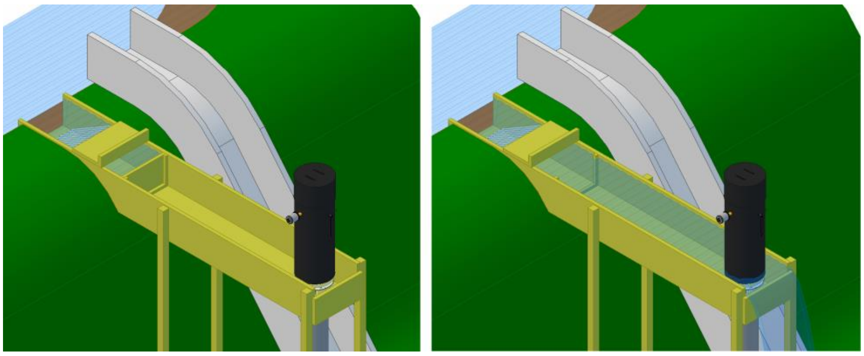
The grate also prevents access from the river/lake by recreational users into the intake flume.

Some on site experimentation will be needed to fine-tune the intake design to make it work well on your site and be easy to clean.



5.3. Stopping the water flow

You need to be able to stop the water flow. A simple plywood sheet gate can be used to do this as shown.



5.4. Installing a vertical draft tube into a timber flume.

In this example the total head water to water level is 3.6m and a 250mm OD PVC draft tube will be installed using the fittings that are available at time of purchase of your PowerSpout LH.

Pipes are always purchased locally. Thin walled PVC pipes are commonly used for culverts on farms. In this example a 6m length of 250mm OD PVC pipe was purchased for 200 $NZ (approx. 150 $US). This 6m length was almost enough pipe to make 2 draft tubes.

The parts needed:

- Draft tube to turbine fitting 200mm (supplied with turbines)
- 200-250mm Draft tube fitting adaptor (extra - not supplied with turbine)
- 200mm OD PVC pipe 230mm length (extra - not supplied with turbine)
- 250mm OD pipe of correct length (draft tube buy locally)

Apply PVC cement to both sides as shown and press both parts together; be quick because the parts will fuse quickly. Up to 80kg of force may be needed to push the parts together. Wipe off excess glue with a clean rag.

Repeat the above for the other components as shown

Measure the length of 250mm OD pipe needed accurately and cut to length.

Glue the pipe into position. A large force is needed to push the final join together. You will need several helpers to assist you to do this. Use gravity to aid you.

Mark in the base of your flume a hole the same size as the OD of the pipe adaptor (275mm approx.). The picture shows the plastic lining of the timber flume being cut with a 275mm plate as a guide. Drill 8-10mm start holes for your jig saw blade.



Cut out hole in the timber flume


Apply adhesive foam seal tape or cut an annular ring from foam sheet. A foam sheet camping matt can be a good cheap source for suitable material.


Install draft tube through hole in timber flume

Secure the pipe to the flume with 4-8 stainless steel tech screws.

Check the end of the flume is at least 200mm under the water line.

Secure the flume (note the webbing strap). Run the flume with full flow (no turbine installed). The exhaust water will then dig a hole in the river bed for you. Once sufficient room has been made, make a timber frame that fits in the river bed to protect it from further erosion. When the turbine is installed the exhaust water velocity is greatly reduced.

Normal flow when the turbine is installed.

The turbine shown here is installed and running at 870 Watts, 3.6m head and 47 l/s. The turbine is doing about 1300 rpm.

Note that the water depth is about 300mm, the turbine has all the water it needs to run at full power for the head of the site. Surplus water not needed continues down the flume, over a height control weir and back into the river.

Some fish can escape by this surplus flow route.

This is the same turbine running with about 50-60% of the water needed. The MPPT controller has slowed the propeller speed to stay at the maximum power point, output has dropped to 400 Watts and falling, head has fallen to 3.4m and speed to 800 rpm.
If the flow continues to drop then almost complete loss of generation can be expected.

At flows below 25 l/s either a Pelton, Turgo or LH-mini turbine should be employed so generation can continue during prolonged dry spells. This is also the time your solar PV panels will be working well, i.e. dry summer conditions.

A PowerSpout LH turbine can replace a water wheel at a fraction of the price as it has at this site.

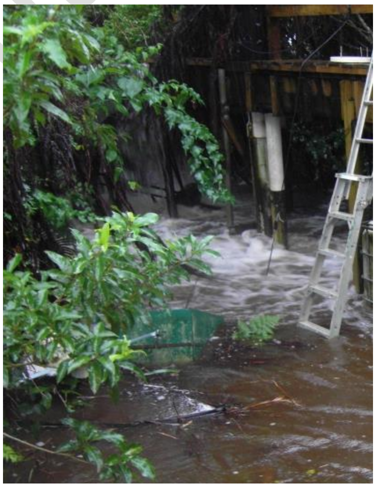
The following pictures illustrate several aspects at an install on an old duck shooting pond:

Concrete intake barrier connected to a PVC pipe (under the road crossing) then to a 20m timber flume to the get the fall required.

Primary flood path using the original riverbed route and weir to control pond height. Note adjustable wood section to alter height for fine-tuning. This flood path has no residual flow most of the time but it is very steep and no fish could navigate it. This site was checked by the local regional council prior to installing hydro equipment and it was determined not to require a permit.

Secondary flood path employing a concrete spillway over the top of the dam

The timber flume on other side of road is shown opposite. This site has a recorded minimum drought flow of 4 l/s and estimate maximum flood flows of 2000 l/s. It will flow over 50 l/s for 2-3 months of the year, normally when generation from solar PV is minimal. This site has been used as a test site to develop the PowerSpout Low head range of water turbines.



In contrast, the same site 4 years later during a 20 year flood event. Note the horizontal timber between the 2 steel support posts, this is level with the flood water in the next picture!.

LH turbines can generally cope with significant flood heights over 50% of their operational head.

6. Turbine Commissioning

Grease the bearings (20 ml grease) prior to first use. If you are fitting an automatic grease canister you will still have to pre-charge the bearings and the grease pipe first. Set up the controller correctly with guidance from the relevant **PS MPPT guide**.

Before connecting the MPPT controller or inverter to the PowerSpout, you must run the turbine with full flow and check the Voc as in the commissioning checks in section 6.2.

Once the turbine has been mounted and voltage commissioning checks below have been **completed** and passed, you may connect the inverter or MPPT controller. In most cases it is best to start the turbine first and allow the draft tube to purge itself of air before closing the relevant circuit breaker.

- Check for current flow to the load.
- Check you have plenty of water to feed the turbine.
- Check that the delivered Watts is similar to what you were advised after allowing for cable and MPPT regulator/inverter losses.
- Check for erosion/scouring/flume overspill and fix if needed.
- Check battery charge control is working.
- Check correct operation of the diversion loads.

It is important to formally commission the turbine and associated system to ensure it is working correctly prior to leaving the site for the day. If you do not have the time to correctly commission your turbine, then do not leave it running. Complete the procedure another day. Once you are happy that you have successfully commissioned the turbine you should record in the Log Book:

- Flow rate through turbine
- Actual operating head (water to water distance)
- Output Watts displayed on meter
- Settings of the MPPT controller or inverter
- Generator equilibrium temperature
- Picture of installation
- Date for next service check

6.1. Regulations and good practice guidance

In many jurisdictions around the world electrical work on equipment with operating voltages over 50 V AC and 75 V DC must be carried out by a registered electrical worker. The voltage limits are defined as the maximum voltage across any two points in the system.

A system operating with balanced DC, which is +60 and -60 V DC relative to ground, has a maximum potential of 120 V and is at the limit of unregistered electrical work in NZ and Australia. Most of Europe is 75 VDC. This limit if often referred to as the ELV (extra low voltage).

PowerSpout LH turbines do not meet these requirements for unregistered electrical workers (other than in NZ and Australia for models with a maximum voltage less than 120 V DC). You must ensure that an electrician, who is also a registered electrical worker, completes your installation and commissioning. In many cases you can install the equipment yourself and then have the electrician complete the final hookup, commissioning and turn on, but you should talk to your electrician before you start. The electrician will be responsible for your workmanship and may be reluctant to certify your workmanship, which may not be accessible after the work has started.

6.2. Commissioning tests (important!)

All LH turbines are connected directly to electronic controllers such as off grid MPPT regulators and grid-tied inverters. You must do the following commissioning tests **prior to hook up**. This test must be done by a qualified electrician and documented as proof they have been done.

- Run the turbine electrically **disconnected** with maximum water flow and head possible and measure the DC voltage on the output terminals.
- To allow for a small ripple in the supply from the 3-phase rectification add 10% to the above value to obtain the maximum voltage.
- Check that this maximum voltage is less than the maximum input voltage approved for your MPPT regulator or grid-connect inverter by a margin of at least 10 volts.
- If the maximum voltage is too high, then **do not** hook up the equipment.
- If the maximum voltage is only just above the rating of the equipment then you can pack the rotor with 1-2 washers to solve the issue.


Turn the knob to pull the magnet rotor slightly outward, and run the turbine to check the voltage. Once the best position has been found, pack behind the rotor with washers and tighten by hand to ensure rotor stays in the chosen position.

(Note two 1mm thick stainless steel washers are supplied for packing).

- Should the maximum voltage still be too high then contact your supplier. Do not hook up your turbine until you get a valid test as above. A fail means there is a problem that needs to be resolved before you can continue with the commissioning process.
- You must repeat these tests after a turbine service, as it is easy to forget to replace the packing washers.

No liability for damage to connected electronic equipment is accepted, as if you had correctly done the above checks this could not happen.

6.2.1. Commissioning example

An LH turbine connected on a 3.0m head was supplied with a stator that had the code 100-7S-2P- D engraved on the back. The 3 wires from the stator are internally connected in Delta.

The turbine was run disconnected from the MPPT controller and the voltage measured, 136 VDC was recorded. 136 +10 ripple = 146.

This has to be less than 150 VDC maximum input for an FM60 minus a 10 VDC safety margin. As the safety margin is only 4 VDC, one packer was placed under the magnetic stator and retested the unit. This time a margin of 12 volts was measured, so it was OK to proceed with hook up. Once hooked up the unit ran loaded at the maximum power point at 70 volts with a 3 V drop on the cable, i.e. 4.2% cable power loss.

The unit ran at 600 W on the display of the FM60. Allowing for 4% FM60 loss and 4.2% cable loss, it is calculated that the turbine is generating 600/(0.96*0.958) = 652 Watts. This compared very closely with the published output for the turbine at 3m head and 43 l/s flow rate.

All the above was documented and placed in the system manual folder for future reference.

7. Operating your system efficiently

7.1. Power meters

It is important that you have a means of permanently displaying the power generated by your hydro turbine. Most MPPT regulators and grid connect inverters do this.

A meter enables you to see any change in the output power, which could indicate a problem that needs your attention, such as:

- Blocked flume screen
- Blocked intake vanes or jammed auto cleaner
- Reducing river levels and available water flows making operation of the turbine no longer practical

Annual output for a continuously running turbine can be calculated as follows.

kWh/year = generation Watts x 24 x 365

For example a 500 W (0.5 kW) hydro will generate 4,380 kWh/year

To read amps in the cable you can buy a DC clamp meter (be careful not to buy the cheaper AC clamp meter).

We strongly recommend that any household living off the grid buys a good quality DC clamp meter, and learn how to use it, as this will be very useful in a Renewable Energy (RE) system. We also advise you to learn the difference between volts, amps, Watts and Watt-hours as it is very difficult for installers/advisors to assist over the phone or by email if you confuse these terms.

7.2. Maintenance

The PowerSpout is a durable machine but it runs 24/7 in a testing environment, so regular checks and maintenance are advised. A PowerSpout LH may do more revolutions in one year than a car engine during the life of the car. A car engine has a filtered and pumped oil lubrication system, whereas a small hydro turbine does not. You must pay special attention to the bearings.

Full details of the maintenance schedule and operations including how to assemble the machine are to be found in the **PS LH Service Manual**. A bearing maintenance schedule is described in the **PS LH Service Manual** and you are required to follow it if your 2-year warranty is to be honored. Should you have a failure during the 2-year warranty period **we will ask to see your logbook** as proof you have followed the maintenance schedule.

8. Troubleshooting

The fault-finding procedure here is concerned with only the PowerSpout LH operation. For assistance with your system please contact your equipment installer or provider. The following is designed to locate the majority of possible faults.

If you do not understand the electrical measurements below then please consult your installer or electrical worker for assistance. Never expose yourself or others to contact with any live parts during turbine operation, as there may be lethal voltages present.

If you are concerned your system is not operating correctly then measure the PowerSpout LH Watts and compare with the data supplied with your PowerSpout LH.

If Watts from your PowerSpout is within 10-20% of the design Watts provided for your site then the PowerSpout LH is working correctly and the difference is likely due to: cable losses, MPPT regulator/inverter losses, and small variations in the site data (head and flow).

If the Watts are between 20% and 80% of the design Watts.

- Confirm you have sufficient water and the head you are operating at. If it is the first assessment of your PowerSpout LH installation then also check the accuracy of your water resource information supplied when you ordered your PowerSpout.

If there is no generation check the following

- If output voltage is 0V and current is 0A then check water flow, and that the turbine is spinning and is electrically connected.
- If output voltage is 0V and current is at or above the design current then check electrical connections for a short circuit and correct fault.
- If output voltage is correct and the current is 0A then check and correct electrical connections to MPPT controller or grid tied inverter

8.1. Noise

Noise is not normally an issue. All PowerSpout LH turbines are quiet; there will be more noise generated from the flowing water. Our turbine in normally quieter than others as it turns slower and is enclosed. Hence if noise is an issue at your site you should check the following:

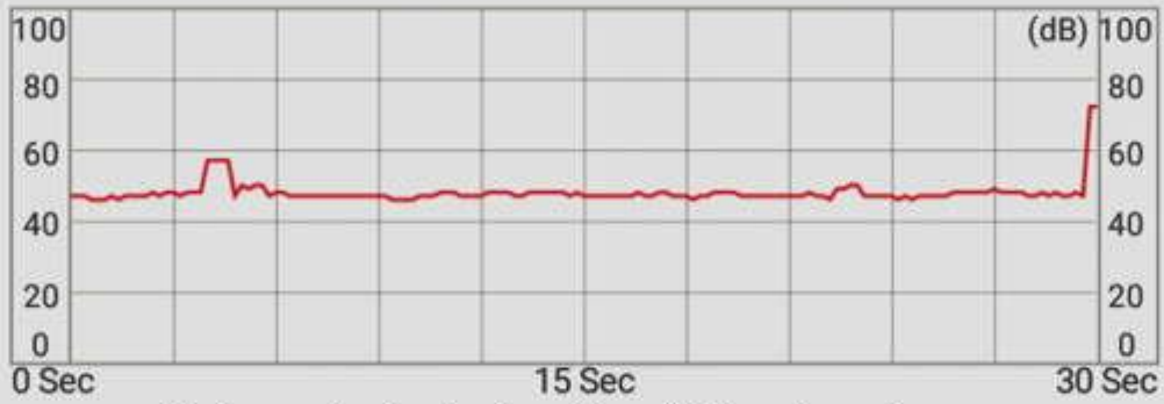
- The magnetic rotor turns freely, you have not picked up magnetic debris on the magnets when putting in together
- The bearings have been greased correctly as per the manual
- The bearings are in good condition (likely to be the cause if noise has increased gradually over time)
- The unit is running at the correct speed, it will run fast if your batteries are fully charged or the grid is down. If installed on an off grid battery based system fit a diversion load to turn on once batteries are full, most MPPT regulators have this functionality.
- The cutter bar is not hitting the top of the propeller blade? If it is the lower the position of the propeller.

Generally the higher the output power is, the more noise the unit will produce. It sounds like a washing machine in spin from behind a closed door. Vegetation around the turbine will dramatically reduce the distance that noise carries.

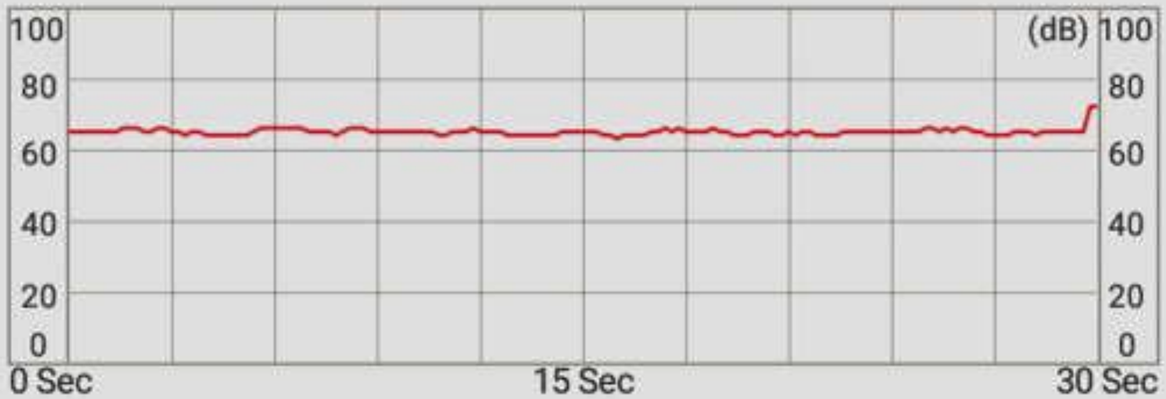
8.1.1. LH Noise Readings Monday, 27 July 2015

Site: EcoInnovation test site, 671 Kent Road, New Plymouth, New Zealand.
Head: 3.6m
Output: 850 Watts
Distance from turbine: 10m

Background noise level reading - flow stopped
Trace line steady at 48-50dB - light rain, birds and river noise.
Noise level reading – in operation
Trace line steady at 68dB – noise increase in the range 18-20dB



Background noise level reading with flow stopped



Noise level reading in operation

Comments.
Noise level will increase slightly with head/power output, likely to reach low 70's.

For comparison:
Weakest sound heard 0 dB
Normal conversation at 3 to 5 ft. 60-70 dB
Telephone dial tone 80 dB
City traffic from inside your car 85 dB

9. Site data for hydro required

9.1. PowerSpout Low Head site data

In order to assess your hydro site potential you can either

- Visit our web site www.powerspout.com and complete the Advanced Calculator tool, or
- Complete the table below and email it to questions@powerspout.com or a PowerSpout dealer. We/they will reply promptly with the best hydro option available for your site.

Table 4. Hydro site data required for product order/manufacture

		Units
Head at site (vertical drop/fall of pipe)		m or ft.
Flow available		l/sec or USgal/min
Can a vertical draft tube be installed	Yes / No	
Have you checked that you can buy 200mm and 250mm OD thin walled PVC pipes locally	Yes / No	
If No above then state the inside and outside dimensions of the PVC pipes you can obtain of a similar size. State these dimensions for both the plain and flared ends on the pipe.	Flared end ID mm/Inch ____ Plain end OD mm/Inch ____	Flared end OD mm/Inch ____ Plain end OD mm/Inch ____
What is the cable length from turbine to MPPT battery controller or grid-tied inverter?		m or ft.
If cable is installed what size is it		mm^2 or AWG
Do you want us to advise cable size?	Yes / No	-
For off grid system state your battery voltage	12/24/48	Volts
For off grid system state which MPPT controller you intend to use		
For grid connect state the make and model of grid-tie inverter you intend to use		

Your turbine will be designed for the site data you supply above. If you operate it on a different site, the output power will differ and not necessarily match the prediction of the advanced calculator. A new generator core may be required to obtain the best results in such cases. LH turbines can only run over a maximum 2:1 variations in flow rate ie it can tolerate a reduction in the flow rate to half the design (maximum) flow. While it will still run, it will produce less than half the power because the head and the turbine efficiency will also have dropped a little. For example, if a turbine is designed to generate 1000 W with 50 l/s and the water flow drops to 25 l/s it will generate approximately:

25/50 x 1000 x 0.9 = 450 W

Once flow drops below 50% the MPPT tracker cannot slow the blade sufficiently and air will get drawn in. This means the vacuum will be lost and generation will be minimal if any at all (10-50 Watts).

9.2. Installation details

We recommend you take note of and let us know the final system details (as below) for future reference and to help with ordering replacements or upgrading the system.

We would also like you to let us know your performance data so that we can determine conversion efficiency at your site. This helps us refine our calculations for future clients. As every site is different efficiency will vary slightly from site to site.

Table 5. Hydro installation and performance data

Installation details	
Date installed	
Location of installation	
Draft tube inside diameter	m or inch
Draft tube outside diameter	m or inch
Draft tube length	m or ft.
System nominal voltage	V
Cable length	m or ft
Cable wire size (if installed)	mm^2/conductor
Generator name (e.g. 100-14S-1P delta)	100/80/60/60dc - ____S-____P delta/star
MPPT regulator or inverter installed	
Performance data	
Flow rate of water through turbine	l/s or gal/min
Watts delivered	W
Maximum power point operating voltage	V

10. Feedback

We welcome your constructive feedback on how we can improve our products, including this manual. Testimonials for our hydro products can be view at www.powerspout.com/testimonials/
As EcoInnovation endeavors to reduce their footprint in many different ways, e.g. to save on paper and airfreight, this manual is only supplied electronically to customers. We encourage users to minimize printing where appropriate and to provide feedback via our website or via email (see Contact details inside front cover).

11. Units and conversions

- An **ampere** (amp, A) is the unit of measurement of electric current produced in a circuit by 1 volt acting through a resistance of 1 ohm.
- A **Btu** or British Thermal Unit is a standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound (16 ounces) of water by 1 degree Fahrenheit.
- A **current** is a flow of electrons in an electrical conductor. The strength or rate of movement of the electricity is measured in amperes.
- An **ohm** is the unit of measurement of electrical resistance. It is the resistance of a circuit in which a potential difference of 1 volt produces a current of 1 ampere.
- A **Watt** is the electrical unit of power: that is, the rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unit power factor.
- A **Watthour** is an electric energy unit of measure equal to 1 Watt of power supplied to (or taken from) an electric circuit steadily for 1 hour.

Volts x Amps = Watts

To convert	To	Multiply by
centimeters	Inches	0.3937
sq millimeters	sq inches	0.0015
meters	Feet	3.2808
miles per hour	Feet per second	1.4667
liters	Gallons	0.2641
liters per second	Gallons per minute	15.900
kilowatts	horsepower (electrical)	1.3405
degrees Celsius	degrees Fahrenheit	x 9/5 +32

To convert	To	Multiply by
inches	Centimeters	2.5400
Feet	Meters	0.3048
feet per second	Miles per hour	0.6819
US gallons	Liters	3.7854
US gallons per minute	Liters per second	0.0631
Horsepower	Kilowatts	0.7460
degrees Fahrenheit	degrees Celsius	-32 x 5/9

12. Annex I: Flow calculations and generator options

Table 6. PowerSpout LH1500 and LH1500 Pro

PowerSpout LH1500 and Pro (12/24/48 via MPPT regulators)											MPPT regulators up to 150 OCV			MPPT Regulators & Inverters up to 250 OCV			Grid tied inverters up to 400 OCV			Grid tied inverters up to 500 OCV		
Head		Flow approx		Watts	Efficiency	RPM	Runaway RPM	W/RPM	*Draft Tube I.D. mm	Watts lost in Draft tube	Stator fitted	Open Circuit Voltage	Running Voltage	Stator fitted	Open Circuit Voltage	Running Voltage	Stator fitted	Open Circuit Voltage	Running Voltage	Stator fitted	Open Circuit Voltage	Running Voltage
m	ft	l/s	GPM																			
1.0	3.3	24.8	394	91	37.5	688	1032	0.13	190.00	9	100-7s-2p- star	137	69	80-7s-2p-delta	205	103	80-7s-2p-star	361	181	80-14s-1p-delta	411	205
1.1	3.6	26.0	413	107	38.0	722	1083	0.15	190.00	11	100-7s-2p- star	144	72	80-7s-2p-delta	215	108	80-7s-2p-star	379	189	80-14s-1p-delta	431	215
1.2	3.9	27.1	431	123	38.5	754	1131	0.16	190.00	12	100-7s-2p- star	150	75	80-7s-2p-delta	225	113	80-7s-2p-star	396	198	80-14s-1p-delta	450	225
1.3	4.3	28.2	449	176	49.0	785	1177	0.22	190.00	14	80-2s-7p-star	118	59	80-7s-2p-delta	234	117	100-14s-1p-star	313	157	80-14s-1p-delta	468	234
1.4	4.6	29.3	466	199	49.5	814	1221	0.24	190.00	16	80-2s-7p-star	122	61	80-7s-2p-delta	243	122	100-14s-1p-star	325	162	80-14s-1p-delta	486	243
1.5	4.9	30.3	482	223	50.0	843	1264	0.26	190.00	17	80-2s-7p-star	126	63	100-14s-1p-delta	192	96	100-14s-1p-star	336	168	80-7s-2p-star	442	221
1.6	5.2	31.3	498	248	50.4	870	1306	0.28	190.00	19	80-2s-7p-star	130	65	100-14s-1p-delta	198	99	100-14s-1p-star	347	174	80-7s-2p-star	457	228
1.7	5.6	32.3	514	272	50.5	897	1346	0.30	190.00	21	80-2s-7p-star	134	67	100-14s-1p-delta	205	102	100-14s-1p-star	358	179	80-7s-2p-star	471	236
1.8	5.9	33.2	528	297	50.6	923	1385	0.32	190.00	23	80-2s-7p-star	138	69	100-14s-1p-delta	211	105	100-14s-1p-star	368	184	80-7s-2p-star	485	242
1.9	6.2	34.1	543	323	50.7	949	1423	0.34	190.00	25	80-2s-7p-star	142	71	100-14s-1p-delta	216	108	100-14s-1p-star	378	189	60-7s-2p-delta	413	206
2.0	6.6	35.0	557	349	50.8	973	1460	0.36	190.00	27	80-2s-7p-star	146	73	100-14s-1p-delta	222	111	100-14s-1p-star	388	194	60-7s-2p-delta	423	212
2.1	6.9	35.9	571	376	50.9	997	1496	0.38	190.00	29	80-2s-7p-star	149	75	100-14s-1p-delta	227	114	100-14s-1p-star	398	199	60-7s-2p-delta	434	217
2.2	7.2	36.7	584	404	51.0	1021	1531	0.40	190.00	31	80-2s-7p-star	153	76	100-14s-1p-delta	233	116	80-7s-2p-delta	305	152	60-7s-2p-delta	444	222
2.3	7.5	37.6	597	433	51.1	1044	1565	0.42	190.00	33	100-7s-2p-delta	119	59	100-14s-1p-delta	238	119	80-7s-2p-delta	312	156	60-7s-2p-delta	454	227
2.4	7.9	38.4	610	463	51.2	1066	1599	0.43	190.00	35	100-7s-2p-delta	122	61	100-14s-1p-delta	243	122	80-7s-2p-delta	318	159	60-7s-2p-delta	464	232
2.5	8.2	39.2	623	493	51.3	1088	1632	0.45	190.00	37	100-7s-2p-delta	124	62	100-7s-2p-star	217	109	80-7s-2p-delta	325	162	60-7s-2p-delta	473	237
2.6	8.5	39.9	635	524	51.4	1110	1664	0.47	190.00	40	100-7s-2p-delta	126	63	100-7s-2p-star	221	111	80-7s-2p-delta	331	166	60-7s-2p-delta	483	241
2.7	8.9	40.7	647	555	51.5	1131	1696	0.49	240.00	16	100-7s-2p-delta	129	64	100-7s-2p-star	226	113	80-7s-2p-delta	338	169	60-7s-2p-delta	492	246
2.8	9.2	41.5	659	587	51.6	1151	1727	0.51	240.00	17	100-7s-2p-delta	131	66	100-7s-2p-star	230	115	80-7s-2p-delta	344	172	80-7s-2p-delta	344	172
2.9	9.5	42.2	671	620	51.7	1172	1758	0.53	240.00	18	100-7s-2p-delta	134	67	100-7s-2p-star	234	117	80-7s-2p-delta	350	175	80-7s-2p-delta	350	175
3.0	9.8	42.9	682	654	51.8	1192	1788	0.55	240.00	19	100-7s-2p-delta	136	68	100-7s-2p-star	238	119	80-7s-2p-delta	356	178	80-7s-2p-delta	356	178
3.1	10.2	43.6	693	688	51.9	1212	1817	0.57	240.00	20	100-7s-2p-delta	138	69	100-7s-2p-star	242	121	80-7s-2p-delta	362	181	80-7s-2p-delta	362	181
3.2	10.5	44.3	705	723	52.0	1231	1846	0.59	240.00	21	100-7s-2p-delta	140	70	100-7s-2p-star	246	123	80-7s-2p-delta	367	184	80-7s-2p-delta	367	184
3.3	10.8	45.0	715	759	52.1	1250	1875	0.61	240.00	22	100-7s-2p-delta	143	71	80-2s-7p-star	187	94	80-7s-2p-delta	373	187	80-7s-2p-delta	373	187
3.4	11.2	45.7	726	795	52.2	1269	1903	0.63	240.00	23	100-7s-2p-delta	145	72	80-2s-7p-star	190	95	80-7s-2p-delta	379	189	80-7s-2p-delta	379	189
3.5	11.5	46.3	737	832	52.3	1287	1931	0.65	240.00	24	100-7s-2p-delta	147	73	80-2s-7p-star	193	96	80-7s-2p-delta	384	192	80-7s-2p-delta	384	192
3.6	11.8	47.0	747	870	52.4	1306	1959	0.67	240.00	25	100-7s-2p-delta	149	74	80-2s-7p-star	196	98	80-7s-2p-delta	390	195	80-7s-2p-delta	390	195
3.7	12.1	47.6	758	908	52.5	1324	1986	0.69	240.00	26				60dcHP-1s-12p-star	185	92	60dcHP-2s-6p-star	371	186	60dcHP-2s-6p-star	371	186
3.8	12.5	48.3	768	947	52.6	1341	2012	0.71	240.00	28				60dcHP-1s-12p-star	187	94	60dcHP-2s-6p-star	376	188	60dcHP-2s-6p-star	376	188
3.9	12.8	48.9	778	986	52.7	1359	2038	0.73	240.00	29				60dcHP-1s-12p-star	190	95	60dcHP-2s-6p-star	381	191	60dcHP-2s-6p-star	381	191
4.0	13.1	49.5	788	1026	52.8	1376	2064	0.75	240.00	30				60dcHP-1s-12p-star	192	96	60dcHP-2s-6p-star	386	193	60dcHP-2s-6p-star	386	193
4.1	13.5	50.2	798	1067	52.9	1393	2090	0.77	240.00	31	Not possible use 250 vdc regulator			60dcHP-1s-12p-star	194	97	60dcHP-2s-6p-star	391	195	60dcHP-2s-6p-star	391	195
4.2	13.8	50.8	807	1109	53.0	1410	2115	0.79	240.00	32				60dcHP-1s-12p-star	197	98	60dcHP-2s-6p-star	396	198	60dcHP-2s-6p-star	396	198
4.3	14.1	51.4	817	1151	53.1	1427	2140	0.81	240.00	33				60dcHP-1s-12p-star	199	100	60dcHP-3s-4p-delta	342	171	60dcHP-2s-6p-star	400	200
4.4	14.4	52.0	826	1193	53.2	1443	2165	0.83	240.00	34				60dcHP-1s-12p-star	201	101	60dcHP-3s-4p-delta	346	173	60dcHP-2s-6p-star	405	202
4.5	14.8	52.5	836	1236	53.3	1460	2190	0.85	240.00	35				60dcHP-1s-12p-star	204	102	60dcHP-3s-4p-delta	350	175	60dcHP-2s-6p-star	409	205
4.6	15.1	53.1	845	1280	53.4	1476	2214	0.87	240.00	37				60dcHP-1s-12p-star	206	103	60dcHP-3s-4p-delta	354	177	60dcHP-2s-6p-star	414	207
4.7	15.4	53.7	854	1325	53.5	1492	2238	0.89	240.00	38				60dcHP-1s-12p-star	208	104	60dcHP-3s-4p-delta	358	179	60dcHP-2s-6p-star	418	209
4.8	15.7	54.3	863	1370	53.6	1508	2261	0.91	240.00	39				60dcHP-1s-12p-star	210	105	60dcHP-3s-4p-delta	362	181	60dcHP-2s-6p-star	423	211
4.9	16.1	54.8	872	1415	53.7	1523	2285	0.93	240.00	40				60dcHP-1s-12p-star	212	106	60dcHP-3s-4p-delta	366	183	60dcHP-2s-6p-star	427	214
5.0	16.4	55.4	881	**1462**	53.8	1539	2308	0.95	240.00	42				60dcHP-1s-12p-star	215	107	60dcHP-3s-4p-delta	369	185	60dcHP-2s-6p-star	432	216