PowerSpout Installation Manual

Domestic installs

Industrial install

Please read this manual carefully before beginning installation

February 2011. Version 1.2

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1.1. Minor text and picture revisions. Jan 2011.
1.2. Updated PowerSpout versions available and further minor revisions. Feb 2011.

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.

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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.

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1. Introduction

Congratulations on your choice of PowerSpout. This ingenious little device will give you years of trouble free generation, avoiding the need for expensive generators or power bills. Not only does the PowerSpout 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.

This manual will help guide you through the process of installation so that your PowerSpout is installed correctly and runs efficiently. PowerSpout turbines have been shown to achieve up to 60% efficiency and with multiple units up to 16 kilowatts (kW). Single turbines can generate up to 1.6 kW. You can estimate your generation capacity with our online Advanced Calculator (www.powerspout.com). Be assured that our calculations take into account pipe and cable losses, so we will not fall into the common trap of overstating output.

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 includes information and links to relevant tools to facilitate this process. It should take no more than one day for two people to install a PowerSpout, depending on site terrain.

The manual is intended to guide you through PowerSpout assembly[1] and the installation process. It starts with an overview of a micro-hydro system and then proceeds through each stage of the installation. Advice is also provided on basic maintenance to ensure safe and reliable supply of power for years to come.

Videos to introduce PowerSpout and demonstrate PowerSpout assembly and bearing replacement are available via www.powerspout.com.

A video on the history of the Smart Drive generator over the last 20 years may interest many customers.

[1] The PowerSpout is larger than a standard airfreight carton. In order to get economic global freight that can be included in the price (and to allow for global drop shipping) for no extra charge, the unit has to be broken down into 3-4 sub assemblies which only take 5-10 minutes to put back together again. Each turbine has been fully assembled and tested prior to being broken down for freight. Putting the turbine together also helps dealers/customers fully understand the product for future servicing needs.

2. Components of your hydro system

A typical hydro system includes a good water supply, a generator and some type of electricity storage.

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). A rough estimate of generation potential 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 www.PowerSpout.com for more information and to use the Advanced Calculator tool. There is also an Advanced Calculator manual available for download, giving instructions and worked examples.

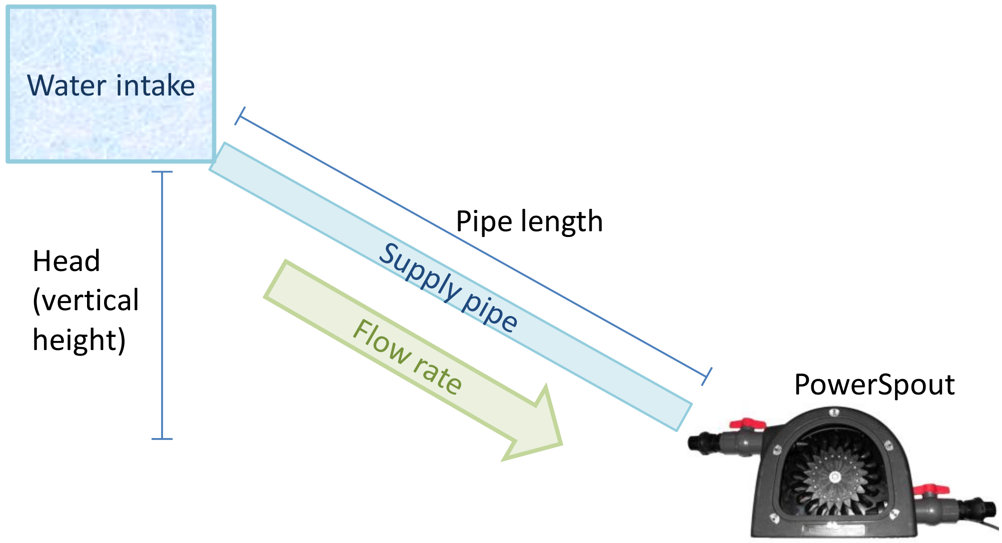


Figure 1. Water supply system.

2.1. Generator (PowerSpout)

A micro-hydro generator like the PowerSpout converts the potential energy of a watercourse to electricity. This is achieved by water jets impacting on the turbine rotor, spinning the rotor and hence the generator, which generates electricity. Micro-hydro generators produce 3-Phase AC power.

There are different versions of the PowerSpout available to suit different situations[2]. These are briefly described in Table 1 and further information is provided in the PowerSpout Technical Manual. Seek advice if you are unsure on the best PowerSpout option to meet your needs.

Cable choice is a key factor in selecting your PowerSpout version since this can have a significant impact on the installed system cost. Some versions enable you to reduce cable costs by increasing the system voltage:

[2] There are also Education and Demonstration versions available. Please contact us for more information.

- If you are living off grid and cable cost for your hydro is affordable (e.g. the cable costs less than the hydro turbine cost) then you should use the **BE version** (at 12, 24 or 48 V DC) direct to your battery bank.
- If you are living off grid and cable cost for your hydro is a major part of your overall cost then you should use the appropriate **ME version** at up to 250 V DC with a Maximum Power Point Tracking (MPPT) function regulator to alter the voltage and harvest optimum power (while charging your battery at 12, 24 or 48 V DC).
- If you are living on the grid/network you **may** use the **ME version** where the maximum input voltage of the inverter does not exceed 100/120/140 or 250 V DC depending on ME version. Most clients will use the **GE 400 version** that is designed for grid-tied situations via inverters that commonly operate at up to 400 V DC.
- For customers in New Zealand only, there is the **HE version** for up to 500 V AC 3-Phase output. Only consider the HE version if your supply cable can be installed safely. The HE turbine is rarely used as the ME or GE turbine can usually be employed and will be more efficient because transformers are not required.

Table 1. Different versions of PowerSpout

Version	Description	Cable length (m) approx.	Features
BE	Battery Enabled	0 - 250	Connected directly to a battery bank with a diversion load controller for system regulation.
ME 100	MPPT Enabled	50 - 750	Designed for inverters and MPPT regulators operating at less than 100 V DC (120 ELV*) or for the Latronic grid-tied inverters made in Australia.
ME 120	MPPT Enabled	50 - 1000	Connected to a battery bank through a MPPT controller such as the Outback FM60. Designed for inverters and MPPT regulators operating at less than 120 V DC (120 ELV*)
ME 140	MPPT Enabled	50 - 1500	Connected to a battery bank through a MPPT controller such as the Outback FM60. Designed for inverters and MPPT regulators operating at less than 140 V DC.
ME 250	MPPT Enabled	50 - 2000	Connected to a battery bank through a MPPT controller such as the Midnite Classic 250. Designed for inverters and MPPT regulators operating at less than 250 V DC.
GE 400	Grid Enabled	0 - 2000	Connected to a grid tied inverter to feed hydro generated power into the national grid or for use in mini grids via Sunny Island type inverters. Designed for inverters operating at less than 400 V DC.
HE (NZ only)	High-voltage Enabled	500 - 2000	Connected directly to a battery bank via three step-down transformers with a diversion load controller for system regulation.

*120 ELV (extra low voltage) laws in some countries allow home owners to install equipment up to 120 V DC without regulatory control applying to them.

Each of the key components is briefly described below. For further information please refer to the PowerSpout Technical Manual.

2.1.1. Setup for different systems

Different systems use different configurations of components as shown in the diagrams below. Instructions for electrical connections are included in Section 7.

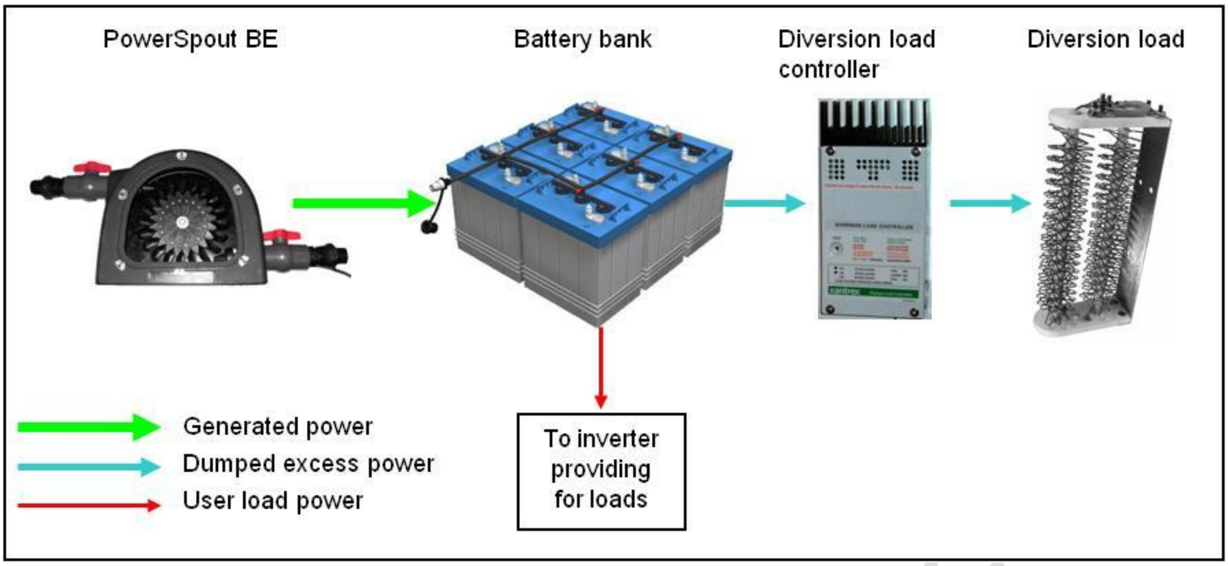


Figure 2. PowerSpout BE system setup

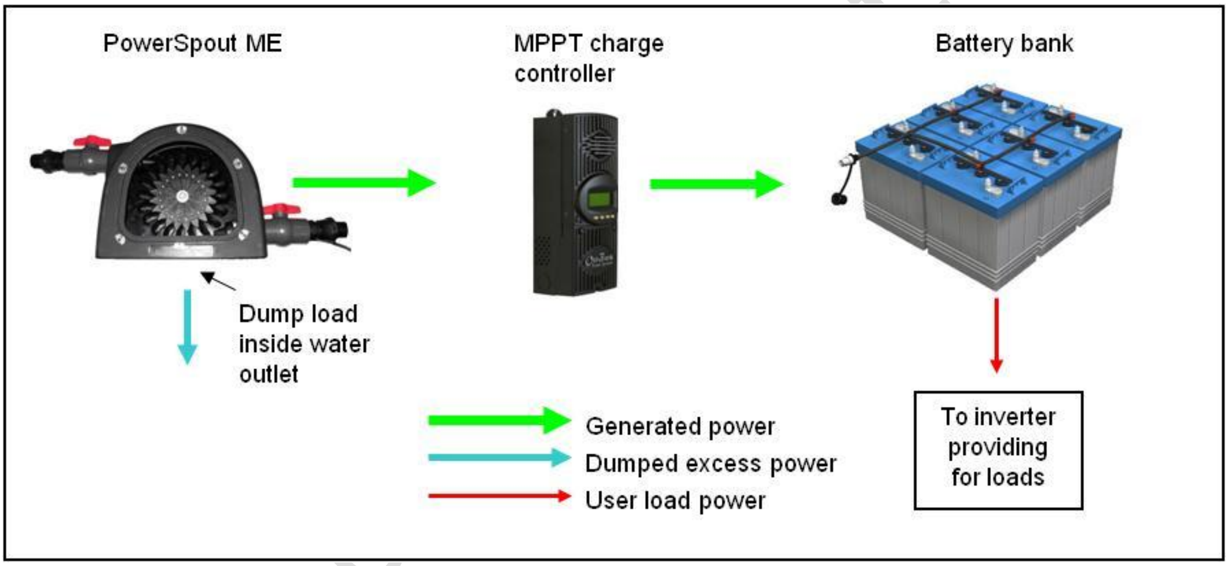


Figure 3. PowerSpout ME system setup

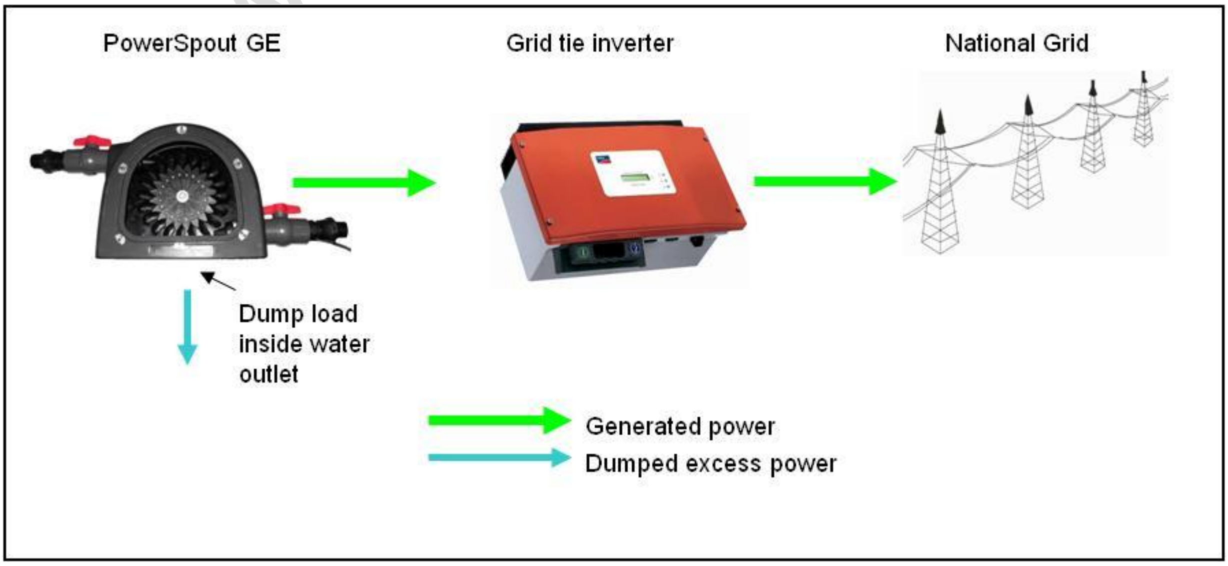


Figure 4. PowerSpout GE system setup

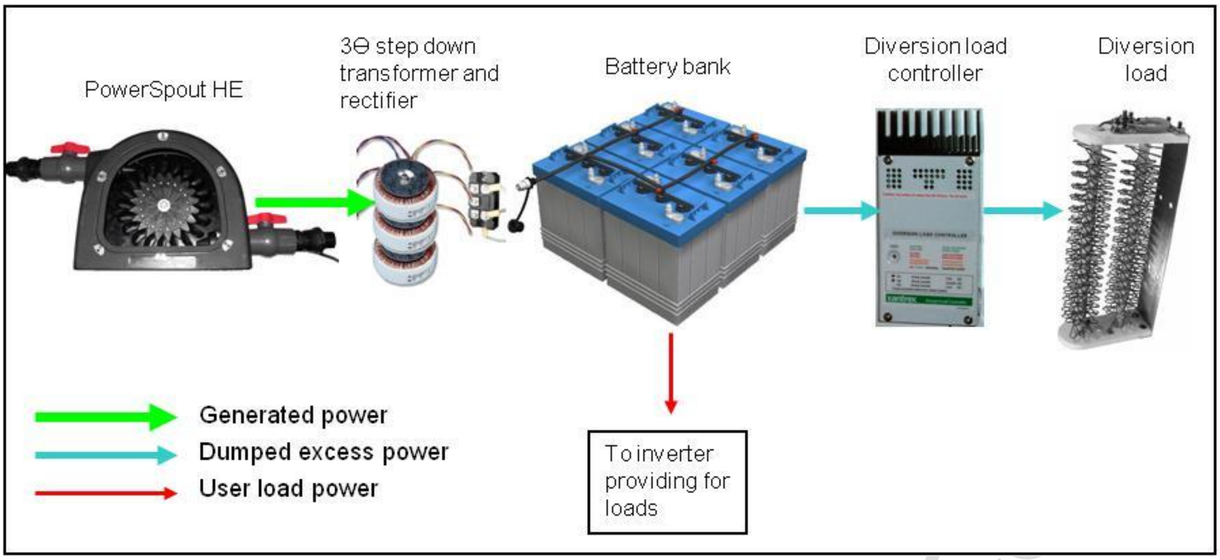


Figure 5. PowerSpout HE system setup

2.1.2. AC or DC power

Contrary to the common myth, it is more efficient to send DC along a cable than AC for the same cable size. The only exception is where you already own a cable with 3 conductors suitable for 3-phase AC. If we rectified the 3-phase AC and sent it as DC down 2 of the cables then the losses would be more, the cable area used is less in this case. If you do have a 3 core cable installed then combining 2 of the cables into one and sending DC down these 2 cables is more efficient that sending AC.

If you do not already have such a cable then you should use DC for transmission unless you intend to install the PowerSpout HE.

2.2. Rectifier

3 phase rectifier

A rectifier converts the 3-Phase AC produced by the micro-hydro to DC for supply to the battery bank to minimise losses. Generally DC is conveyed from the turbine to your battery bank. The main exception is the HE version that uses transformers.

Rectifiers get hot due to losses and lower voltage systems have greater losses. On new systems the preferred option is 48 V DC, though 24 V DC is also common provided cable costs are not too high. 12 V DC cannot be used for sites where more than 50m of cable is needed.

2.3. Battery Bank

Battery bank

In off-grid systems a battery bank is required to store power. The voltage of the battery bank dictates the voltage of the system (12 V, 24 V or 48 V DC) with 48 V being the most common. The quantity of batteries in the bank is dependent on the power requirements and the intermittency of power generation at your site. It is typical to have a number of batteries arranged in parallel and series to provide the desired voltage. Lead-acid batteries are most commonly used, although most other types are also suitable.

Batteries can also be used in on-grid systems to provide power when the grid is down. If there is a grid power cut your GE PowerSpout will disconnect itself from the grid so your home will also lose power. The extra cost to install a backup battery bank is difficult to justify unless you have frequent grid outages.

2.4. Inverter

Inverters convert the energy stored by the battery bank to a voltage and frequency suitable for typical household appliances – usually 230/240 V in Europe/Australasia and 110/120 V in North America. Square wave inverters tend to be cheaper but pure sine wave inverters produce a higher quality waveform that is necessary for more sensitive electronics commonly found in the modern home. Induction motors (as found in most refrigerators, workshop machine tools and air compressors) tend to overheat when used on square wave or “modified sine wave” inverters. Large induction motors starting direct on line may fail to start even on large pure sign wave inverters.

Outback inverter and regulator system

Inverters are available in a variety of power ratings (depending on the intended loads) and with a variety of surge ratings. A high surge rating allows loads with a high start-up power surge to run without overloading/tripping the inverter, or failing to start at all. Some inverters can also serve as charge controllers to regulate input from backup petrol/diesel/LPG generators.

2.5. Regulator (charge controller)

Regulators, also known as diversion load controllers or charge controllers, are an essential component of your renewable energy system. Regulators are responsible for ensuring correct charge rate and protection of your battery bank from overcharging. Once the regulator recognizes that your battery bank is fully charged it diverts additional incoming power to a diversion load. Regulators often allow you to set the voltage threshold at which power diversion starts.

Xantrex C40 regulator

Charge control is provided using any good quality charge controller such as a Xantrex C40 or Morningstar TS45. A Photovoltaic (PV) regulator is NOT suitable for micro-hydro and wind applications. The positioning and type of regulator used in a renewable energy system is critical to protecting not only the generator but also the rest of the system from damage. It is highly recommended that two regulators be used to reduce the likelihood of damaging your system should a single regulator fail.

When using a MPPT tracking charge controller and ME PowerSpout an additional backup controller is not normally required.

2.6. Backup Regulator

A secondary or backup regulator is recommended in all renewable energy systems. Since regulators are relatively inexpensive components redundancy will protect the higher value components in your system in the event of failure of the primary regulator.

2.7. Diversion Load: Hot Water Element

Hot water diversion element

A diversion load is required to dissipate excess power. Typically, with micro-hydro units diversion occurs regularly due to the constant power generation and hence it is advantageous to divert to a hot water heater element (special element required) to make use of this excess power.

Some regulators also contain programmable relays that allow 230/240/110 V AC loads to be turned on when there is surplus power. For example, when there is surplus a water pump or water heater can be turned on to soak up this excess power. Generally diversion loads need to be very robust and where there is any chance of failure a secondary diversion load to an air resistive element should be installed.

2.8. Diversion Load: Air-Resistive Coil

Air diversion element

The secondary or backup regulator should dissipate power through diversion to an air-resistive coil that expends excess power through generation of heat. This is also recommended for wind and PV systems where the random nature of excess energy diversion will not contribute significantly to the water heating requirements of the household.

2.9. Diversion within turbine (ME/GE versions)

In the PowerSpout ME and GE power is dumped into a water cooled load inside the turbine if the output voltage exceeds a preset limit. The preset voltage limits are set just below the maximum e.g. 115 V and 385 V for ME 120 and GE 400 respectively. This ensures the maximum voltage of 120 V and 400 V is never exceeded. See Technical Manual for more information on this voltage clamp (VClamp) function.

2.10. MPPT regulators

Outback FlexMax FM60 MPPT regulator

Maximum Power Point Tracking (MPPT) regulators have become common in recent years mainly for the large solar PV market. These regulators can also be used on hydro and wind applications as long as additional voltage protection is provided. The PowerSpout ME includes this additional voltage protection so that it can be used with most types of MPPT regulators. Different versions of the ME turbine are available from 100 to 250 V DC to match the maximum input voltages of your MPPT regulator and local wiring rules.

2.11. MPPT regulators – BE and ME turbine options

The PowerSpout BE turbine has been designed to run directly connected to the battery bank at 12/24/48 V DC. Our ME turbines have been designed to run just below 100, 120, 140 or 250 V DC via an MPPT regulator to your battery bank at 12/24/48 V DC.

The main advantage of the ME turbines is that you can save significant costs on cabling at the higher voltage. Although an MPPT regulator will get more power from the turbine (by not clamping the generation voltage) such regulators have internal losses of about 5% so there only a small net gain. A correctly optimized BE turbine will generate just as much, but an ME will automatically optimize for you and is a more flexible platform for variable flow sites.

We have noticed a trend by other hydro manufactures to approve MPPT regulators without any voltage limiting control in the turbine. We can advise that our BE turbine may be used with MPPT regulators if you have a 12 or 24 V DC battery bank. This is because the risk of overvoltage and hence regulator damage is increased at 48 V DC.

- MPPT Regulators have a maximum input voltage above which they will be damaged. You can estimate the maximum battery voltage you can have without voltage protection if you assume that most MPPT regulators stop working 10 volts below their stated maximum input voltage.
- The static head of the site determines the maximum revolutions (RPM) of the unloaded turbine. This occurs when the rotor is running at the same speed as the water jet.
- Measurement errors of the head may result in a 10% overestimate (90% correct) of the jet velocity. The running voltage of the hydro turbine will be 60% of the open circuit voltage at the correct running RPM.
- A free spinning unloaded hydro turbine spins at 2 times its normal speed.

For example, MPPT regulators like the Outback FM60/80 will be damaged if voltages exceeds 150 V DC, but will stop working at 140 V DC. Therefore the maximum battery voltage you can have without any over voltage protection is:

140 x 0.9 x 0.6 / 2 = 37.8 V DC

Therefore 24 and 12 V DC battery systems will be suitable since they are below 37.8 volts. A turbine that was designed and set up for an operating voltage below 37.8 volts will not have a voltage high enough when free spinning to damage the MPPT regulator.

For installations done by those who are not registered electricians, the maximum DC voltage you are allowed to work at replaces the maximum input voltage (140 V DC in the calculation above). 120 V DC is the upper limit in Australasia and some other parts of the world, and 50-70 V DC is also common globally.

If the ELV limit in your country is less than 90 V DC then you can only use our BE turbine on 12 VDC battery bank via an MPPT regulator to comply with both the Law over voltage limit of your FM60/80. 12 V DC systems are not common these days with the majority of systems being 24 or 48 V DC.

The example above illustrates that if you use a BE turbine and an MPPT regulator on a 24 V DC battery your cable voltage will be about 38 V DC. The losses at 38 V DC compared to 100 V DC (that our ME 120 turbine typically runs at) results in a cable that is 1/7 of the area, and about 1/7 of the cost.

So if you intend to run a BE turbine on a MPPT regulator you must:

- Tell us prior to ordering
- Have a short cable run
- Have a 12 or 24 V DC battery bank
- Have an accurate measure of the head of your system

If a BE turbine causes overvoltage damage to a MPPT regulator, EcoInnovation will not be liable. You should buy an ME turbine that will prevent this and allow you to use a 48 V DC battery bank.

If an ME turbine can be shown to have damaged an MPPT regulator then EcoInnovation will pay for it to be repaired.

2.12. MPPT regulators – Future trends

As the cost of MPPT regulators fall we will see a move towards MPPT regulation, for the following reasons:

- ME turbines are fail safe, unlike a BE turbines with diversion regulation that in the event of a failure may damage your system. It is for this reason we recommend a backup regulator and diversion load on BE systems.
- Clients have less time/inclination to manually optimise the turbine, automatic optimisation is great.
- Professional installers prefer a plug in and go solution that the ME and MPPT regulators offer.

Midnight solar 250 VDC MPPT regulator

We are also starting to see MPPT regulators that can operate at up to 250 VDC. This means that BE turbines can be used on 12/24/48 V DC sites without any internal regulation (68 V DC line voltage) and at up to 250 V DC with internal voltage regulation.

2.13. Fuses

In order to prevent system damage through shorts and malfunctions, and for general ease of maintenance, it is recommended that a number of fuses be placed in the system for protection. Fuse ratings will be dependent on the overall power rating and type of components in your system.

Main battery fuse holder

2.14. Meter box

We strongly recommend our standard cabinet and meters with pre-wired regulator and diversion load to go with your hydro turbine.

Standard cabinet and diversion load (air resistive coil)

3. Assembling your PowerSpout

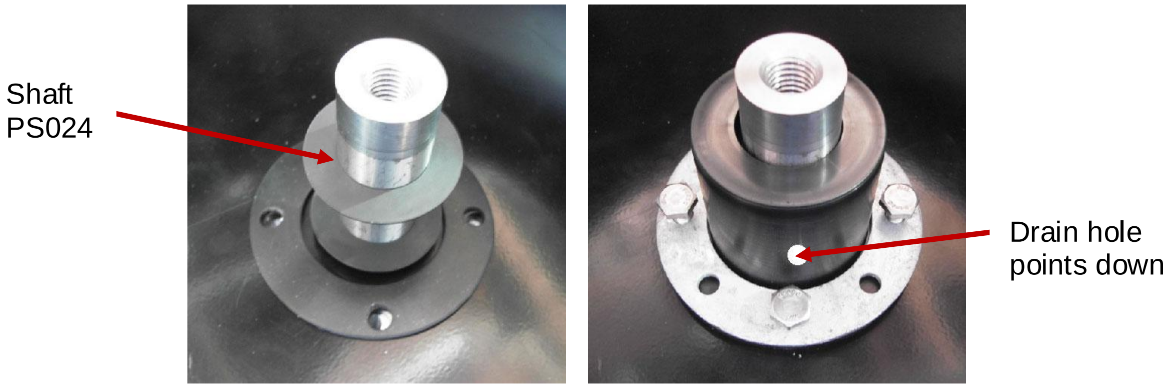
As soon as you receive your PowerSpout please unpack and unwrap the parts and check them against the online parts list. Please inform us immediately if you find any parts that appear to have been damaged in transit or are missing.

Videos of turbine assembly are available from www.powerspout.com.
Products manuals are updated on a regular basis and should be used in preference to video material for ensuring compliance with the latest updates.

3.1. Installing bearing block, shaft and slinger.

Take the turbine casing (PS001) which already has the bulk head (PS005) attached. Remove the eight stainless steel fixings (PS026 and PS034) from the bearing block and all other items until you have only the bearing block, and installed shaft remaining.

From the back of the turbine casing (with the circular opening where the end cap PS002 attaches) insert and align the bearing block as shown. Note that the bearing block has a small drain hole in it protected by a deflection shield, this should be pointing downwards.



Assembling shaft and seal slingers
Front (Pelton wheel side) Back (smart drive side)

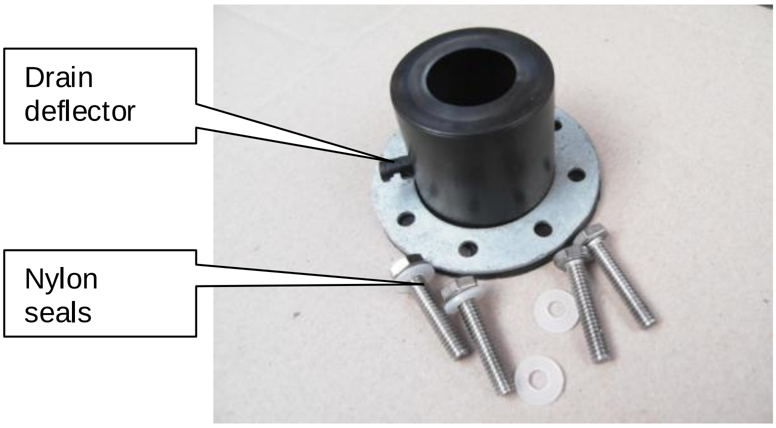
Position seal PS032.

- Position the two slingers PS031: one close to the bulk head one close to shaft end.
- Position slinger housing top-hat PS030 with the drain hole down.
- Position slinger galvanized steel washer PS033.
- Insert the four fixings PS034.
- Tighten fixings to 5 Nm (4 lb/ft).

Revision of PowerSpout water sealing
Testing the PowerSpout seals with a water blaster showed it is possible for water to track along the 4 x ¼ BSW fixings. This water can then enter the bearing block and drops out of the drain hole.

To prevent this water ingress we have made a number of small changes:

- Addition of hard nylon washers under the head of the ¼ BSW fixings to seal them from water ingress
- Addition of a deflector on the “Top Hat” drain hole to prevent exhaust spray water from entering



New sealing parts

3.2. Jet size

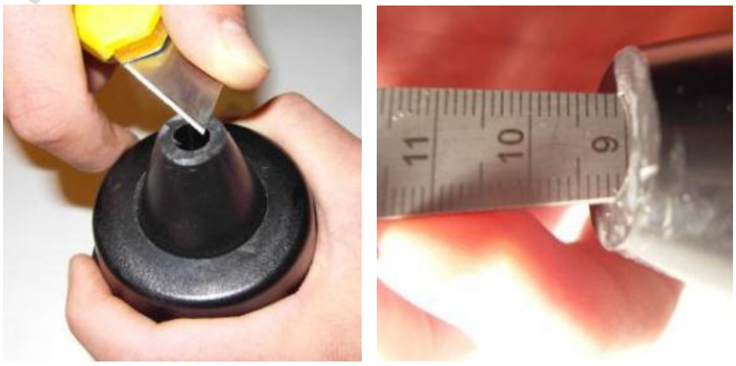
The jet-sizing tables (see Annex I: Jet sizing tables) enable you to quickly determine the approximate jet size required for your site i.e. at the head and available flow rate. These four tables are provided in both metric and imperial units for one and two jet hydro installations[3]. They are based on theoretical calculations. Flow rates in the field will vary slightly from these tables and some fine tuning of the jets may be required.

If your water source dries up in summer you may need to reduce jet size. This ensures water cover over the intake so you do not draw air into the pipe at the intake. In situations where you always have plenty of water at your site, and then once jets have been sized for your pipe line, no further adjustment is needed.

3.2.1. <u>Cutting the jets to correct size</u>

The plastic tapering jets can be cut on site with a sharp knife. The jets are inexpensive so a trial and error approach can quickly determine the correct jet size. It is important to cut your jet to the correct size cleanly so that the water jet can break smoothly without spray. We recommend using a sharp knife and paring away at the jet, cutting from the inside edge out. With practice a very accurate and sharp edged jet can be prepared in the field. The taper gauge and knife supplied in the optional tool kit help to make this task easy.

Holding the plastic jet (PS072) within a spare holder sleeve (PS070) and end cap (PS071) will ensure the jet is held firmly while you cut it to size. Take care as it is easy to slip, which could result in a significant flesh wound.



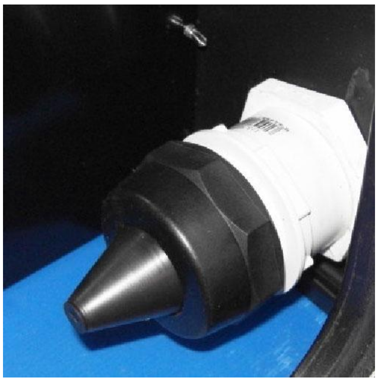
Cutting the jet to size and checking it with the taper gauge

[3] Two equal sized jets must be used for turbines with an output greater than 500 Watts.

If you have plenty of water and want to generate the most amount of power that your pipeline can deliver (before pipe friction chokes the output power) you should set the jet size so that the pressure on the gauge drops to 2/3 of the static pressure.

3.3. Installing jet assemblies

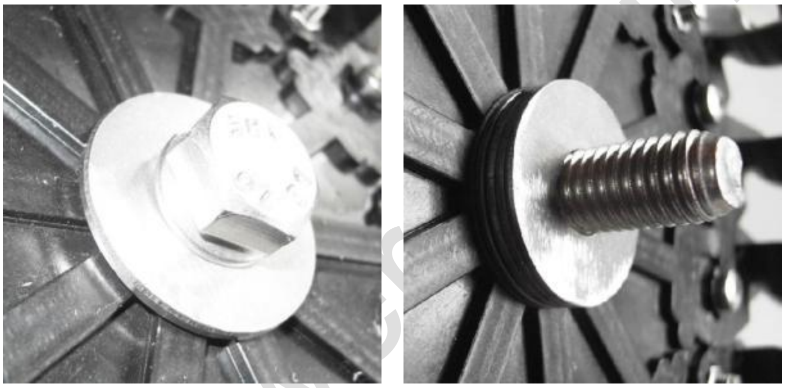
Install the jet assembly as shown. The PVC jet sleeve (PS070) is mounted inside the turbine with the PVC ball valve on the outside. Note that there is also a Jet 'O' ring (PS076) that fits on the jet sleeve thread after being inserted into the casing. This 'O' ring ensures the valve and jet sleeve seals onto the casing and does not leak. The 'O' ring is on the **outside of the casing**.



Jet assembly in position

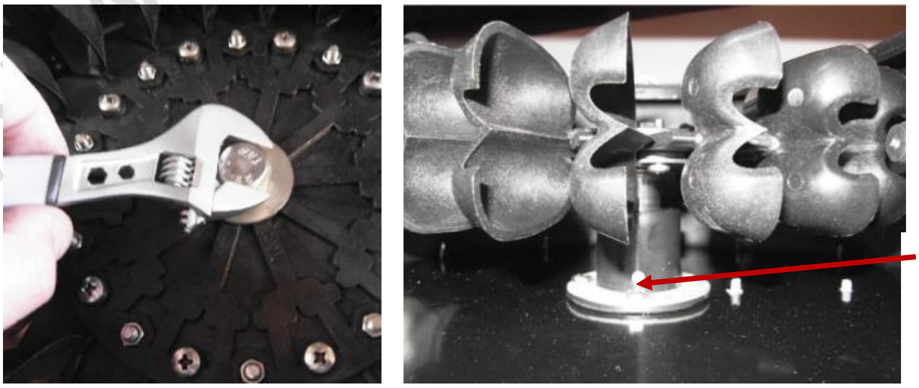
3.4. Installing the Pelton rotor

Ensure that when you mount the Pelton rotor you fit it the correct way round. The water jet should hit the splitter (the straight knife edge) of the Pelton spoons.



Pelton fixing washers front and rear views

- Insert bolt PS040, spring washer PS1043 and washer PS042 as shown.
- Install alignment washers PS041 as shown. Note you will need to alter the number of washers until the centre of the jet aligns with the splitter of the Pelton spoons.
- Attach the Pelton rotor to the shaft as shown below.



Attach Pelton rotor to the shaft and tighten to 50 Nm (35 lb/ft).

Ensure that the drain holes in both the slinger housing top-hat and the bearing block are pointing downwards.

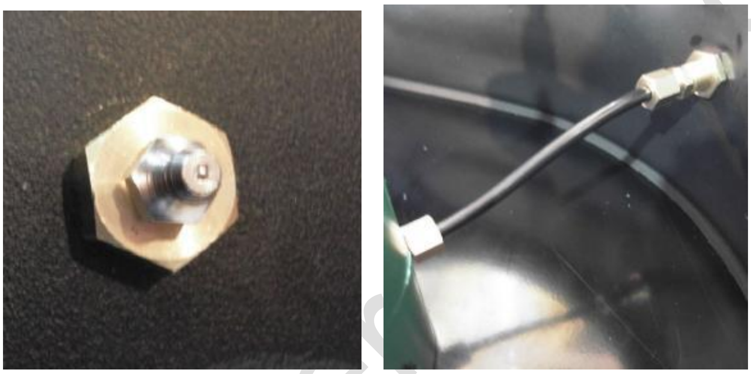
3.5. Pelton Rotor Alignment

You can view the Pelton rotor by looking through the jet as shown. The water jet needs to hit the middle of the Pelton spoon splitter. If the jet is misaligned then pack the rotor across using the washers supplied. You can see in the picture that the Pelton rotor needs packing to move the rotor to the left.

Pack Pelton rotor to align in middle of jet

3.6. Assemble lubrication system

Attach the lubrication components (PS091 – PS094) as shown below and tighten

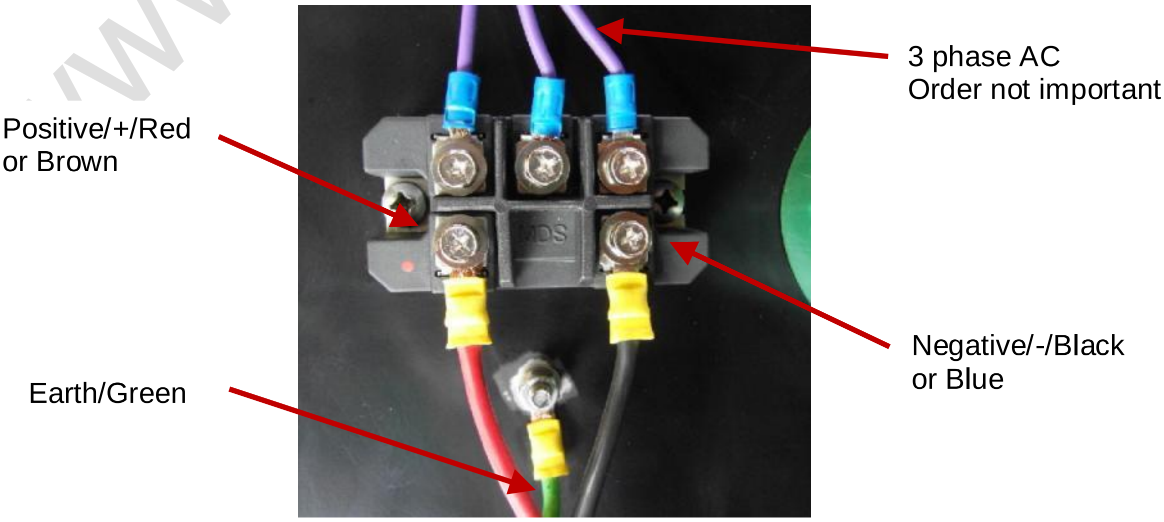


Grease lubrication system

3.7. Assembling rectifier, wire and plug lead

Pass the pre-wired PS083 plug and flex PS082 through the gland PS084 (mounted in the case wall), and tighten the gland to restrain the cable.

Note that many countries do not require extra low voltage equipment to be earthed. You will need to check with the rules in your own country. In many counties earth connections are optional, the USA is the main exception that does require an earth connection.

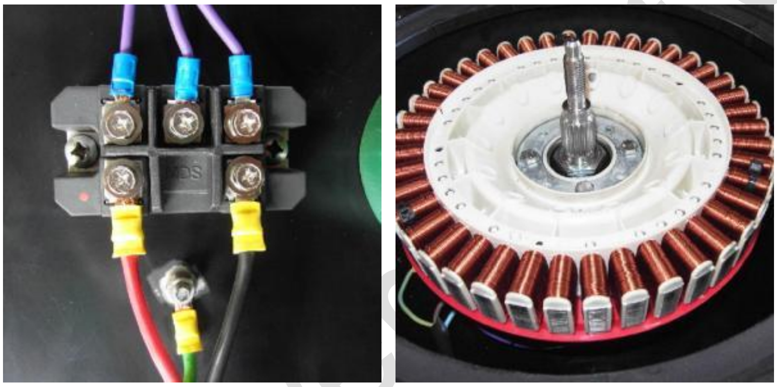


Rectifier wiring BE version

- Connect rectifier as shown. There is no incorrect wiring sequence into the rectifier from the generator for the 3-Phase AC input.
- The DC output for correct polarity must be connected brown or red/+/positive and black or blue/-/negative. The rectifier has + and - markings and you must connect them the correct way round. Reverse polarity may damage the rectifier.
- The thermal paste PS085 supplied ensures that a good thermal connection is made between the rectifier and the bulk head that acts as a water-cooled heat sink.
- Where an earth connection is not required connect as shown above.
- For positive earth connection link from the brown/red/+/positive wire to the green earth wire connection.
- For negative earth connection link from the blue/black/-/negative wire to the green earth wire connection.

3.8. Assembling Smart Drive Generator

First connect the AC wires as shown below (wire order is not important).



Shots showing wiring and location of generator stator

Place the generator stator and washer into position, attach with four fixings and tighten to 10 Nm (7 lb/ft). Insert extractor knob then place the rotor over the shaft. Wiggle the rotor until the knob engages on the thread. Turn the knob clockwise until the rotor is pulled fully home (magnets are fully over the steel laminations); do not over tighten - finger tight only.

Attaching the Smart Drive rotor

3.9. Electrical checks with covers off.

These instructions are for PowerSpout BE only. Similar tests for other versions of PowerSpout are included in the Technical Manual and should only be conducted by suitably qualified electricians.

These tests ensure you have completed the output connections and have no unwanted connections through wiring faults to the PowerSpout chassis.

1. Connect a DC volt meter to the DC output from the generator.
2. Use an electric drill with a 19 mm (3/4”) socket to spin the rotor by slowly driving the rotor fixing bolt PS040.
3. Watch the voltmeter and increase the drill speed until the voltmeter reads close to your system battery voltage.
4. The turbine should spin freely with little noise.

If you are using the PowerSpout BE without a ground connection

5. Connect an ammeter (use a 10 A DC range) between the chassis ground connection and negative output and spin the turbine to near the same speed as in step 3 above.
6. The turbine should spin freely with little noise and the ammeter must read zero.
7. Repeat steps 5 and 6 above but with the ammeter between the chassis ground connection and positive output.

3.10. Installing rear cover

Once all internal components have been installed the rear cap can be attached. To prevent rain water leaking into the casing a sticky-backed sealing-strip PS003 is attached to the main casing PS001. The lid is then held in place with six fixings PS004. Do not over tighten fixings or you will strip the thread in the plastic housing. It you do strip the plastic holes you can rotate the lid and make new ones.

View showing rear cover installed

For the BE and HE version the lid will need to be removed while turbine performance is being optimized. Remember to replace the lid once optimization is complete. The Smart Drive rotor is a rotating hazard that will cause injury if touched during motion.

The rear cap of this turbine forms part of an electrical enclosure and carries warning signs indicating there are both rotational and electrical hazards present. The turbine must be turned off and unplugged (or breaker turned off) prior to removing this cover.

3.11. Installing front glazing

The front glazing enables the owner to see that the turbine is running at the correct speed and that the water jet is clean and hitting the Pelton rotor at the correct position. It also protects anyone from accidently touching the rotating Pelton rotor and from getting very wet.

View showing front glazing installed

Six toggle latches allow you to quickly attach and remove the front glazing for jet size optimization. Once optimization is complete six self-tapping fixings also need to be attached to prevent accidents. Turbines that are installed in locked buildings do not need these fixings though it is best to use the fixings so that water does not leak.

4. Where and how to site the turbine

4.1. Regulations and good practice guidance

In many jurisdictions around the world electrical work on equipment with operating voltages over 50 V AC and 120 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.

PowerSpout BE, PowerSpout ME 100 and ME 120 meet these requirements for unregistered electrical workers in New Zealand (NZ) and Australia (AUS).

For PowerSpout HE and GE options please ensure that an electrician, who is also a registered electrical worker, completes your installation. In many cases you can install the equipment yourself and then have the electrician complete the final hookup 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.

4.2. Siting your PowerSpout 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 that has the most fall, even if it lengthens the cable needed to send the power to the usage site.
- In many situations it is possible to divert the water pipe close to the home to provide a pressurised water supply as well as electrical generation. In combined power and water schemes electric power is often employed to UV treat the water. In some cases the PowerSpout is only used for UV treatment at remote water storage tanks for small communities, this is often more cost effective that installing grid power to the site.
- Place it as close to your battery bank or point of grid connection as possible.
- Hydro turbines do make some noise, so keep them at least 30 m from your home.
- Keep your turbine as low as possible while ensuring that is it above maximum river flood level.
- Your turbine should be positioned at least 50-100 mm above ground height to allow exhaust water to escape.
- Choose a site where the exhaust water can be returned back to the river cleanly.

The distance between your turbine and batteries has a significant bearing upon the cable size required. To keep cable size (and hence cost[4]) down we usually recommend 48 V DC systems be installed. In such cases we generate a voltage at the turbine about 5% higher that your battery voltage (due to voltage sag in the cable). Turbine sites up to 500 m away are often economically viable using 2-core aluminium cable.

The PowerSpout ME offers an opportunity to reduce the cost of the cable by generating at higher voltage. For example the PowerSpout ME 120 which generates and transmits at about 100 V DC to a MPPT regulator close to your battery bank can reduce the cost of the

[4] EcoInnovation holds considerable stocks of cable at very good prices for our NZ customers

cable by up to 75% by doubling the generation and cable transfer voltage. The regulator changes the voltage to suit your 12/24/48 V DC battery bank.

The benefit of this approach is that existing 12/24 V DC systems can be cost effectively integrated with the PowerSpout. For example, solar PV systems can struggle in winter time when you have viable stream flows. Adding a PowerSpout to your system can often eliminate the need for fossil fuel generation, as solar and hydro resources tend to complement each other.

For very long cable runs up to 2 km the PowerSpout HE and GE are also possible options.

Typical good domestic install on natural rock foundation

Typical good commercial install – power for reservoir Auckland city storage

4.2.1. Cable sizing – rule of thumb method for long cables

Multiplying the current by the cable length in meters and dividing this answer by 100 determines approximate cable size for long runs at 50-100 V DC.

For example, 5 amps over 500 m cable length needs a cable size of 5 x 500/100 = 25 mm^2.

- If the cable voltage is 100 then power loss is 7.3%.
- If the cable voltage is 50 then power loss is 15%.

If you use this rule of thumb method for cable sizing and then round up to the next cable size available then losses are typically in the 5-10% band. There are many tools on the web that will determine the % power lost in the cable for you. The Advanced Calculator 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. This tool clearly demonstrates the effect that increasing the cable loss has on the cable size (and hence the cost of the cable).

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).

4.2.2. Connecting two small streams into one PowerSpout

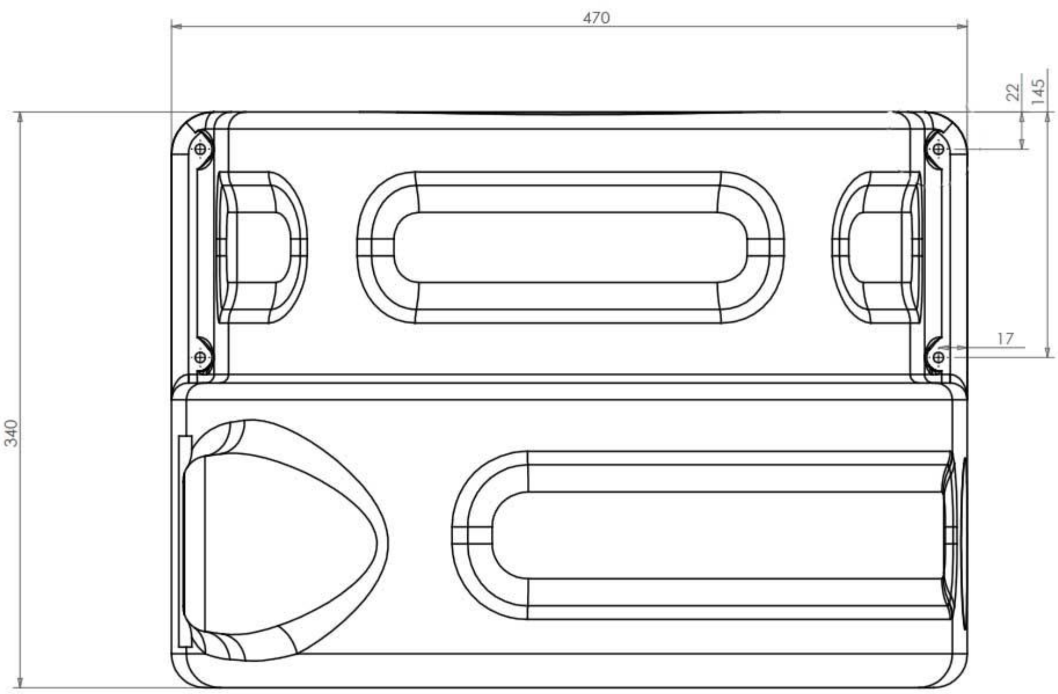
We are often asked if two small streams can be piped into a common two jet turbine. This is not recommended, unless the head and pipe friction losses for each pipe are very similar.

Generally we would advise two turbines, one for each site. The electrical output of both would then be joined together into a common supply cable.

Dual install, one unit runs on 30m (98 ft) head the other 10m (33 ft) head

4.3. Mounting

The main case dimensions (mm) and the four holes in the PowerSpout casing for turbine mounting are illustrated in the plan view below. Fixings are provided with the PowerSpout for connection to a timber framed base. These dimensions are sufficient to plan for the mounting of the turbine prior to its arrival on site. A PowerSpout unit is 400 mm high.



Plan view of a PowerSpout turbine

A timber or concrete turbine base is less likely to produce resonant noise issues than say a steel or aluminum base.

At sites where no water leakage can be allowed (slip hazards for staff etc) you can attach sealing strips of adhesive neoprene to the base of the turbine before bolting it down to ensure the turbine is completely sealed around the base.

In situations where there is a high risk of dropping tools into the floor sump you should cover the floor opening with stainless steel mesh so that any dropped tools or parts will not disappear under the floor. This tends to apply to industrial sites, including common applications such as city water intake reservoir facilities for control valves and instrumentation power, and power for large hydro schemes at the intake. This precaution is not required at domestic sites where the turbines are typically mounted outside.

A mesh (or exhaust pipe) over the exhaust water opening will prevent access into the rotating Pelton rotor from underneath, thus preventing serious damage to the fingers of inquisitive children.

Fixing a turbine to a timber base

4.4. Protection

The PowerSpout is encased in a very durable LDPE housing, ensuring all internal parts are protected from rain, moisture ingress, rodents, children and UV.

The internal aluminum bulkhead (PS005) has been designed to help control the temperature in the enclosed generation compartment of the PowerSpout. The Smart Drive generator has a peak efficiency of up to 80% and will get warm. Heat is dissipated from the generator core by a fan which blows the warm air over the water cooled aluminum bulk head, ensuring that temperatures within the PowerSpout remain at acceptable levels. Extra cooling is provided by three louver vents inserted in the PowerSpout casing. These are generally only required for turbines generating more than 400 Watts (or more than 10 amps). Below this output these vents are not normally installed.

2 x side air vents and 1 x rear lid air vent

This warm enclosure ensures the generator and electrical junction box do not become corroded from damp ingress. In higher power situations (>400 Watts) the generator temperature needs to be checked as part of the turbine commissioning by the installer.

The LDPE enclosure also helps reduce noise and dampens any slight vibrations. The main benefit, however, is that there are no exposed rotating hazards that might catch the fingers, clothes or hair of inquisitive children - ensuring a very safe product. Access to the rotating parts is only achieved with the use of a tool to remove the covers. All tools to do this are supplied in the optional tool kit.

We have noticed in our monitoring log data that humidity within the casing is higher when no vent is provided. Hence at least one vent is installed on all turbines and 3 vents are installed on all high power versions.

5. Ensuring good water supply

The online advanced calculator at www.powerspout.com will have advised the appropriate size of pipe based on the site data you entered. You should position the PowerSpout to obtain the greatest fall possible in the shortest possible distance. Try to lay the pipe to avoid high spots in the line that might trap air bubbles. If this is unavoidable you will need to place a bleed valve at the high point in the pipeline to purge air. Air locks in the line will significantly affect the power output of the turbine. The longer the line is the more of a problem this tends to be. Pipelines over 1 km long can be problematic if there are many high spots in the line.

5.1. Pipe sizes

Many different standards exist for pipe sizes which vary depending on industry and geographical area. The pipe size designation normally includes two numbers - one that indicates the outside diameter (OD) and the other that indicates the wall thickness. American pipes were categorized by inside diameter (ID) in the past but this was abandoned to improve compatibility with pipe fittings and joiners that usually fit the OD of the pipe.

Inside diameter is critical for calculation of pipe friction loss since a variation of as little as 1 mm can have a very significant effect on the output power of the turbine. Take care with which diameter you are referring to since if calculations are done based on pipe ID and the pipe is then purchased based on OD your turbine will generate less power than predicted due to increased pipe friction. Pipes below 40 mm ID cannot normally be used as friction losses are too high.

Pipe sizes commonly used with our hydro products include:

- PVC for larger sizes based on OD (110-300 mm normally)
- LDPE based on ID in NZ/AUS (40-50 mm normally)
- MDPE or HDPE based on OD (50-110 mm normally)

LDPE and MDPE pipes
Pipes have different pressure ratings so a given pipe size is often available in a number of pressure ratings. These different ratings are achieved by either altering the material grade or increasing the pipe wall thickness. The OD is kept constant so standard pipe joiners still fit.

In NZ, for example, polyethylene (PE) pipes can be purchased from 35 m (50 psi) head rating to 160 m (230 psi) head rating. Some (mainly LDPE) sizes are based on ID but most are based on OD sizing, so be careful and double check with your supplier the OD and ID of the pipe.

5.2. Pipe criteria

A pipe should be:

- Equal to or larger than recommended from the calculations that specified the output power (Watts) of your turbine.
- Cost effective, tough and durable for 20-50 years.
- Able to handle the static pressure of the head of water.
- Easy to lay and bend around obstacles.
- Able to be purchased in long lengths.

The PowerSpout has a maximum running head rating of 100 m (120 m in special cases) and, allowing for up to 30% pipe friction loss, sites up to 130 m static head can be used. A higher water head can be used successfully but with reduced lifespan and warranty.

LPDE and MDPE pipes can work in this range. The range and the fact that they are durable, low cost and commonly available in a wide range of sizes, pressure ratings and lengths makes these pipes the obvious choice for the PowerSpout.

Remember that you can change the pipe grade to minimise costs. For example, if you have a 100 m head you can use a length of low grade 35 m (50 psi, 3.5 bar) pipe, a length of 6 bar, then 9 bar and finally 12 bar. Laying 12 bar pipe all the way would almost double the cost of the pipeline. If you do this the pipe ID will change so the calculated output may not be correct. To avoid disappointment use the smallest pipe ID in the online calculator and your turbine should generate a little more than predicted.

Table 2. Pipes common in NZ – indicative prices 2009

Pipe OD mm	Pipe ID mm	Material	Pressure rating PSI	Pressure rating M	Pressure rating kPa	Pressure rating Bar	Approx cost/m NZ$	Approx cost/m US$
44	**38**	LDPE	65	45	450	4.5	2.6	1.8
44	**38**	LDPE	87	60	600	6	3.0	2.1
57	**50**	LDPE	51	35	350	3.5	3.4	2.4
57	**50**	LDPE	102	70	700	7	3.8	2.7
63	55	LDPE	87	60	600	6	3.6	2.5
63	55	MDPE	131	90	900	9	4.9	3.4
63	50	MDPE	174	120	1200	12	7.4	5.2
75	65	MDPE	116	80	800	8	7.4	5.2
90	79	MDPE	116	80	800	8	8.5	6.0

Bold indicates the change from ID to OD sizing

5.3. PVC pipes

PVC pipes are widely used in applications ranging from low cost road culverts to mains pressure water distribution networks in cities. PVC pipe sizes vary around the world (see Annex II: Common PVC pipe sizes) and frequently the available pipe sizes differ between countries. Most countries seem to either use the American or British pipe size dimensions, or develop their own standards for pipe sizes.

PVC pipes are often more cost effective than PE pipes in sizes above 90 mm. As the pipes glue together the cost to join them is low, so short lengths can be used (normally 4-6 m). They can be bent in-situ by applying heat to the tension side of the bend. We therefore see them mainly used at lower head sites where more water flow is available and often on sites running multiple turbines from a common pipe line.

PVC is not as durable as PE and can be shattered by falling rocks and trees. Where these risks can be managed and the price is right for the application they are commonly used. PVC left in direct sunlight will weaken and become brittle with age.

We see larger PVC pipes (150 mm and larger) used for lower head applications below 20 m and often with less than 200 m of pipe needed. In this case, culvert grade farm pipes glued together are the lowest cost PVC pipe you can obtain.

There are also larger sized HDPE culvert pipes up to 450 mm but these often require expensive joiners as they cannot be glued together, though plastic welding is possible.

5.4. Pipe myth

We often get told that the pipe has to reduce in size in order to keep up the pressure. This is a huge misconception and arises from confusion with irrigation schemes. If you decrease the pipe size you decrease the pressure, you do not increase it.

The pipe for an irrigation scheme supplying many farms will reduce in size as the last farm has to convey a smaller amount of water. The start of the pipe has to be larger because it has to convey the water needed for all the farms on the line. The pipe myth arises because pictures of irrigation schemes have often been used to depict hydro schemes.

People also confuse pressure with velocity, if you increase the velocity by reducing pipe size the pressure will decrease. Reducing pipe size increases water velocity, increased water velocity further increases pipe friction and reduces even further the pressure in the pipe, resulting in less power generation.

Another common myth is that pipe bends are the cause of a lot of losses. In reality, relative to the long hydro pipe, a few bends will make no noticeable difference.

5.5. Laying and securing pipes

When laying the pipe try to do the following:

- Install a good strong intake structure.
- Secure the pipe against flash floods during the install process.
- Obtain a good fall in the first 5-10 m of pipe.
- Lay the pipe on a gradual always descending line where possible.
- Keep the number of high points to a minimum and vent these to avoid air locks.
- Avoid siphon systems if possible.
- Securely fasten the pipe line to rocks, trees, or ground anchors to prevent it moving down the incline.

5.6. Intake design and placement

The intake for a Pelton turbine should be positioned at the base of a small set of rapids to allow room for a sloping intake screen. Water flows over the top of the screen falling into the chamber below that feeds the supply line. Leaves and twigs are washed away preventing the intake from blocking.

Intakes often need to be made to suit each site. The examples below illustrate different ways to do the same job. The picture of the “angled guides and screen” is the recommended way to make a good strong maintenance free intake screen. You must ensure you securely attach the intake screen to the riverbed by driving galvanized stakes into the ground or attaching to large boulders with brackets and cement.


Angled screen


Flat screen in road culvert


Stainless steel perforated tube


Perforated galvanized cable tray intake


Angled guides and screen


Perforated box in concrete


Commercial intake on road culvert


Perforated box

Stainless woven tube from scrap yard

Intake made from stainless steel scrap

Intake screens such as these can be purchased. However, they are easy enough to make to suit your site. You can use a stainless steel mesh and a plywood box, make sure you support the screen from behind with stainless steel rods/frame otherwise during floods the mesh will be pushed in. A fine, smooth stainless steel gauze with a hole size no more than 1mm should then be placed over the stronger frame. This smooth gauze will allow debris to slide off easily and prevent small aquatic life forms from entering the pipe line.

Some ideas for intakes made from scrap stainless steel components

5.7. 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.

Most micro-hydro systems divert a fraction of the main water flow through an intake screen to the generator. A good intake will lead to negligible erosion and the screen will minimize the chance of fish, leaves, etc entering the supply pipe. Taking 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.

You should take care to ensure that the exhaust water from the turbine can return to the river without scouring the bank of your waterway. Line the bank with concrete, timber or plastic sheet as required. Some systems utilise the exhaust water for irrigation, allowing the water to percolate through the soil before returning to the waterway.

Good example showing:

- Concreted river bank
- Timber boards to prevent river bed erosion

5.8. Connecting the pieces

5.8.1. Connecting your pipe to the PowerSpout

Two standard nylon pipe fittings are supplied that will allow connection to 50 mm or 2” ID LDPE pipe where this pipe size has been selected.

For larger pipe sizes we have pipe joiners available for purchase that fit onto LDPE and MDPE pipe with the following OD: 63 mm (2.5”), 75 mm (3”), 90 mm (3.5”). These joiners have 2” British Standard Pipe threads (BSP threads) on the end to connect into the valves on the turbine. These larger fittings are supplied for an extra charge.

5.8.2. Advice for USA and all countries that use NPT threads

Fittings obtained in the USA will have 2” National Pipe Tapered threads (NPT threads). A PowerSpout sent to these destinations will have a ball valve with a 2” BSP thread on one side and 2” NPT thread on the other side. These clients connect to our turbine and the pipeline by buying a suitable fitting locally.

5.8.3. Two-jet connection

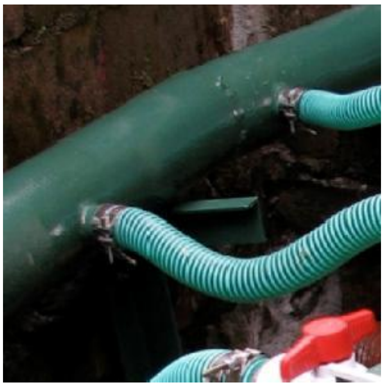
Connection of 2 jets to a common pipe line is normally done by one of the following means:

- Placing a “T” in your LDPE or MDPE pipe line and plumbing the pipe to both jets. The losses due to one “T” will make no difference to turbine performance.
- Using our two-jet PVC manifold that connects the two jets together, all you need to do is connect to the 75 mm OD (3”) PVC pipe. We have many options for our manifold, including LDPE pipe connectors, mac-unions and bolted flange connections if required.

PowerSpout with factory fitted manifold

Common PE pipe fitting options

Do not connect the 2 jets to the main supply pipe line using undersize pipes or this can cause significant losses.



Turbine supply pipes too small

Correct size

6. Getting the best from your batteries

6.1. Battery type, size and life

Flooded or Wet Cells are the most common lead-acid battery type in use today. They are available in a wide range of sizes and are often the most cost effective solution. Light duty batteries are for cars (thin plates with lots of surface area). Heavy duty batteries are for trucks, boats and deep cycle for renewable energy applications.

Gel cells are sealed and cannot be re-filled with electrolyte. Controlling the rate of charge is important or the battery will be ruined.

Absorbed Glass Mat (AGM) batteries, instead of using a gel, use a fiberglass like separator to hold the electrolyte in place. Since they are also sealed, controlling the rate of charge is important or the battery will be ruined.

Many people are often confused by terms such as voltage (V), amp hours (Ahrs), Watts (W) and Watt hours (Whrs). Your batteries store energy (power is the rate of delivery of energy)[5].

Energy stored in a battery (Watt hours) = amp hours x volts. For example:

- A 6 volt 225 amp hour battery can store 6 x 225 = 1350 Watt hours
  this will have a mass of about 30 kg = 66 lbs.
- A 12 volt 200 amp hour battery can store 12 x 200 = 2400 Watt hours
  this will have a mass of about 55 kg = 120 lbs.

Do not make the mistake of evaluating batteries only by amp hours as this is not an indication of total energy storage. Battery weight is often a good measure by which to compare batteries. This quality can be used to help spot the over enthusiastic sales person.

6.1.1. What is electricity and batteries?

Electricity is the flow of electrons along a wire. Metal is a good conductor of electricity as the electrons in each atom of metal are free to move from one atom to another.

Consider how difficult it is to store the energy of a car that is moving. Understanding the fact that electricity is the flow of electrons helps us to understand that electricity is also difficult to store as it is energy in motion.

Batteries do not store electricity as such but use the flow of electrons to alter the number of electrons in the chemicals inside the battery. Then when the battery is discharged the chemicals return to their original state. However, the chemical process means that batteries degrade with use and time.

Renewable energy systems normally use batteries based on lead-acid chemistry as they are still the most cost effective and readily available type. Lead-acid batteries are made from plates of lead in a solution of sulfuric acid. While the discharging and recharging of lead acid batteries is a reversible process all lead acid batteries lose health when not charged.

The car battery is a lead-acid battery. A car battery is designed for starting a car's engine and so has thin plates to provide as much surface area as possible, which allows the chemical reaction to occur in a short time. This type of battery can provide large currents to meet the high power demands of starting an engine. As the duration of engine starting is

[5] For further information on energy and units see Section 14 or refer to the PowerSpout Technical Manual

very short the total amount of energy is not that great, automotive batteries suffer when significantly discharged. The thin plates are quickly damaged and may even disintegrate. The plates also have a high resistance, so loose energy, making a car type battery less efficient as an energy storage device. They can be employed in some hydro situations where there is plenty of power to meet the base load of the home, the battery merely providing short duration peak load storage.

A deep cycle battery designed for standby energy systems has heavy plates that are much more robust against deep discharges. However, a deep cycle battery has limited surface area and cannot convert stored energy as quickly. Thus deep cycle batteries must not be subjected to heavy currents or there will be damage to the battery.

For battery bank sizing we generally refer to the 10:10:10 rule of thumb.

For a 10 year life:

- Cycle batteries no more than 10% depth of discharge (DOD) each day.
- Limit the maximum sustained draw to 10% of battery capacity.
- Limit the maximum charge rate to 10% of battery capacity.

For example for a hydro turbine generating 500 W (0.5 kW) into a 48 V DC battery bank that consists of two banks at 200 Ah each use:

- DOD each day = 10% x 2 x 200 x 48 = 1920 Whrs.
- Maximum sustained draw of 10% x 200 x 2 x 48 + 500 = 2420 W for a time not exceeding 1 hour.
- The charge rate is 500/48 = 10 A, maximum allowable = 10% x 2 x 200 = 40 A. This 40 amp limit is a concern only when backup charging from a gen-set.

Average daily draw from the battery bank (allowing for 10% battery loss and 10% inverter loss 500W x 0.9 x 0.9) is 400 W = 9.6 kWh/day (0.4 kW x 24 hrs/day) total consumption. This is normally fine for an energy efficient home using a 3 kW inverter. If you wish to draw more than 2.42 kW for a sustained period you should install a larger battery bank and inverter.

In practice battery life is generally around 3-12 years, with 7-8 year life typical. Batteries are occasionally flattened accidentally and this can have a significant impact on their total life.

Although there are many instruments to help determine battery state of charge, the most reliable method is a hydrometer. A hydrometer can only be used with wet cell batteries. Check your battery state of charge weekly and keep a log book. Either increase generation or decrease consumption if your state of charge is falling. You need to generate at least 20% more than you use to allow for system losses.

Two parallel battery strings are better than one - if you do get a loose connection or forget to turn off the hydro turbine when working on your system you may not face any ill effects. Generally it is regarded as good practice not to have more than three parallel banks.

Connecting batteries in series increases the voltage but not the amp hour capacity.

Connecting batteries in parallel increases the amp hour capacity but not the voltage.

6.2. Housing

Batteries need to be understood for what they are. Here are some key points:

- Batteries operate best when kept cool, around 10ºC to 20ºC, but <u>never</u> freeze them. Fully charged batteries are hard to freeze but flat batteries are more easily frozen.
- Batteries are full of sulfuric acid, lead and small amounts of other chemicals which must not leak into the environment.
- Chemicals must not fall on or into batteries as this may cause a chemical reaction. Rain water should be avoided as it may wash other material into the cells.
- Batteries store energy in chemical form and can release this as electricity very quickly if there is a short circuit. A short circuit can convert a steel ruler or spanner to molten metal spray and cause significant personal injury. Protection from falling objects is required. Protection from electrical faults is also required.
- Batteries are heavy and need a solid flat supporting surface. Good access for installation and replacement to avoid lifting injuries is required.
- Batteries give off hydrogen and oxygen gas during charging in the correct proportions for an explosion. Ventilation is required.
- Batteries are not maintenance free. All batteries need to be measured individually for voltage and flooded batteries also need to be checked with a hydrometer.
- Batteries are not for anyone to touch. Sufficient security is required to prevent a child or unknowing adult from tampering with them.
- Not everybody understands batteries. There are recommended safety signs that must be displayed above your battery bank warning people of the possible hazards.

You should always take care when working with batteries. Burns, acid splashes and electric shocks can occur. If you do not have sufficient skill and/or experience to install and care for this equipment you should engage a renewable energy professional to do it for you.

Myth: The old myth about not storing batteries on concrete floors is just that - a myth. This story has been around for 100 years, and originated back when battery cases were made up of wood and asphalt. The acid would leak from them, and form a slow-discharging circuit through the now acid-soaked and conductive floor.

6.2.1. <u>Battery installation example 1</u>

Here each battery is in a separate battery case. Each case provides ventilation and prevents accidental contact with the terminals.
Note the very clear safety warnings making it obvious what is inside the boxes.
Access for servicing is straight forward.

6.2.2. <u>Battery installation example 2</u>

This example provides excellent mechanical protection for batteries and ensures safe seismic restraint.

Ventilation slots at ground level on the front and at the top of the lid behind the hinge provide through flow ventilation so any hydrogen gas produced can rise easily up and away from the batteries.

Ideally the lid should be slanted to prevent incidental use of the lid as a shelf. (Objects will slide off).The use of a child proof catch and signage on the outside (top) of the lid is also required.

6.2.3. <u>Battery installation example 3</u>

This locked battery room example provides good mechanical protection for the batteries and safe seismic restraint.

Ventilation vents at ground level and at the top of the battery room ensure good air flow ventilation so any hydrogen gas produced can rise easily up and away from the batteries.

The installation includes:

- Seismic restraint
- Distilled top up water storage
- DC disconnect – below battery terminals
- Fire extinguisher
- Eye wash
- Battery care box with gloves, apron, hydrometer and log book
- Smoke alarm
- Hazard warning signs

Minimum safety clothing includes:

- Plastic apron
- Rubber gloves
- Eye protection
- Boots
- Eye wash

7. Cable connections (PowerSpout BE)

This section includes wiring diagrams for PowerSpout BE only: for other versions please refer to the PowerSpout Technical Manual.

Earthing of your renewable energy generation system may be required for personal safety and protection of the system from electrical faults. Not all 12/24/48 V DC systems are earthed and the rules vary from country to country. Systems operating over 140V should almost always have an earth connection.

New Zealand electrical regulations allow you to work on systems up to 50 V AC and 120 V DC without qualifications. Outside NZ you need to check your rules to see what you can legally do yourself.

In the USA the National Fire Protection Agency (NFPA) provides wiring rules that are generally adopted by each state. You can access these wiring rules free on line at http://www.nfpa.org/freecodes/free_access_document.asp?id=7005SB. Please also check with your local state authority if you are in the USA, as each state may vary from the NFPA wiring rules.

The 2005 release of the NFPA National Electric Code (NEC) indicates a ground connection is required for all DC power systems in the USA. This is not the case for many other countries, so check if a ground connection is needed.

Many home owners attempting to install a renewable energy system themselves for the first time can make some fairly serious errors. All the following errors we have observed over the last 15 years:

- Connecting a hydro turbine to a solar regulator not designed for a hydro turbine.
- Connecting the hydro turbine polarity in reverse (this normally destroys the rectifier).
- Connecting the hydro turbine to the inverter lead and then removing the battery and regulator fuses. This results in a high voltage input to the inverter, which damages it.
- Using a poor quality second hand battery bank with dirty/corroded terminals, which results in the battery not being connected in the system. This is fatal to inverters as the battery is the primary voltage regulation and must remain connected to the turbine at all times when the turbine is running.
- Forgetting to tighten the battery terminal bolts, resulting in the battery bank being disconnected from the systems, result as above.
- Not checking that the regulator is working correctly prior to leaving the site.
- Installing a regulator that is too small or one that does not work and not knowing how to determine if the regulator is working.
- Installing a regulator (close to its maximum amp rating) in a tin shed that works most of the time but in summer trips out resulting in the batteries being overcharged/damage. The backup regulator (if fitted) also trips. It is not the regulator(s) that have failed but the summer environment in the tin-shed that is too hot. You have to de-rate regulators in summer when above 20 degrees Celsius. Such a failure is the result of an incorrect installation environment.
- Installing equipment in a damp/humid environment resulting is corrosion problems.
- Insect infestation in equipment resulting in corrosion damage from insect excrement.

- Bird and rat nests inside and behind cooling fans or inside electrical enclosures resulting in failure and fire hazard. In most cases this would have been avoided if good installation practice had been followed.
- Connecting the plug supplied with the PowerSpout turbine in reverse polarity. This will result in the turbine wire fuse blowing and may damage the rectifier in the turbine.

NEVER work on your renewable energy system with the hydro in operation.

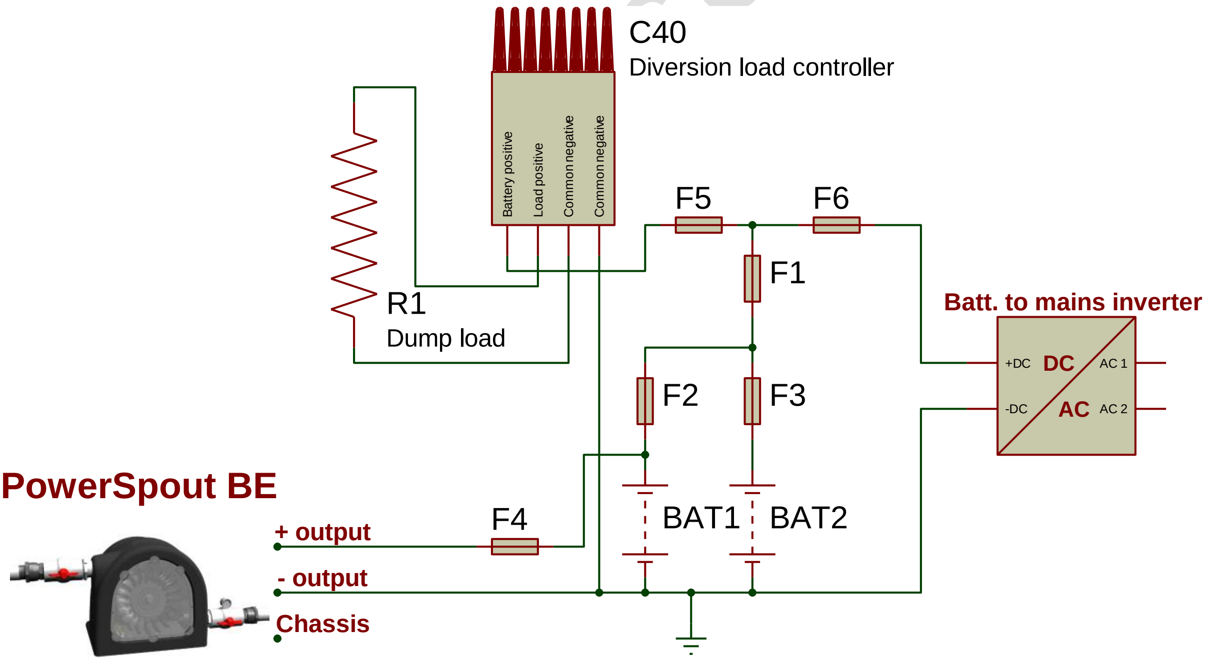
EcoInnovation will not be liable if you connect this equipment incorrectly and in doing so damage other equipment in your system. If you are not skilled then have a suitably qualified professional install the equipment for you.

7.1. PowerSpout BE wiring (Battery Enabled)

The drawing below shows the minimum installation requirements for the PowerSpout BE. This drawing shows a negative ground installation. Each component and its selection criteria are discussed below.

If the ground connection is not to be installed, then additional fuses are normally required by local wiring regulations on each of the negative connections to the common negative battery terminal. Please refer to your local wiring regulations for what is required in your location.

<u>Negative ground battery</u>



Please note that both fuse 4 and fuse 2 connect directly to the battery. The hydro turbine must connect directly to a battery string. If fuse 4 was accidently connected at the junction of fuses 1, 5 & 6 then removing fuse 1 will result in over voltage to the inverter. Be careful to avoid this potential problem.

Remember also that the cables used in each part of the circuit need to be large enough to carry any currents that do not blow the corresponding fuses. The fuse has to be between the rating of the cable and the rating of the load/duty (cable highest, fuse middle, load smallest).

7.1.1. Fuse 1

Fuse 1 is required by most electrical jurisdictions around the world to protect against damage in the event of a short circuit within the wiring of the main switchboard. Should fuse 1 blow, the charge controller will not provide over charge protection for the batteries. If left with fuse 1 removed then the batteries and inverter may be damaged. This system relies on the diversion load controller for charge control so it is very important that this fuse never actually blows in normal operation.

Fuse 1 must be large enough so that the inverter can never draw enough current to break under maximum load conditions. Fuse 1 must also be small enough that the batteries have sufficient energy to break it in a fault situation.

It is normal for fuse 1 to be twice the rating of fuse 6. Or for fuse 1 to be a motor rated fuse while fuse 6 is not motor rated for the same current rating.

7.1.2. Fuse 2 & 3

Each parallel string of batteries must have its own individual fuse. This is to limit the damage caused by internal failures such as an internal short-circuits within a cell in a battery string. These fuses are also an advantage when working on batteries so that an individual string can be isolated for testing without shutting down the entire system. Like fuse 1 these fuses should never blow in the event of an external fault.

Fuses F2 and F3 can be omitted when 1 battery string is used.

7.1.3. Fuse 4

The cable from the PowerSpout BE to your battery room can be very long and needs to be protected from excess current. The excess current comes from the battery end of the cable, not the PowerSpout. The maximum operating current for the PowerSpout is typically 30% higher than normal operating current and is not able to blow a fuse. Fuse 4 is therefore located at the battery room to protect the cable from battery supplied current in the event of a cable short circuit.

When you order your PowerSpout BE you will be advised of the maximum current your PowerSpout BE can deliver at your site. Please ensure that you use a fuse that is just large enough to carry this current.

Fuse 4 is connected to the battery side of all other fuses. This is essential to ensure that the failure of any one fuse will not result in damage to any other equipment. A battery must be connected when using a PowerSpout BE to prevent over voltage from damaging the inverter.

7.1.4. Fuse 5

Fuse 5 carries all excess energy within the system to the division load controller for dumping in the dump resistor. Fuse 5 should not break unless fuse 4 has already broken or been disconnected. To achieve this, fuse 5 should be chosen to be twice the breaking rating of fuse 4.

Linked circuit breakers (see picture) are available with two poles linked together where if one breaker breaks then the others will also break. This can be used to replace fuse 4 and 5 in a single unit. Be sure to use breakers rated for the DC current at the battery voltage your system uses.

7.1.5. Fuse 6

Fuse 6 carries all load current from the batteries to the AC inverter. It is important that fuse 6 will always blow before fuse 1. If there is a major fault in the inverter only fuse 6 should break and so leave the rest of the fuses in place. This way the PowerSpout BE output will continue to be connected to both the batteries and the diversion load controller, and maintain DC voltage regulation.

Warning – many breakers are not DC rated and must not be used. Breakers rated for DC will say on the body of the breaker. DC breakers cost more than common AC breakers. DC type breakers are often polarized, this means that they have to be installed the correct way round. The side of the breaker with the + sign means this side is connected in the system on the side that is more positive in a fault condition - the battery side will always be more positive.

7.1.6. Earthing requirements

This configuration only fuses one side of all DC connections. In most countries an earth connection is required for the common side. Please refer to your local country wiring rules to determine the correct size of this conductor.

Only one earth connection should be provided to the common wire connection. Adding a second or more earth connection(s) to the common side may result in additional electrical noise which could interfere with radio reception.

8. Power meters

It is important that you have a means of permanently displaying the power generated by your hydro turbine. We strongly recommend our standard cabinet and meters with pre-wired regulator and diversion load to go with your hydro turbine (Section 2.14).

A separate meter is only needed if you purchased a BE version. The ME and GE versions of the PowerSpout do not need a power display meter as the MPPT regulator or grid tied inverter will display the generation Watts and often log this information for you.

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

- Blocked intake screen or
- Reducing river flow requiring smaller jets to be fitted.

You may notice a gradual decline in output power that may be due to sediment and organic growths in the pipeline. This may need to be cleaned out using a pipe pig or by flushing the pipe with high velocity water.

As the voltage of most systems is relatively constant, the output Watts is determined by multiplying the system voltage and the generation amps. Annual output can be calculated as follows.

kWh/year = generation Watts x 24 x 365

For example a 500 W (0.5 kW) hydro will generate 4380 kWh/year

To read amps in the cable you can either buy:

- A DC clamp meter (be careful not to buy the cheaper AC clamp meter).
- PS110 amp box that can be used at either end of the cable and provide a permanent display of generation amps in your power shed.

One of the meters above is required so that the BE turbine can be optimised for your site.

We strongly recommend that any household living off the grid buys a good quality DC clamp meter, as this will be very useful in a Renewable Energy (RE) system, and learn how to use it. 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. The Technical Manual has further information and there are numerous websites on this topic.

9. Turbine Commissioning

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. Once you are happy that you have successfully commissioned the turbine you should record (see Section 13.2):

- Jets sizes installed
- Flow rate through turbine
- Output Watts (= amps x volts)
- Static pressure of pipe (turbine valves turned off)
- Dynamic pressure of pipe (turbine running)
- Generator equilibrium temperature, (see Section 9.2)
- Picture of installation
- Date for next service check (see Section 10.2)

Once the turbine has been mounted on a suitable base, the pipe attached and secured, and the power cable connected to the inverter, MPPT regulator or battery bank you may turn on the turbine.

- Allow pipe to run and purge of air bubbles (on long small pipes this can take a few hours).
- Check for current flow to the load.
- Check regulators are working.
- Check that the intake still has surplus overflow water. If not fit smaller jets so you are not drawing air into the pipe at the intake.
- Check for pipe and turbine fitting leaks, and remedy as required.
- Walk the pipe and lift sections to locate any air locks and fit riser vents as required.
- Check that the drain hole in the rear turbine case is at the lowest point. If condensing water from the bulk head pools onto the floor of the turbine case, drill a small hole at this low point to allow this water to drain out.
- Check there is no water leaking from the drain hole in the rear bearing block. If you see a leak make sure you have installed the slinger, top cap seal and tightened correctly

Standard meter cabinet and resistive load

The meters above confirm that both units are operating: hydro 1 at 20 amps and hydro 2 at 11 amps respectively. The air diversion meter shows 3 amps diverted to the resistive load. The picture shows the air diversion element with a slight glow, indicating that it is working.

Make sure the pipe is secured firmly just prior to the turbine. A large pipe full of water can be heavy and may need support. You can support the pipe by installing a wooden post either side of the pipe with a horizontal member above and below the pipe to secure it.

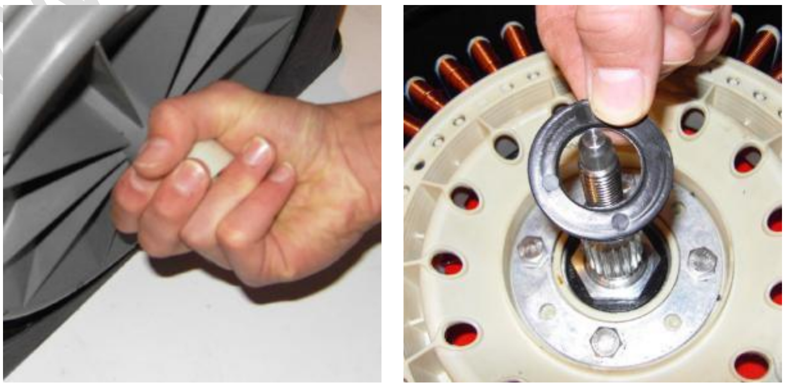
As a check it is recommended that the exhaust water from the turbine is collected to determine the flow rate of water through the jet, measure this by noting the time to fill a container of known volume.

Cutting and aligning the jets are fundamental to turbine optimization. Please refer to sections 3.2 and 3.5 above for more details.

9.1. Packing out the rotor

Once plumbed in, the jets should be turned on and the output of the turbine optimized.

Optimization of BE and HE PowerSpout options is done by noting the output current on the meter and then gradually packing out the magnetic rotor until the point of maximum power is achieved. This is very important and will make a significant difference to power generation. Once this point has been found the rotor should be packed with the packing washers provided and the rotor tightened - finger tight only.



Turn knob to optimize, pack with plastics washers and tighten to ensure rotor stays in position set (note 1mm thick stainless steel washer are supplied for packing).

If you are using our ME or GE option then the MPPT in this equipment will automatically adjust the speed of the turbine and optimize it for you, with no packing required.

If the MPPT controller is unable to automatically find the correct operating point then manually set the MPPT controller load voltage. Adjust MPPT set point (load voltage) from highest to lowest voltage and note power output at each setting. Then select best power result. If best power is achieved at the maximum or minimum limits of either the MPPT controller, PowerSpout ME/GE or your battery bank voltage (ME version), then please contact EcoInnovation for further assistance.

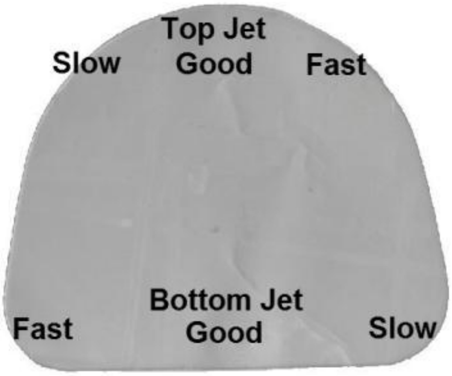
Once optimization is complete the turbine exhaust water should be hitting the clear glazing at 90 degrees to the jet. If the exhaust water bounces back towards the jet then the turbine is running too slow and you should pack it more. If the exhaust water travels through and hits the opposite side of the casing then the turbine is running too fast and you should reduce the packing.

Top and bottom jet exhaust water is bouncing back towards the jet, turbine is running slow, a little more packing is needed

Too slow

Good

Too fast



The above illustration shows where the top and bottom jet exhaust water should be hitting the clear screen for optimal performance

If the exhaust water does not hit the clear front at 90 degrees to the jet, then there are a few possible issues that should be checked.

- Note the output power and compare this to what you were advised prior to purchase. If this is similar then it is likely all is well and no further adjustment is needed.
- Check that the Pelton rotor knife edge aligns with the centre of the jets and adjust by altering the packers behind the rotor.
- Apply downwards, upwards and sideways pressure to the jet to alter the angle slightly and see what effect this has on output. The jet position can be moved slightly within the casing. Once optimized, secure and support the pipe. The jet retaining cap should only be hand tight and ensure the thread is well greased so it will come apart in the future.
- Check that the running voltage for your turbine is less than the maximum ME/GE voltage you purchased. If more than advised below then the turbine might be activating the internal voltage clamp load that will divert some of the power generated to internal water heating. The ME and GE Smart Drive stators may be supplied with 6 wires for Star or Delta connection. Changing the connection type may solve this problem (see Technical Manual).

  ME 100 – turbine runs at 95 V DC or less

  ME 120 – turbine runs at 115 V DC or less

  ME 140 – turbine runs at 135 V DC or less

  ME 250 – turbine runs at 240 V DC or less

  GE 400 – turbine runs at 385 V DC or less
- Try increasing the swept range of the MPPT controller or grid tied inverter, so that they sweep over a wider range of the open circuit voltage of the generator.
- If you cannot resolve a problem email all your data and pictures of the install to us via our web site at www.powerspout.com with and we will try to help you find a solution.

Note the number of washers required for a particular jet size and when running on one or two jets. Change the packers with the corresponding jet sizes as your river flow changes with the seasons. Hang the jets and packing washers on nails in your power shed for wet, normal and dry period flows.

You may be able to further increase the power output from your turbine using larger jet sizes. This has the effect of increasing the flow rate. There comes a point when the increase in flow rate causes a dramatic drop off in pressure due to increased pipe friction losses. This occurs when the pressure in the pipe (just prior to the jet) drops to 2/3 of the static pressure (pressure when valve closed). When this point is reached increasing the jet size further will reduce the power output but consume more water. The jet sizes required will have been calculated based on the head, pipe size and flow indicated. Some fine-tuning on site will be required.

When operating your Smart Drive generator near the maximum power level for the rpm it is operating at, you will notice that a little more or less Smart Drive rotor packing does not make a significant difference. A 10% reduction in rotor magnetism results in approximately a 10% drop in Smart Drive generator input torque which results in an approximately 5% rise in Pelton wheel rpm which results in a 5% increase in Smart Drive torque. The two 5% rises will be almost as much as the 10% reduction in rotor magnetization.

This is best illustrated in the Smart Drive test graph (Figure 6). A 10% reduction in the rotor magnetism to the stator reduces the power line's height by 10% and the amps / volts lines by 5% approximately.

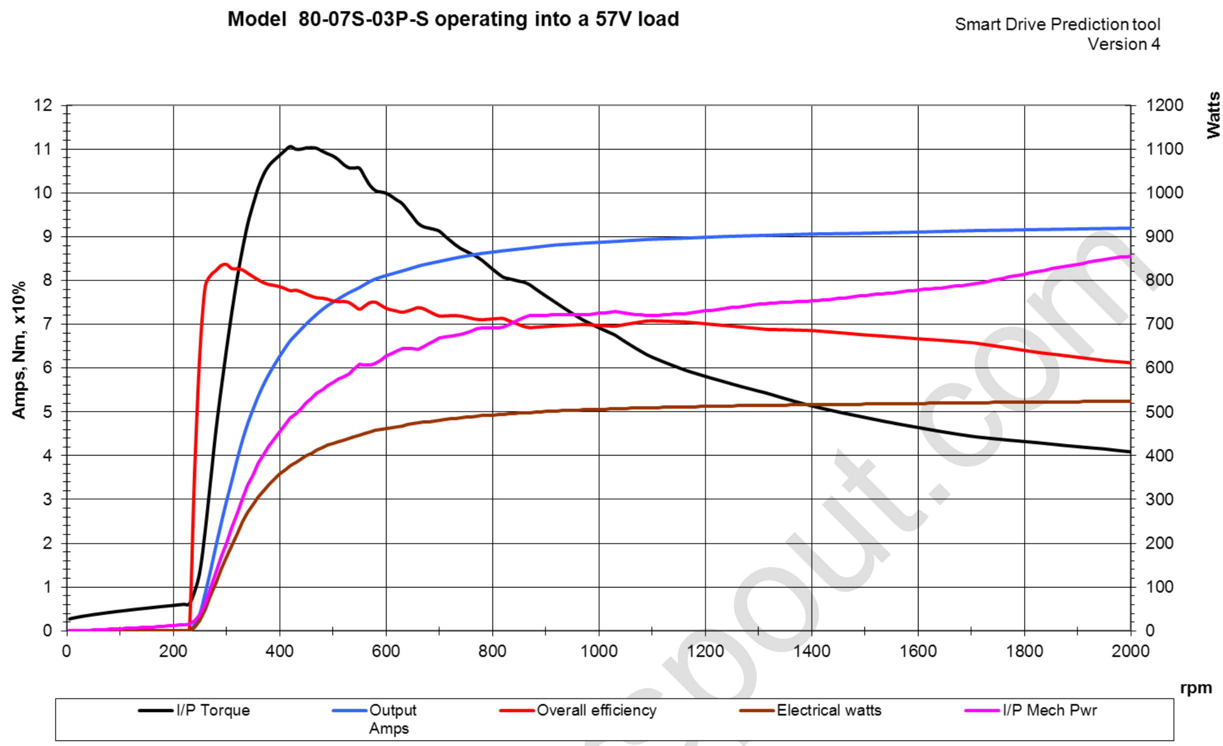


Figure 6. Simplified Smart Drive test graph

This example assumes that calculations for your site data predicted that you could get 530 W at 1000 RPM (brown line) and 70% generator efficiency (red line) on a fully charged 48 V DC bank at 56 V DC.

At maximum power, increasing or decreasing the RPM of the Smart Drive by packing will make little difference to the output power it can produce, as the gradient of the brown line is shallow.

In summer when a smaller jet is used and generation potential falls to only 200 W, the turbine operates at close to the static pressure of the pipe line and the power curve has a steep gradient. The speed of the turbine will be slow due to an oversized generator combined with poor Pelton rotor efficiency (because it is not running at the optimum speed). Packing the rotor out a small amount will have a dramatic effect. Rotor packing flattens and moves to the right the brown power line and the red efficiency line; this allows the Pelton rotor to pick up speed and become more efficient at extracting power from the water jet, increasing the RPM even more.

Your PowerSpout will have been shipped with a Smart Drive generator optimized for maximum efficiency at your maximum power level expected. This has the result of reducing the requirement to pack the rotor. However if you are using your PowerSpout BE on a wide range of flow rates some rotor packing will be needed. To improve efficiency at low flow rates you should purchase a reduced core stator.

9.2. Thermal Checks

A PowerSpout has an enclosed generator. The inside stator core temperature of the generator will depend on:

- Output power of the turbine
- Revolutions (speed) of turbine – higher rpm has more cooling
- Ambient air temperature
- Water temperature
- Voltage of operation (less heat at higher voltages due to lower currents)

The generator core is cooled by air flow across the stator. The warmed air then transfers this heat through the aluminum bulk head into the exhaust water of the hydro turbine. The air temperature inside the housing is typically 30 degrees Celsius. This warm environment ensures a near constant temperature of the Smart Drive bearings thus reducing moisture ingress due to condensation that is common in the damp environments in which hydro turbines are often installed.

After the turbine has been running for 2-3 hours, turn off the water supply, remove the rear cover, remove the Smart Drive magnetic rotor and hold your hand on the copper coils: if it is too hot to comfortably hold your hand there, more cooling is needed.

2 x side air vents and 1 x rear lid air vent

More cooling may be required in warmer climates and where the output of the turbine exceeds 400 Watts (or 10 amps). The ideal stator core temperature should be in the range 40-60 degrees Celsius after 2-3 hours of operation.

EcoInnovation will have fitted 3 air vents for turbines above 500W and 1 vent below 500W, if your turbine is running too hot (hot climate and 12 V operation) then more cooling may be required. Contact EcoInnovation and we will send out vents that you can easily install with a hole saw and drill.

The person responsible for installing and commissioning the turbine needs to do a thermal check as outlined above.

The temperature inside the bottom of a PowerSpout GE (operating at 1.6kW on a 130m running head test site) reached 36°C. Due to a farm animal breaking the water pipe the unit was left not operating. The following data was inadvertently collected:

- Case temperatures rose up to 39°C caused by sunlight heating. Ambient air temperatures were around 25°C.
- Relative humidity was around 40% during operation and increased to 95% when not operating

This observation is interesting and shows that a turbine should not be turned off for extended periods of time. If your turbine is only used for winter generation, then the turbine should be removed to a dry indoor storage area with the back rear cover left off while in storage.

9.3. Turbine case flooding

On low head hydro sites turbines are more exposed to flooding risk. BE and ME turbines (up to 140 vdc) can handle submersion on rare occasions. ME 250, GE 400 and HE turbines cannot and will be damaged.

Immediately following a submersion of the turbine you must:

- Remove the magnetic rotor and clean off any magnetic grit carried by the water
- Regrease the bearings and run the turbine so that internal generator heat will dry it out.
- Clean out any excess grease from the front of the bearing block and top-hat drain hole as this can block with grease preventing water from draining away.

Corrosion damage caused by water submersion is not covered under warrantee.

Flooded turbine

10. Operating your system efficiently

The PowerSpout is a durable machine but it runs 24/7 so regular checks and maintenance are advised. A PowerSpout 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. A bearing maintenance schedule is outlined below and you are required to follow it if your 3-year warranty is to be honored. Should you have a bearing failure during the 3-year warranty period we will ask to see your log book as proof you have followed the maintenance schedule.

To maintain your hydro scheme in a good condition for years to come we recommend you keep a log book and regularly (every week initially, and once you become familiar with your system every 2 weeks) do the following:

- Check the specific gravity of your batteries with a hydrometer and reduce your power usage if battery charge is falling (BE, ME, HE).
- Check the acid level in your batteries and top up with distilled water as required (BE, ME, HE).
- Check PowerSpout air vents are clean
- Check hydro output is normal and has not changed since last checked.
- Check your diversion load is working (BE, ME, HE).
- Check you have surplus water at the intake. If not, reduce your jet sizes.
- Check there are no obstructions (twigs) that have got in your pipe and are partially blocking the jets.
- Walk the pipe line each year and check for any damage to the pipe.
- One a year check termination points on your battery, regulator, inverter, fuses and diversion load. Clean and tighten as required. If you observe any heat damage or corrosion at terminations attend to these and repair. Remember to turn off all generation, your inverter and remove battery fuses before cleaning/tightening any termination points. You should pay special attention to your diversion load and battery terminals.

We also suggest you are wary of complacency. Since these systems work and give free power, people tend to keep adding more and more loads until they reach the limit of the system. Hence we recommend you:

- Fit a remote power meter to your inverter that will alert you if you exceed your peak load and advise you how many kWhrs you are using each day.
- Tell your guests about living off the grid and that they cannot plug in large resistive heaters, as these can knock years off your battery life and overload your inverter system.

Power meter

10.1. Spare parts

If you live in a remote part of the world you should consider having a full spare parts kit on the shelf. These are not expensive and will mean that whatever the problem you can get your system going again quickly. At the very least you should hold a spare shaft and bearing block (Table 3) since spare parts from NZ can take up to 10 working days to arrive to global destinations.

Table 3. Recommended minimum spare parts set

Sub 02	Nos.	Shaft and bearing assembly
PS020	1	Bearing block D76x113mm
PS022	1	Front bearing 6205 OD52 ID25mm
PS023	1	Rear bearing 6005 OD47 ID25mm
PS024	1	Shaft D25x276mm long
PS025	1	Shaft retaining nut 32AFx5mm thick

10.2. Lubricating the bearings

Factory fitted bearings in your PowerSpout hydro turbine are top quality SKF explorer series sealed bearings which can last many times longer than low cost bearings in the same application:

- Front SKF 6205-2Z OD52mm ID25mm
- Rear SKF 6005-2Z OD47mm ID25mm

Sealed bearings do need to be re-greased at times as hydro turbines run 24/7 and see very high cycle rates. The PowerSpout is provided with a re-greasing nipple so this can be easily done with the turbine in operation.

You should lubricate your PowerSpout bearings at the time you first use it and then:

- Every 12 months for generation up to 300 W.
- Every 6 months for generation up to 600 W.
- Every 3 months for generation up to 1200 W.

Remember to grease your new PowerSpout

A good quality grease must be used. We recommend SKF LESA 2 grease for all PowerSpout applications or close equivalent.

http://www.mapro.skf.com/pub/pds/LESA2_datasheet_e.pdf

With the turbine running connect your grease gun onto the grease nipple provided. Pump into the bearing block about 20 mL of grease. This is normally about 20 pumps of a domestic type grease gun. Subsequent re-greasing should be about 5 mL of grease (about 5 pumps).

Do not over grease the bearings as the excess grease forced out can block the drain hole in the bearing block and top hat housing.

If you turn your turbine off during the dry season or for any period greater than 2 weeks you should lubricate as above prior to turning off.

Remember, your PowerSpout 3-year warranty is conditional on bearing replacement every 12 months and the above lubrication regime that you should document in your log book.

10.3. Changing the bearings

You will need to check the bearings every year and replace if required (note our warranty terms require annual replacement). Bearings are inexpensive and easy to replace. We recommend you hold a spare bearing block and shaft on the shelf to make this procedure very easy and quick to do. A spare set of lower quality bearings is supplied with each new turbine (these are only to tide you over until you can buy the correct SKF explorer bearing specified for this equipment). Some of our Pelton turbines have been running on original bearings at customer sites for over three years, though we do not recommend that you do this.

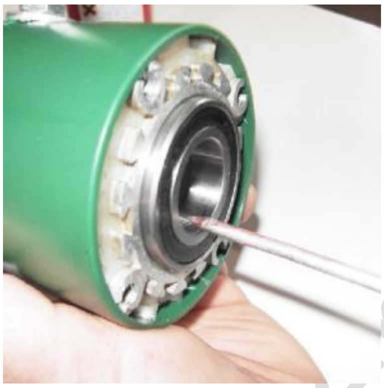
For turbines running at high pressures (above 100 m head) and high output power (above 1200 W) you should seek our advice. Generally units running above our approved ratings only carry a limited 1-year duration warranty. The PowerSpout ME and GE is available in a high power special version that is capable 1.6kW at 1600 rpm on a 120m running head.

To replace bearings

- Remove front glazing (PS008) and casing end cap (PS002).
- Remove Pelton rotor (PS050) by removing bolt (PS040).
- Remove Smart Drive rotor (PS061) by turning extractor knob (PS063).
- Remove Smart Drive stator (PS060) by removing the four fixings (PS026).
- Detach bearing lubrication tube (PS093).
- Remove four slinger fixings (PS034).
- You can now remove the shaft and bearing assembly (Sub 02) from unit.
- Remove shaft retaining nut (PS025). Hold shaft in vice to do this.
- Hit the end of the shaft with a raw-hide mallet (hit the end the Smart Drive attaches to). You may need to use a small workshop press to push the shaft out.
- Remove shaft.
- Use a punch to knock out the old bearings from the bearing block and recycle.
- Thoroughly clean the bearing block (PS020).
- Using a large socket as a drift (on the outer ring of the bearing) tap the new front bearing (PS022) fully home as shown.
- The rear bearing PS023 can be tapped home on the outer ring of the bearing with a hammer as shown.

- Clean the inside bearings and shaft with a solvent.
- Apply Loctite 680 (bearing mount or similar anaerobic adhesive) using the rear bearing inside diameter as shown.


- Loctite 680 the front bearing shaft position as shown.
- Smear the loctite evenly over the surfaces (1-2 drops per surface is sufficient).
- Insert shaft the correct way around (spline protruding through smaller rear bearing). You may need to use a small workshop press to press the shaft home.




- Clean up any excess loctite with a clean rag.
- Attach shaft retaining nut and snug up but do not over tighten. Shaft should spin freely without any tightness. On high power turbines a bearing to bearing inner sleeve tube is installed. Where this tube is installed tighten the shaft retaining nut to 50 Nm (35 lb/ft). This tube helps to prevent bearing spin (that can damage the shaft) and is normally only installed on high power units.
- Spin the shaft in your fingers, there should be no tight spots, if there are it is likely you have not pushed the bearing fully home. Remove the shaft and press the bearing home.

Note, for low output turbines running at less than 200W you can remove the inner bearing dust seals as this will reduce bearing losses. Never remove the outer dust seals.

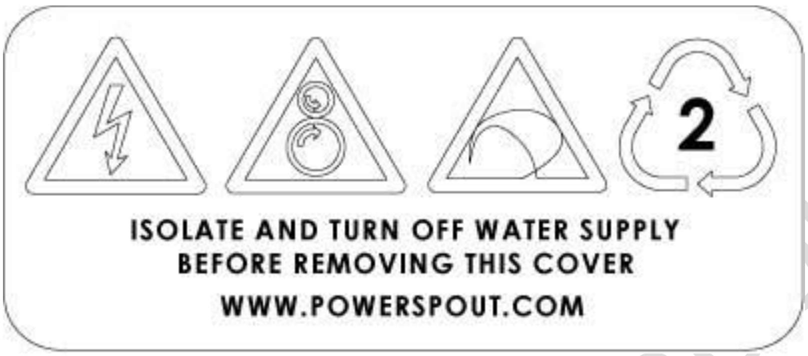
Make sure that the drain holes in the top hat and bearing block are free of grease and obstructions so any water can drain out freely.

11. 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, high pressure water, and taking steps to help others recognize and avoid such hazards.

11.1. Front glazing and rear cap safety warnings

The rear cap of this turbine forms part of an electrical enclosure and carries the following warning sign. 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, the front glazing needs to be fastened in place with the fixings in addition to the quick release toggle latches. The toggle latches are intended for commissioning and jet optimization. Once this is complete permanent fixings need to be used. This precaution ensures that children cannot remove the front cover and be exposed to a rotational hazard. The Pelton spoons are sharp and could cause serious hand injury.

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

11.2. Pressurised water pipes

Legislation covering pressurized pipes applies in most countries for pipe pressures over 10 Bar. The PowerSpout runs at less than 10 Bar in all approved applications. Check with your local authority if you have any legal requirement that may concern this installation in your country.

Generally there is little risk at less than 10 Bar pressure. The biggest risk is insecurely fastened pipe joiners that blow off, with the free end of the pipe hitting people. Securing the pipe at regular intervals, particularly near the joins, and checking all joiners are tight will eliminate such risks.

Ensure you install pipe with the correct pressure rating.

11.3. Grid (power network) connections

PowerSpout GE is a grid-tied option (no batteries required) available for clients that are already connected to the grid and have a good water resource close by.

Figure 4 shows the system configuration for a grid tied PowerSpout using a SunnyBoy inverter from SMA. The PowerSpout Technical Manual contains further details including a wiring diagram and guidance on multiple PowerSpout turbines.

The PowerSpout GE provides a DC output which is electronically limited to never exceed 400 V DC. Internally the output voltage is limited to approximately 385 V DC. With this feature the PowerSpout GE may be connected directly to grid tied inverters and produce AC power to your local electricity distribution network from clean renewable hydro power.

WARNING

Operating voltage within a PowerSpout GE is normally around 350 V DC. At this voltage electrocution is likely. 350 V DC 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.

12. Troubleshooting

The fault finding procedure here is concerned with only the PowerSpout 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.

If you are concerned your system is not operating correctly then measure the PowerSpout output voltage and current at the PowerSpout and compare with the data supplied with your PowerSpout. Also multiply the voltage (V) reading by the current (A) to determine the Watts your PowerSpout is producing.

- If the Watts from your PowerSpout is within 10% of the design Watts provided for your site then the PowerSpout is working correctly but may be in need of further optimization.
- If the Watts are between 20% and 80% of the design Watts.
  - Confirm you have sufficient water. If a first assessment of your PowerSpout installation then also check the accuracy of your water resource information supplied when you ordered your PowerSpout.
  - Check your penstock for leaks, blockages, airlocks, clogged intake, jet sizes etc.
  - Check your PowerSpout turbine for correct jet alignment, bearing health, correct rotor mounting and that no moving parts are rubbing and all wires are connected internally.
- If Watts are less than 20% then do the above plus the following for your version of PowerSpout.
  - PowerSpout BE
    - If output voltage is 0V and current is 0A then check water flow, is the turbine spinning and is the turbine 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 much higher than the battery voltage then check and correct electrical connections to batteries, check for blown fuse (current will be near 0A).
  - PowerSpout ME (and GE)
    - If output voltage is 0V and current is 0A then check water flow and that the turbine is spinning and electrically connected.
    - If output voltage is about 0.8V and there are other PowerSpouts (BE version or other types of generators) connected to the PowerSpout ME (GE) output then disconnect the other PowerSpouts.
    - Stop the PowerSpout ME (GE) and restart. Voltage should then be 115V (380V for GE)
    - The emergency clamp circuit will operate to short the generator to about 0.8V if PowerSpout ME (GE) has no water flow and is being supplied power by other attached turbines.
    - If output voltage is about 0.8V for a single PowerSpout ME (GE) then check and correct electrical connections to internal dump load inside PowerSpout. The internal dump load resistance is 10 Ohm for ME (40 Ohm for GE). If internal dump load is correct contact EcoInnovation for additional help.
    - If output voltage is 115V (380V for GE) and the current is 0A then check and correct electrical connections to MPPT controller (Grid tied inverter for GE)

12.1. Link to online updates

Please refer to our online FAQ for the most recent updates.
www.powerspout.com/faq/

13. Site data for hydro specification and improvements

13.1. PowerSpout 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, or
- Complete the table below and email it to questions@powerspout.com we will reply promptly with the best hydro option available for your site.

Table 4. Hydro site data required for product manufacture

		Units
Head at site (vertical drop/fall of pipe)		m or ft
Pipe length required to get fall		m or ft
Pipe inside diameter if installed		mm or inch
Do you want us to advise your pipe size?	Yes / No	-
Flow available at intake		l/sec or gal/min
What is the cable length from turbine to batteries		m or ft
If cable is installed what size is it		mm^2 or sq inches
Do you want us to advise cable size?	Yes / No	-
For BE and ME version state your battery voltage	12/24/48	Volts
For ME version state the make and model of MPPT controller you intend to use		
For GE version 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. If you intend to run your turbine over a wide range of flow rates, you need to state this at the time of ordering. A different generator core can be supplied for an additional charge.

13.2. 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.

Installation details	
Date installed	
Location of installation	
Pipe inside diameter	m or inch
Pipe length	m or ft
Jet size	mm or inch
Static pressure on gauge (turbine off)	kPa or PSI
Dynamic pressure on gauge (turbine running)	kPa or PSI
System nominal voltage	V
Cable length	m or ft
Cable wire size	mm^2/conductor
Generator name (e.g. 100-14S-1P delta)	100/80/60/60dc - ____S-____P delta/star
Performance data	
Flow rate of water through turbine	l/s or gal/min
Voltage on DC rectifier pins at hydro	V
Voltage at battery terminals	V
Current generated	A

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 from site to site.

13.3. Noise

Noise is not normally an issue. Our turbine in normally quieter than others as it turns slower and is fully enclosed. Hence if noise is an issue at your site you should check the following:

- The Pelton rotor is not hitting the jets, it has been packed out correctly and packer washer have not been missed out
- 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 the cause if noise has increased gradually over time)
- The unit is running at the correct speed – see manual for correct speed images. This is caused by clients installing jets that are too large for the generator power rating resulting in excessive RPM
- The unit is performing as estimated – please supply data as per the manual
- The noise is not related to how the turbine has been mounted. A heavy timber or concrete base will be quieter than steel/aluminum framed base
- The line is free from air, compressed air expansions at the jet are very noisy

We have not taken noise level readings, as all hydro sites are different and it does not seem to be an issue. That said some clients have installed turbines too close to their homes.

Generally the higher the head the more noise from the unit. Our test site at 160m head and 1.6 kW you can talk normally together standing by the turbine, but you are very aware it is there. You can just hear it at 30-40m away. It sounds like a washing machine in spin.

On low head sites less than 10m (30ft) the river is likely to make more noise than the turbine. A turbine can be closer to a dwelling in such cases.

Vegetation around the turbine will dramatically reduce the distance that noise carries.

13.4. 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).

14. 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
gallons	liters	3.7854
gallons per minute	liters per second	0.0631
horsepower (electrical)	kilowatts	0.7460
degrees Fahrenheit	degrees Celsius	-32 x 5/9

15. Warranty and disclaimer

The following applies to complete water turbines only and hence excludes kit sets and parts. Trade customers on selling this product must facilitate warrantee claims with the final client. EcoInnovation will only deal with the Trade customer in such cases.

Our warranty is valid provided the turbine has been correctly installed, commissioned and maintained over the duration of its use. The end user must return installation details[6] to EcoInnovation and keep a log book to record maintenance activity. EcoInnovation may request to see the log book and pictures of the installation and failed component prior to processing any warrantee claim.

Please also refer to warranty upgrades and support options as detailed on our web site.

EcoInnovation is confident in the performance, reliability and cost effectiveness of our range of water turbines. Hence we offer you:

- Full refund if you are not satisfied after the turbine has been running at your site for a 30-day period (this must occur within 3 months of dispatch) and EcoInnovation must be given the opportunity to rectify the problem. Clients need to pay for return freight cost, and the turbine must be returned in as new condition for a full refund.
- Performance guaranteed if our installation advice is followed for turbines that have output power greater than 200 W. Below 200 W a margin of +/- 20% applies.
- 3-year warranty from the time of purchase (invoice date), subject to maintenance specified in the PowerSpout Installation Manual including re-lubrication and replacement of bearings.
- Extended warranty available up to 10 years (premium per additional year).
- If there is a problem email us a picture of the failed part and we will fix it by dispatching a replacement part to you promptly. The labor cost to fit this part to your turbine is not covered under this warranty. The 3-year warranty is limited to the supply of replacement parts within 3 years of initial purchase.
- The cost of any single replacement part excluding the casing (outside the 3 year warranty period) for the original purchaser of our turbine will not be more than $100 US plus freight (5 year limit from purchase date of turbine).
- If you can find a similar quality retail product advertised by a manufacturer or authorized dealer at a more competitive price, we will beat it by 20%. We will require an original copy of the advertisement. This offer excludes trade specials and second-hand units.
- Our maximum liability is limited to the full amount paid for the turbine. If you are an overseas customer that has purchased this equipment by mail order over the internet then this is the maximum extent of our liability.
- EcoInnovation reserves the right to improve the product and alter the above conditions without notice.

EcoInnovation takes safety very seriously and we endeavor to reduce all risks to the extent possible and warn you of hazards. We encourage you to have the PowerSpout installed by a professional renewable energy installer if you do not have the skill, qualifications and experience to install this equipment safely. Customers that ignore such risks and advice do so at their own risk.

[6] The warranty is only valid for 12 months if no documentation (see Section 13.2) is returned within 11 months of sale

16. Annex I: Jet sizing tables

The following tables enable you to quickly determine the approximate jet size required for your site at your head and available flow rate. The tables are provided in both metric and imperial units for one and two jet hydro installations.

Table 5. Flow in liters per second (l/s) with one jet

Head (with turbine running)			Jet Velocity	Jet Size – Diameter in mm															
M	kPa	Bar	m/s	3	3.5	4	4.5	5	6	7	8	9	10	12	14	16	18	19	22
3	29	0.3	8	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.1	1.5	1.9	2.1	2.8
5	49	0.5	10	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	1.1	1.4	1.9	2.4	2.7	3.6
10	98	1.0	14	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.5	2.0	2.7	3.4	3.8	5.1
15	147	1.5	17	0.1	0.2	0.2	0.3	0.3	0.5	0.6	0.8	1.0	1.3	1.8	2.5	3.3	4.1	4.6	6.2
20	196	2.0	20	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.9	1.2	1.5	2.1	2.9	3.8	4.8	5.3	7.2
25	245	2.5	22	0.1	0.2	0.3	0.3	0.4	0.6	0.8	1.1	1.3	1.7	2.4	3.2	4.2	5.4	6.0	8.0
30	294	2.9	24	0.2	0.2	0.3	0.4	0.5	0.7	0.9	1.2	1.5	1.8	2.6	3.5	4.6	5.9	6.5	8.8
35	343	3.4	26	0.2	0.2	0.3	0.4	0.5	0.7	1.0	1.3	1.6	2.0	2.8	3.8	5.0	6.3	7.1	9.5
40	392	3.9	28	0.2	0.3	0.3	0.4	0.5	0.8	1.0	1.3	1.7	2.1	3.0	4.1	5.4	6.8	7.5	10.1
45	441	4.4	30	0.2	0.3	0.4	0.4	0.6	0.8	1.1	1.4	1.8	2.2	3.2	4.3	5.7	7.2	8.0	10.7
50	490	4.9	31	0.2	0.3	0.4	0.5	0.6	0.8	1.1	1.5	1.9	2.3	3.4	4.6	6.0	7.6	8.4	11.3
55	539	5.4	33	0.2	0.3	0.4	0.5	0.6	0.9	1.2	1.6	2.0	2.5	3.5	4.8	6.3	7.9	8.8	11.9
60	588	5.9	34	0.2	0.3	0.4	0.5	0.6	0.9	1.3	1.6	2.1	2.6	3.7	5.0	6.6	8.3	9.2	12.4
65	637	6.4	36	0.2	0.3	0.4	0.5	0.7	1.0	1.3	1.7	2.2	2.7	3.8	5.2	6.8	8.6	9.6	12.9
70	686	6.9	37	0.2	0.3	0.4	0.6	0.7	1.0	1.4	1.8	2.2	2.8	4.0	5.4	7.1	9.0	10.0	13.4
75	736	7.4	38	0.3	0.4	0.5	0.6	0.7	1.0	1.4	1.8	2.3	2.9	4.1	5.6	7.3	9.3	10.3	13.9
80	785	7.8	40	0.3	0.4	0.5	0.6	0.7	1.1	1.4	1.9	2.4	3.0	4.3	5.8	7.6	9.6	10.7	14.3
85	834	8.3	41	0.3	0.4	0.5	0.6	0.8	1.1	1.5	2.0	2.5	3.0	4.4	6.0	7.8	9.9	11.0	14.7
90	883	8.8	42	0.3	0.4	0.5	0.6	0.8	1.1	1.5	2.0	2.5	3.1	4.5	6.1	8.0	10.2	11.3	15.2
95	932	9.3	43	0.3	0.4	0.5	0.7	0.8	1.2	1.6	2.1	2.6	3.2	4.6	6.3	8.2	10.4	11.6	15.6
100	981	9.8	44	0.3	0.4	0.5	0.7	0.8	1.2	1.6	2.1	2.7	3.3	4.8	6.5	8.5	10.7	11.9	16.0

Table 6. Flow in gallons per minute (gal/min) with one jet

Head (with turbine running)			Jet Velocity	Jet Size - Diameter in Inches															
Ft	PSI	Bar	Ft/s	1/32	1/16	3/32	1/8	5/32	3/16	7/32	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
12	5	0.3	25	0	0	1	1	2	2	3	4	6	9	12	16	20	25	30	36
35	15	1.0	44	0	0	1	2	3	4	5	7	11	15	21	27	35	43	52	62
35	15	1.0	44	0	0	1	2	3	4	5	7	11	15	21	27	35	43	52	62
46	20	1.4	50	0	0	1	2	3	4	6	8	12	18	24	32	40	50	60	71
58	25	1.7	56	0	1	1	2	3	5	7	9	14	20	27	35	45	55	67	80
69	30	2.1	62	0	1	1	2	4	5	7	10	15	22	30	39	49	61	73	87
81	35	2.4	67	0	1	1	3	4	6	8	10	16	24	32	42	53	66	79	94
92	40	2.8	71	0	1	2	3	4	6	9	11	18	25	34	45	57	70	85	101
104	45	3.1	75	0	1	2	3	5	7	9	12	19	27	36	48	60	74	90	107
115	50	3.4	80	0	1	2	3	5	7	10	13	20	28	38	50	63	78	95	113
127	55	3.8	83	0	1	2	3	5	7	10	13	21	30	40	53	67	82	99	118
138	60	4.1	87	0	1	2	3	5	8	11	14	21	31	42	55	70	86	104	124
161	70	4.8	94	0	1	2	4	6	8	11	15	23	33	45	59	75	93	112	134
185	80	5.5	101	0	1	2	4	6	9	12	16	25	36	49	63	80	99	120	143
208	90	6.2	107	0	1	2	4	7	9	13	17	26	38	52	67	85	105	127	151
231	100	6.9	112	0	1	2	4	7	10	14	18	28	40	54	71	90	111	134	160
254	110	7.6	118	0	1	3	5	7	10	14	19	29	42	57	74	94	116	141	167
277	120	8.3	123	0	1	3	5	8	11	15	19	30	44	59	78	98	121	147	175
300	130	9.0	128	0	1	3	5	8	11	15	20	32	45	62	81	102	126	153	182
323	140	9.7	133	0	1	3	5	8	12	16	21	33	47	64	84	106	131	159	189
346	150	10.3	138	0	1	3	5	8	12	17	22	34	49	67	87	110	136	164	195

Table 7. Flow in liters per second (l/s) with two jets

Head (with turbine running)			Jet Velocity	Jet Size - Diameter in mm															
M	kPa	Bar	m/s	3	3.5	4	4.5	5	6	7	8	9	10	12	14	16	18	19	22
3	29	0.3	8	0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.6	2.2	2.9	3.7	4.1	5.5
5	49	0.5	10	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.9	1.2	1.5	2.1	2.9	3.8	4.8	5.3	7.2
10	98	1.0	14	0.2	0.3	0.3	0.4	0.5	0.8	1.0	1.3	1.7	2.1	3.0	4.1	5.4	6.8	7.5	10.1
15	147	1.5	17	0.2	0.3	0.4	0.5	0.6	0.9	1.3	1.6	2.1	2.6	3.7	5.0	6.6	8.3	9.2	12.4
20	196	2.0	20	0.3	0.4	0.5	0.6	0.7	1.1	1.4	1.9	2.4	3.0	4.3	5.8	7.6	9.6	10.7	14.3
25	245	2.5	22	0.3	0.4	0.5	0.7	0.8	1.2	1.6	2.1	2.7	3.3	4.8	6.5	8.5	10.7	11.9	16.0
30	294	2.9	24	0.3	0.4	0.6	0.7	0.9	1.3	1.8	2.3	2.9	3.6	5.2	7.1	9.3	11.7	13.1	17.5
35	343	3.4	26	0.4	0.5	0.6	0.8	1.0	1.4	1.9	2.5	3.2	3.9	5.6	7.7	10.0	12.7	14.1	18.9
40	392	3.9	28	0.4	0.5	0.7	0.8	1.0	1.5	2.0	2.7	3.4	4.2	6.0	8.2	10.7	13.5	15.1	20.2
45	441	4.4	30	0.4	0.5	0.7	0.9	1.1	1.6	2.2	2.8	3.6	4.4	6.4	8.7	11.4	14.4	16.0	21.5
50	490	4.9	31	0.4	0.6	0.7	0.9	1.2	1.7	2.3	3.0	3.8	4.7	6.7	9.2	12.0	15.1	16.9	22.6
55	539	5.4	33	0.4	0.6	0.8	1.0	1.2	1.8	2.4	3.1	4.0	4.9	7.1	9.6	12.5	15.9	17.7	23.7
60	588	5.9	34	0.5	0.6	0.8	1.0	1.3	1.8	2.5	3.3	4.1	5.1	7.4	10.0	13.1	16.6	18.5	24.8
65	637	6.4	36	0.5	0.7	0.9	1.1	1.3	1.9	2.6	3.4	4.3	5.3	7.7	10.4	13.6	17.3	19.2	25.8
70	686	6.9	37	0.5	0.7	0.9	1.1	1.4	2.0	2.7	3.5	4.5	5.5	8.0	10.8	14.2	17.9	20.0	26.8
75	736	7.4	38	0.5	0.7	0.9	1.2	1.4	2.1	2.8	3.7	4.6	5.7	8.2	11.2	14.7	18.5	20.7	27.7
80	785	7.8	40	0.5	0.7	0.9	1.2	1.5	2.1	2.9	3.8	4.8	5.9	8.5	11.6	15.1	19.2	21.3	28.6
85	834	8.3	41	0.5	0.7	1.0	1.2	1.5	2.2	3.0	3.9	4.9	6.1	8.8	11.9	15.6	19.7	22.0	29.5
90	883	8.8	42	0.6	0.8	1.0	1.3	1.6	2.3	3.1	4.0	5.1	6.3	9.0	12.3	16.1	20.3	22.6	30.4
95	932	9.3	43	0.6	0.8	1.0	1.3	1.6	2.3	3.2	4.1	5.2	6.4	9.3	12.6	16.5	20.9	23.3	31.2
100	981	9.8	44	0.6	0.8	1.1	1.3	1.7	2.4	3.2	4.2	5.4	6.6	9.5	13.0	16.9	21.4	23.9	32.0

Table 8. Flow in gallons per minute (gal/min) with two jets

Head (with turbine running)			Jet Velocity	Jet Size - Diameter in Inches															
Ft	PSI	Bar	Ft/s	1/32	1/16	3/32	1/8	5/32	3/16	7/32	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
12	5	0.3	25	0	0	1	2	3	4	6	8	12	18	24	32	40	50	60	71
35	15	1.0	44	0	1	2	3	5	8	11	14	21	31	42	55	70	86	104	124
35	15	1.0	44	0	1	2	3	5	8	11	14	21	31	42	55	70	86	104	124
46	20	1.4	50	0	1	2	4	6	9	12	16	25	36	49	63	80	99	120	143
58	25	1.7	56	0	1	2	4	7	10	14	18	28	40	54	71	90	111	134	160
69	30	2.1	62	0	1	3	5	8	11	15	19	30	44	59	78	98	121	147	175
81	35	2.4	67	0	1	3	5	8	12	16	21	33	47	64	84	106	131	159	189
92	40	2.8	71	0	1	3	6	9	13	17	22	35	50	69	90	114	140	170	202
104	45	3.1	75	0	1	3	6	9	13	18	24	37	54	73	95	120	149	180	214
115	50	3.4	80	0	2	4	6	10	14	19	25	39	56	77	100	127	157	190	226
127	55	3.8	83	0	2	4	7	10	15	20	26	41	59	81	105	133	164	199	237
138	60	4.1	87	0	2	4	7	11	15	21	27	43	62	84	110	139	172	208	247
161	70	4.8	94	0	2	4	7	12	17	23	30	46	67	91	119	150	185	224	267
185	80	5.5	101	0	2	4	8	12	18	24	32	50	71	97	127	161	198	240	285
208	90	6.2	107	1	2	5	8	13	19	26	34	53	76	103	135	170	210	254	303
231	100	6.9	112	1	2	5	9	14	20	27	35	55	80	109	142	180	222	268	319
254	110	7.6	118	1	2	5	9	15	21	28	37	58	84	114	149	188	232	281	335
277	120	8.3	123	1	2	5	10	15	22	30	39	61	87	119	155	197	243	294	350
300	130	9.0	128	1	3	6	10	16	23	31	40	63	91	124	162	205	253	306	364
323	140	9.7	133	1	3	6	10	16	24	32	42	66	94	129	168	212	262	317	378
346	150	10.3	138	1	3	6	11	17	24	33	43	68	98	133	174	220	271	328	391

17. Annex II: Common PVC pipe sizes

The tables below are to assist in the understanding of the PVC pipe sizes available in your country. Countries that have sizes very similar to other countries are shown colored the same, so they are easy to spot.

Table 9. NZ PVC Pipe sizes

OD of pipe	PN6 Wall mm	PN6 pipe mm	PN9 Wall mm	PN9 pipe mm	PN12 Wall mm	PN12 pipe mm	PN15 Wall mm	PN15 pipe mm	PN18 Wall mm	PN18 pipe mm	NB
48.3	1.7	44.9	2.1	44.1	2.8	42.7	3.4	41.5	3.9	40.5	40
60.4	1.8	56.8	2.6	55.2	3.4	53.6	4.1	52.2	5.0	50.4	50
75.4	**2.2**	71.0	**3.3**	68.8	**4.2**	67.0	**5.2**	65.0	**6.1**	63.2	65
88.9	2.6	83.7	3.8	81.3	5.0	78.9	6.1	76.7	7.2	74.5	80
114.3	3.3	107.7	4.9	104.5	6.3	101.7	7.8	98.7	9.2	95.9	100
140.2	4.0	132.2	5.9	128.4	7.7	124.8	9.5	121.2	11.3	117.6	125
160.3	**4.5**	151.3	**6.7**	146.9	**8.8**	142.7	**10.8**	138.7	**12.8**	134.7	150
225.3	5.8	213.7	8.4	208.5	11.1	203.1	13.7	197.9	16.2	192.9	200
250.4	**6.4**	**237.6**	**9.4**	231.6	**12.3**	225.8	**15.2**	220.0	**18.0**	214.4	225
280.4	7.1	266.2	10.5	259.4	13.8	252.8	17.0	246.4	20.2	240.0	250
315.5	8.0	299.5	11.8	291.9	**15.5**	284.5	**19.1**	277.3	**22.7**	270.1	300
400.5	10.1	380.3	14.9	370.7	19.7	361.1	24.3	351.9	28.9	342.7	375

NB refers to nominal bore which is the approximate inside diameter of the pipe series

Table 10. China PVC pipe sizes

OD of pipe	0.63 Mpa Wall mm	0.63 Mpa ID pipe mm	0.8 Mpa Wall mm	0.8 Mpa ID pipe mm	1.0 Mpa Wall mm	1.0 Mpa ID pipe mm	1.25 Mpa Wall mm	1.25 Mpa ID pipe mm	1.6 Mpa Wall mm	1.6 Mpa ID pipe mm	2.0 MPA Wall mm	2.0 Mpa ID pipe mm	2.5 MPA Wall mm	2.5 Mpa ID pipe mm
50	2.0	46.0	2.2	45.6	2.4	45.2	3.0	44.0	3.7	42.6	4.6	40.8	5.6	38.8
63	2.0	59.0	2.5	58.0	3.0	57.0	3.8	55.4	4.7	53.6	5.8	51.4	7.1	48.8
75	**2.3**	**70.4**	**2.9**	**69.2**	**3.6**	**67.8**	**4.5**	**66.0**	**5.6**	**63.8**	**6.9**	**61.2**	**8.4**	
90	2.8	84.4	3.5	83.0	4.3	81.4	5.4	79.2	6.7	76.6	8.2	73.6	10.1	69.8
110	2.7	104.6	3.4	103.2	4.2	101.6	5.3	99.4	6.6	96.8	8.1	93.8	14.6	80.8
160	**4.0**	**152.0**	**4.9**	**150.2**	**6.2**	**147.6**	**7.7**	**144.6**	**9.5**	**141.0**	**11.8**	**136.4**	**18.2**	**123.6**
200	4.9	190.2	6.2	187.6	7.7	184.6	9.6	180.8	11.9	176.2	14.8	170.4		
250	6.2	237.6	7.7	234.6	9.6	230.8	11.9	226.2	14.9	220.2				
315	7.7	299.6	9.7	295.6	12.1	290.8	15.0	285.0	18.7	277.6				
355	8.7	337.6	10.9	333.2	13.6	327.8	16.9	321.2	21.1	312.8				
400	9.8	380.4	12.3	375.4	15.3	369.4	19.1	361.8	23.7	352.6				

Table 11. USA PVC pipe sizes

OD of Pipe	Schedule 40 Pipe ID mm	Schedule 80 Pipe ID mm	OD of pipe	Schedule 40 Pipe ID inch	Schedule 80 Pipe ID inch
48.3	40.4	37.5	1.9	1.6	1.5
60.3	52.0	48.6	2.4	2.0	1.9
73.0	62.1	58.2	2.9	2.4	2.3
88.9	77.3	72.7	3.5	3.0	2.9
101.6	89.4	84.5	4.0	3.5	3.3
114.3	101.5	96.2	4.5	4.0	3.8
141.3	127.4	121.1	5.6	5.0	4.8
168.3	153.2	145.0	6.6	6.0	5.7
219.1	201.7	192.2	8.6	7.9	7.6
273.1	253.4	241.1	10.8	10.0	9.5
323.9	302.0	286.9	12.8	11.9	11.3
355.6	332.1	315.2	14.0	13.1	12.4
406.4	379.5	361.0	16.0	14.9	14.2
457.2	426.9	406.8	18.0	16.8	16.0
508.0	476.1	452.5	20.0	18.7	17.8
609.6	572.6	544.0	24.0	22.5	21.4

Provided in metric and imperial