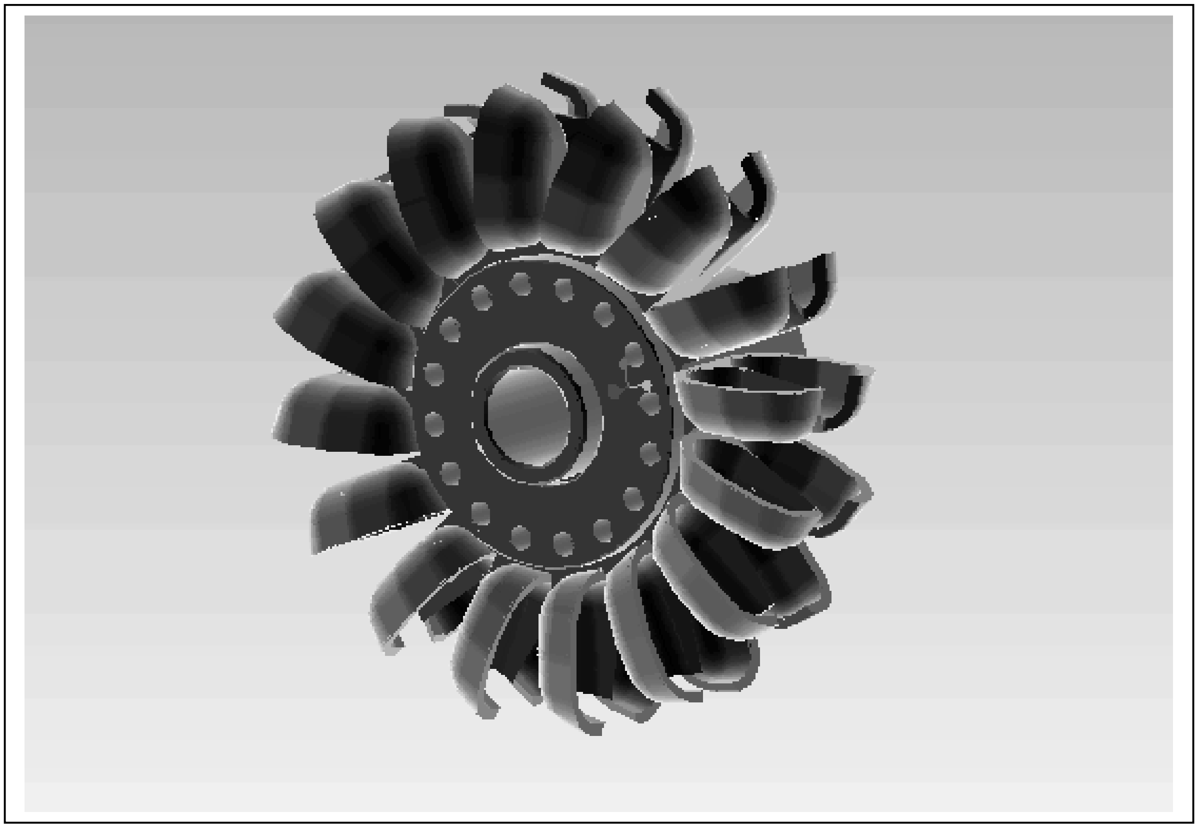
The Pico Power Pack

Fabrication and Assembly Instructions



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Disclaimer

The author accepts no responsibility for injury or death resulting from incorrect manufacturing, installation or operation of equipment described in this manual. All electrical and mechanical installation work and repair work should always be supervised and checked by a qualified and experienced technician or engineer.

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1 Introduction

The 'Pico Power Pack' is a design of water-powered turbine and generator unit which can be installed in regions where there is a drop, or 'head', of at least 20 metres. Useful amounts of electricity can be generated even if the flows of water are small. Up to 5KW a.c. electricity (for example, using a head of 70 metres and a flow of 15 litres per second) can be generated using this design. That is enough power to light 500 energy efficient lamps distributed over a 1km radius from the generator. Any other electrical devices which use mains electricity can also be directly connected providing that they draw no more power than the generator is producing.

At the heart of the unit is a small Pelton turbine directly attached to an induction generator. A shaft extension is located on the opposite end of the generator which can be connected to mechanical equipment by using a belt drive. The advantage of this arrangement is the increased power and high starting torque provided by direct drive from the Pelton turbine. This type of drive is ideal for many types of workshop and agricultural machinery

These guidelines are intended to provide a basis for the construction and assembly of the Pico Power Pack. They have been written to accompany the implementation guide "Pico Hydro for Village Power."

The high cost per kilowatt of pico hydro systems and poor availability has in the past, been an obstacle to wider adoption in developing countries where the largest markets for this technology exist. The Pico Power Pack is a standardised design which uses low-cost materials that are easily available in most countries. Additional components such as the induction motor as generator and PVC pipe flange seal can be purchased 'off-the-shelf'. This standardisation of design and components simplifies manufacturing and encourages batch production techniques whilst helping to minimise variations in quality and performance. This in turn, it is hoped, will lead to a reduction in the cost per kilowatt and increased affordability.

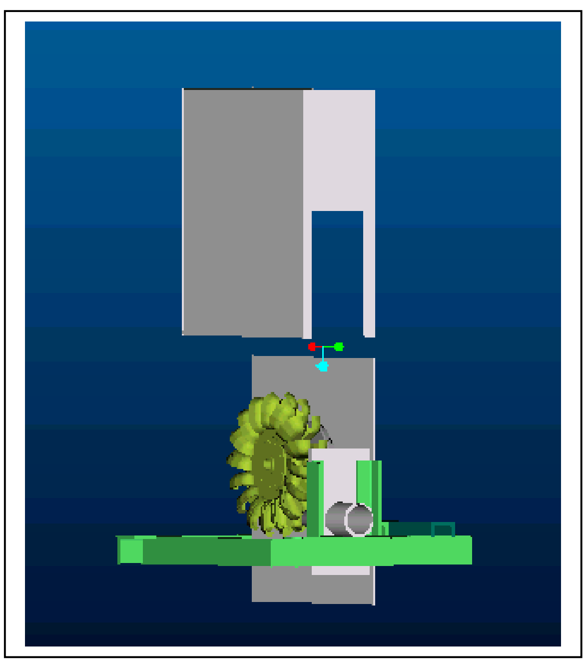

Figure 1 The 'Pico Power Pack' Turbine Assembly

2 Turbine and generator combinations for different sites

This manual includes dimensioned drawings for three sizes of Pelton runner (120mm, 160mm, 200mm p.c.d.) and a base frame and case arrangement which can accommodate generator frame sizes from D90 to D132 (a D90 has a distance of 90mm between the shaft centre and the base). The turbine and generator combination for a particular site needs careful selection. However, a small number of turbine runner sizes and the use of standard induction motors as generators make this process easier. The aim of careful turbine selection is to maximise the efficiency for a particular rotational speed (the speed is fixed by the generator). The best rotational speed for small turbine runners is higher than for larger ones.

The operating speed of an induction machine is determined by the number of poles. Using the table below, it is possible to select combinations of turbines and generators for particular sites. Using the table, identify the head which is closest to that at the site. Read off the size of turbine and type of generator which will be required

	Ideal Head (metres) for various runner and generator combinations to generate 50Hz		
P.c.d. of Pelton Runner (mm)	**2 pole generator**	**4 pole generator**	**6 pole generator**
120	98.5m	24.6m	______
160	175m	44m	19.5m
200	______	68.5m	30.4m

Table 1 Pelton turbine and induction generator selection

Due to the shape of the Pelton turbine power-speed curve, the head may be ±20% of the ideal values given without significant effect on the efficiency. The turbine will no longer be operating at the speed for best efficiency but as the speed graph is quite 'flat' in the centre (see Figure 2) some variation is possible without large amounts of power being lost.

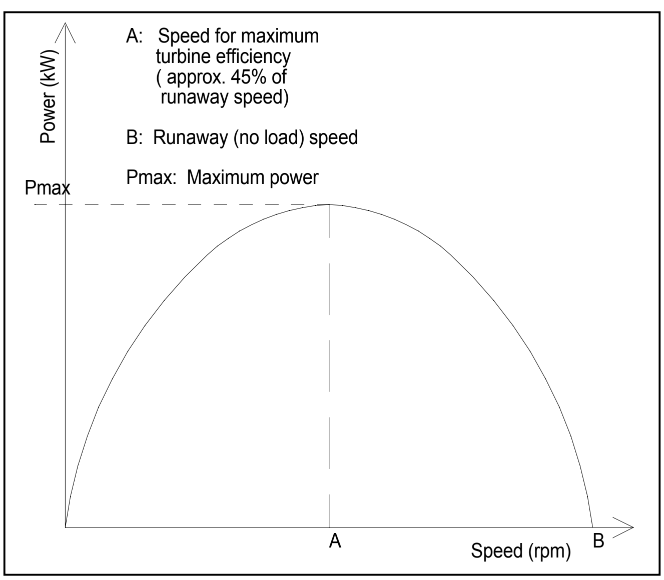

Figure 2 Pelton turbine power-speed curve

An additional consideration when sizing the turbine, is the flow rate. Most Pelton turbine buckets are designed to work with a maximum jet diameter of around 12% of the p.c.d. The maximum jet diameter for a particular turbine is limited because more water begins to miss the turbine or splash in the wrong direction as the jet becomes larger. This results in a drop in efficiency which is likely to cancel out any benefit from the extra flow. If more flow is required than the maximum size of nozzle will allow, then it will be necessary to select a larger runner and to reconsider the generator speed.

Calculate the maximum flow with the selected p.c.d of runner and net head as follows:

$$\textbf{Maximum flow (m}^3\textbf{/s) = } 0.05 \times p.c.d^2 \times \sqrt{H}_{net}$$

Where p.c.d. and head are measured in metres and the maximum jet to p.c.d. ratio is 12% (for the actual limit, check with the pattern manufacturer. e.g. limit is 15% of p.c.d. for patterns obtained from NTU).

Calculate the nozzle size required using these equations:

$$\textbf{Nozzle area (A) in metres}^2 \textbf{ = } \frac{Flow(m^3/s)}{\sqrt{2 \times 9.81 \times H_{net}}}$$

$$\textbf{Nozzle diameter in metres = } 2 \times \sqrt{\frac{A(m^2)}{\pi}}$$

Note: It is assumed throughout that the jet and nozzle diameter are equal. In practice the jet diameter is marginally smaller but this difference can be considered negligible for pico Pelton systems.

At high head sites the strength of the material used to make the buckets should also be considered. If there is any abrasive silt in the water then aluminium buckets will be quickly worn down by a high velocity jet. When the head is above 50 metres, bronze buckets should therefore be chosen.

Example: Turbine and Generator selection

a) What size of turbine and generator could be selected for a site where the net head is 50 metres and the design flow rate is 5 l/s

b) What nozzle size could be used?

c) What power could be expected from this combination? (turbine eff=70%; generator = 77%)

d) What power rating of induction motor could be selected for use as a generator if the motor power must be de-rated by a factor of 0.5 to 0.8?

Answers

a) 160 p.c.d. runner and 4 pole generator
b) max. flow = 5.1 l/s so nozzle will be less than 12% of p.c.d. ; nozzle diameter for 5l/s = 14.2mm
c) 1.3kW
d) 2.2kW motor should be selected. (frame size D100L for 4 pole from manufacturers info.)

For more details on selection of induction generators refer to the accompanying implementation manual, 'Pico Hydro for Village Power.'

3 Tools and equipment required

The following tools and equipment are essential for manufacture of the 'Pico Power Pack'

- Lathe - with tailstock, reaming tools, callipers
- Lathe tools – facing off tool, reaming tool (diameter depends on generator shaft), boring bar, recess cutting tool, soft jaws for holding an 8mm plate, centre drill, variety of drilling bits.
- Milling machine with 6 - 10mm cutter
- Welding Apparatus (gas, electric arc, or M.I.G etc.)
- Workbench with vice
- Pillar drill and bit sizes 5mm to 12mm
- Grinder
- General workshop tools; files, chisels, tin snips, scribe, methyl blue or similar, hammer, mallet, hacksaw and new blades, variety of clamps, blocks of wood, tap and die set for thread cutting (M6 and M8), screwdrivers, emery cloth, paintbrushes

The following equipment will greatly facilitate manufacturing:

- Dividing head
- Horizontal band saw or piston saw
- Guillotine
- Sheet metal bending machine
- Spot-welding equipment
- Electric hand drill
- Leather punch (for rubber gaskets)
- Large hole saw (44 - 50mm) or trepanning tool

4 Pelton turbine runners

This section provides guidance for the manufacture and assembly of small Pelton turbine runners from individual bucket castings.

4.1 Preparation of Bucket castings

1. Individual buckets are cast from suitable casting patterns. Good quality patterns will have an excellent surface finish and sized to allow for the shrinkage that will occur when the shape is cast in metal. The shrinkage allowance for aluminium is about 1.3%. Previously cast buckets are often used as the first pattern because no other examples are available. This leads to an inevitable reduction in the size and quality of the next generation of bucket castings. Avoid this if possible by seeking out authentic patterns.

2. Once buckets have been obtained the first step is to inspect them. Reject buckets with large defects or holes. If castings have excessive shrinkage on the root, modify pattern and cast buckets again. The root is important because this is machined to provide reference surfaces and ensure that all the buckets are correctly aligned.

3. Newly cast buckets should be carefully fettled to remove excess metal which has resulted from the casting process. Carefully finish the back of notch with a small file but not the front. The front edge of the notch should be sharp. Particular care should be taken not to remove too much material when fettling around the notch as shape changes here will have a significant effect on the bucket performance.

4. Polish inside surfaces with emery cloth. Surface roughness of the individual buckets can cause a significant reduction in overall performance of the runner

5. Machine backs of buckets flat and smooth. The easiest method is to polish the buckets with course emery cloth on a flat surface. It is also possible to use milling machines or shapers for this operation.

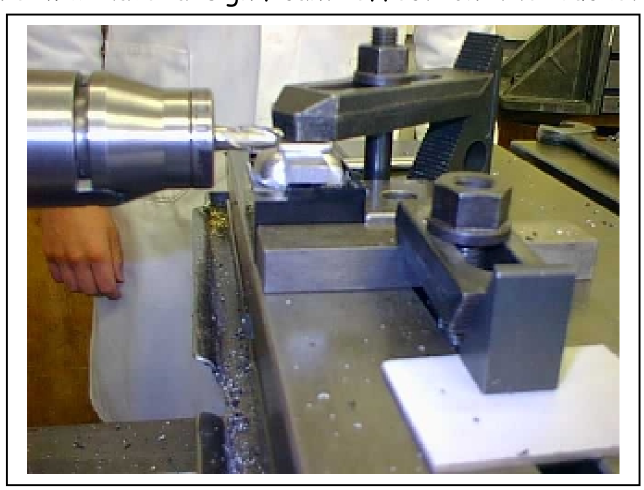

Figure 3 Machining reference surface on bucket

6. The buckets should be clamped into a fixture which allows a reference surface to be machined on the root. One method of producing a suitable fixture is described in Appendix A. Suitable clamping arrangements are shown in Figure 3 and Figure 4. The buckets are machined so that there is an equal distance between the side of the root and the splitter ridge on each bucket. This allows the bucket centres to align when they are bolted on to the hub.

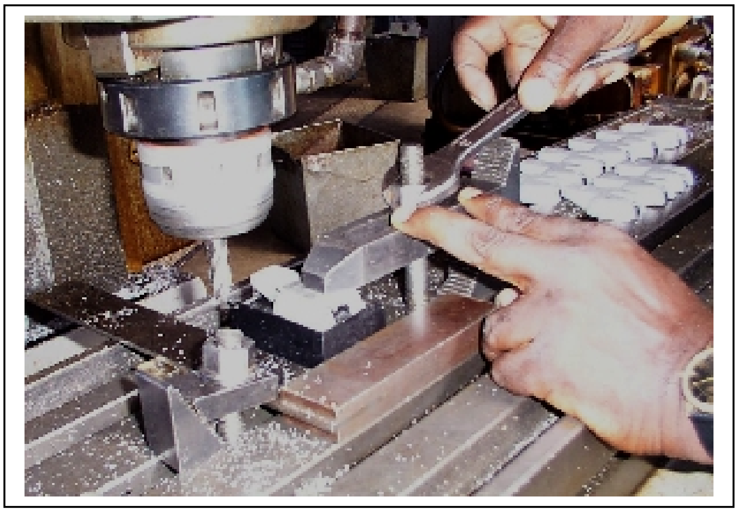

Figure 4 A vertical milling machine can also be used as shown. Ensure that the root is machined exactly parallel to the splitter by clamping each bucket in the same position.

7. Drill a hole in each bucket root. It is important that each hole is drilled in the correct position to allow the buckets to be assembled onto the hub, giving the appropriate runner p.c.d. Use the end of the bucket or the tip of the splitter as a reference to mark the correct distance of the hole along the root. A simple jig using a drilling vice and guide piece to support the root can be used to drill each bucket identically once the table has been locked in position using the hole in the first bucket. Hole dimensions are given in the Appendix.

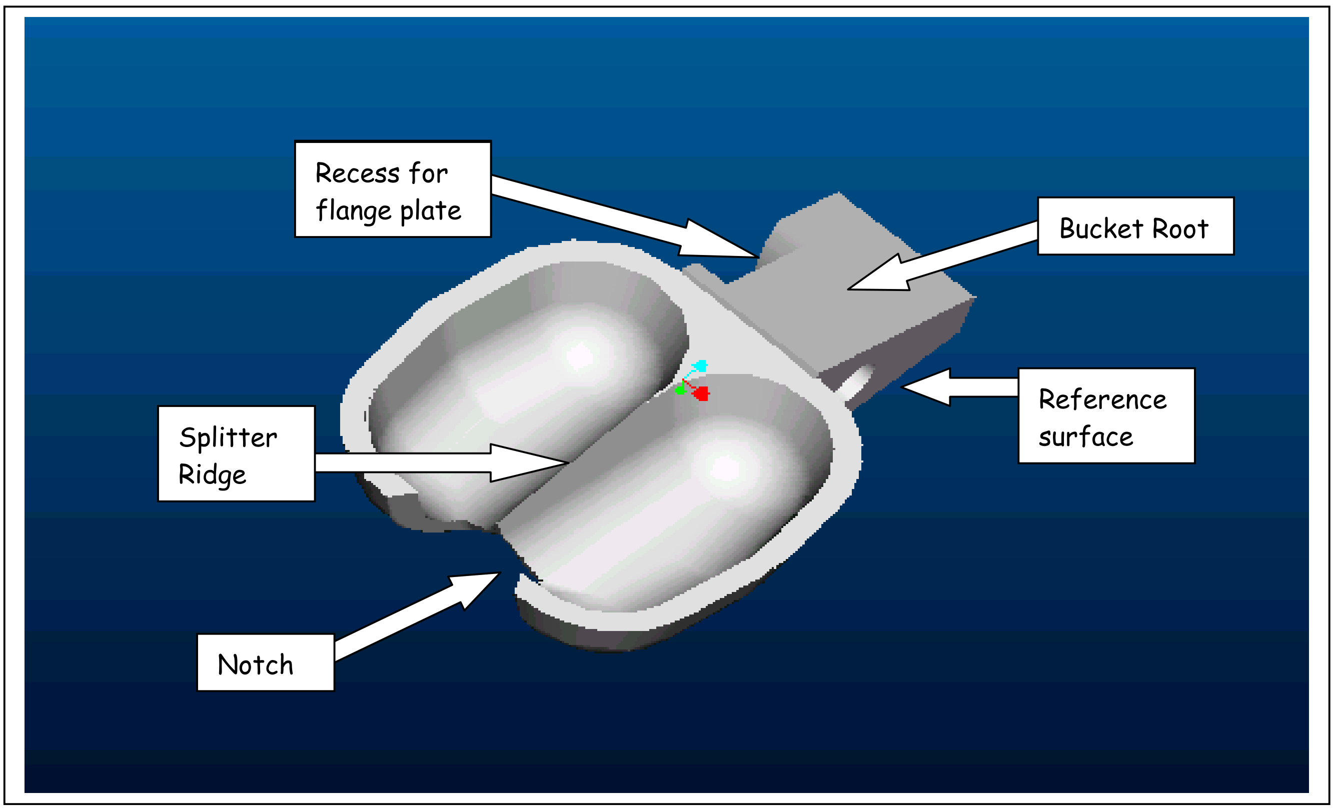

Figure 5 Fully machined Pelton bucket

8. Tap the hole to fit the size of bolts which are being used to hold the buckets in place. For example, if M6 bolts are used, then drill a 5mm hole and use an M6 tap. Make sure that adequate amounts of threading paste are used if the buckets are cast from aluminium. Without sufficient lubrication, the thread may not be well enough defined due to the softness of the metal.