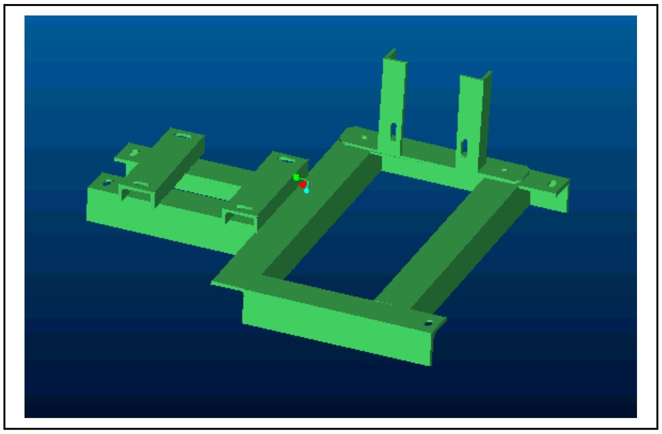
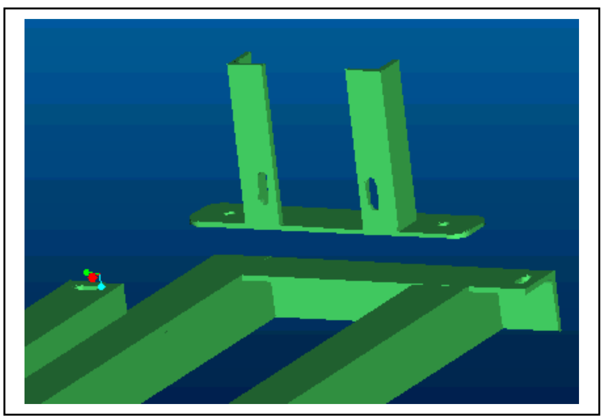
5 The base frame



Cut out sections as per Drawing No.5 (Appendix C). Mill away where required to allow angle sections to be linked without overlapping. Use hacksaw if no milling machine is available. For slotted holes, drill and file into shape. Otherwise mill away the required area.

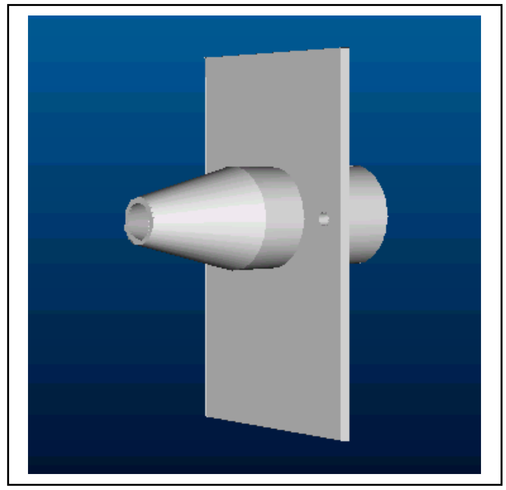
Weld sections together after loose assembly and marking. Ensure the dimensions for the generator mounting (A, B, and C, Drawing No.4) are carefully adhered to. Use the generator if necessary to double check before welding the channel section supports. The nozzle brackets must be positioned at exactly 90° to the frame otherwise nozzle alignment will be wrong. The slotted holes in the nozzle bracket must also be parallel to allow successful adjustment of the nozzle plate.

Grind off excess weld from the bottom of the nozzle brackets to allow the nozzle plate to sit squarely and the jet to hit the runner at right-angles. Clean up rough edges coat the surface with several layers of a durable water-proof paint.



A useful modification to the base frame design is to first attach the nozzle brackets to a separate plate as shown. The brackets and plate are then bolted to the frame underneath. This arrangement allows the case and nozzle to be removed together for access to the runner without altering the nozzle alignment or disturbing the seal between the nozzle plate and turbine case.

6 The turbine nozzle



The nozzle creates a high pressure water jet which directs the flow at the centre of the Pelton buckets. Correct alignment of the nozzle is critical to achieving the best performance from the turbine. Since the flow is restricted at the nozzle, additional friction losses occur which reduce the net head. The extent of these losses depends on the flow and nozzle design. A nozzle which tapers at an angle of 14° will minimise the friction losses. Attention should also be paid to the surface finish on the inside. A rough surface will cause a greater frictional loss than a smooth one. The diameter of the hole at the end of the taper is very important as the flow is proportional to the square of the diameter.

6.1 Methods of nozzle fabrication

Method 1: From flat plate and pipe section
Shape the cone around a suitable former using a piece of flat plate and welding along the seam. The former is turned on a lathe; a metal bar of minimum 2.5" diameter which is machined so that it tapers to a point at one end. The angle of taper should be 14°.

Method 2: Machined from solid bar
Machine the complete nozzle from a solid bar on the lathe. This will be easier if aluminium bar rather than steel bar is used. A boring bar is required to reach inside the reamed bar and machine to the correct dimensions. When machining the cone, it is necessary to rotate the tool post to the correct angle (14°). For small nozzles (jet diameter less than 15mm) it may be necessary to make a narrower boring bar in order to avoid interference when machining the inside tip of the cone.

Method 3: Use a pipe cap and pipe section
A less efficient, but low cost nozzle can be made by drilling a hole of the correct diameter in a plastic or metal pipe cap. The cap is then threaded onto a section of pipe. The thread should be sealed using suitable means available such as with PTFE (plumbers) tape or 'Boss White' and hemp string.

6.2 Nozzle plate

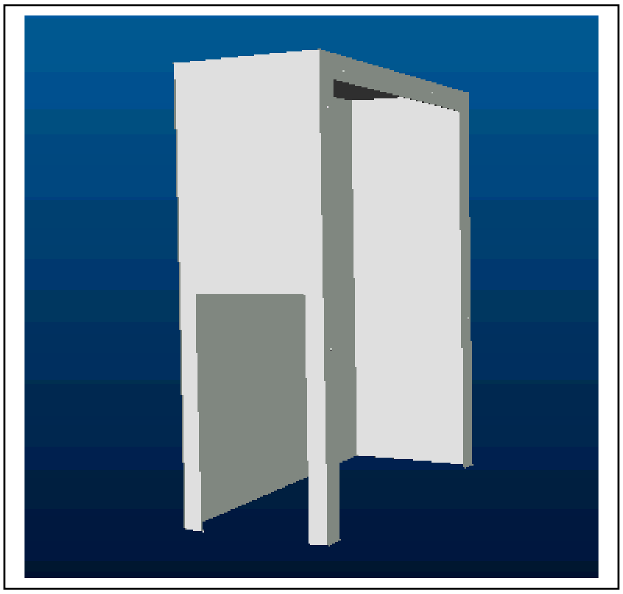
The plate is cut to size and the holes drilled for the locating bolts. The centre hole is carefully marked. The metal can be removed by drilling and filing out to give a round hole unless another method such as a trepanning tool is available. The nozzle pipe should *just* fit through.

Positioning the Generator, runner and nozzle on the base-frame, allows the required length of the nozzle to be judged. The nozzle must be as close to the buckets as possible for maximum efficiency. Slide the nozzle forwards in line with the p.c.d. of the runner until the buckets almost touch when the runner is rotated. Mark the position where the pipe and the plate meet and weld together. Make sure that the plate is perfectly at right angles to the nozzle to ensure that the jet interacts correctly with the runner.

An alternative method of securing the nozzle and plate together is to thread the outside of the nozzle and use back nuts either side of the plate. In this way the distance from the nozzle tip to the runner can be modified during assembly at the site. Use plumbers (PTFE) tape or a similar method to seal between the nuts and thread.

7 Turbine casing, side plate and seal arrangement

7.1 Turbine Case



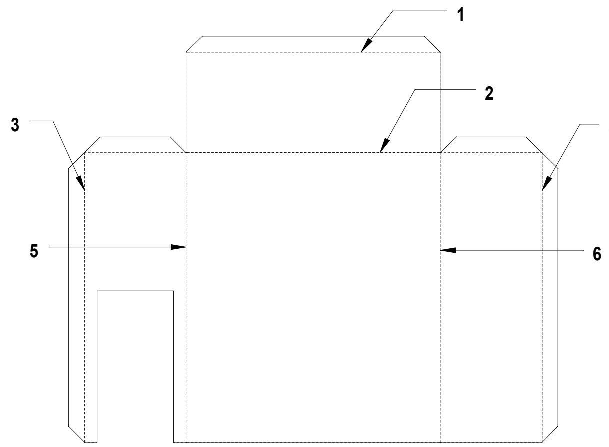
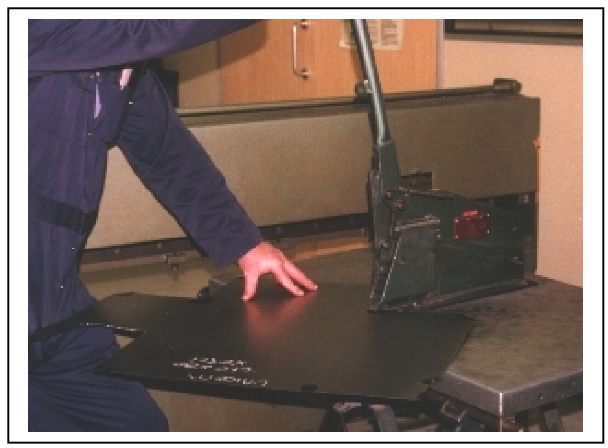


Figure 7 Folding sequence for turbine case

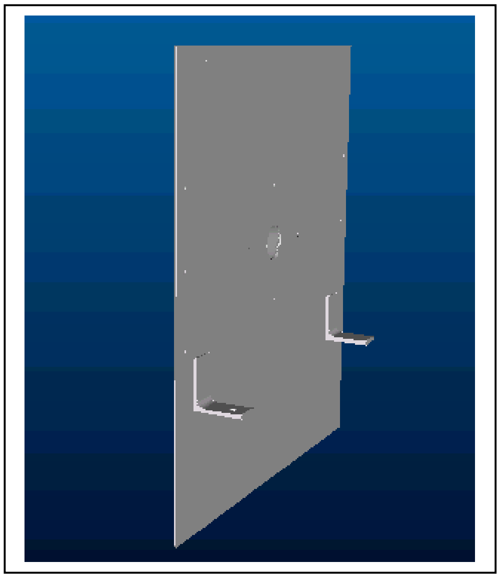


Mark out the inside face of the sheet using a scribe by following the development of the case (Drawing No.8). The lines will then be visible when bending the sides in. Methyl blue will make the marks more visible and should be used particularly at the ends of fold lines. Chop out the waste sections, preferably using a guillotine. Use a hacksaw in the corners where three sides join. Chop out the slot for the nozzle using a chisel. Clamp the sheet firmly along the edge to be cut (use a block of wood). This prevents bending caused by the chisel. Use a file and emery cloth to finish off the rough edges.

Mark on the positions for the holes around the lip (8.0mm) and for the angle brackets. This is easier while the sheet is still flat. Fold the sides in the order described above. When the last two sides are folded in (5 and 6) the top will need to be bend back slightly if using a box bender. It is important to fold the corners as tightly as possible to prevent leaking. The corner flaps are tucked inside and spot-welded. If using an electric spot-welder, check the current setting on two scrap pieces of the same material first.

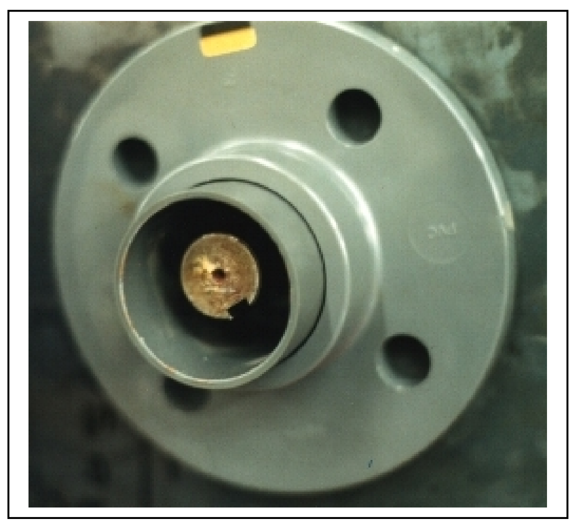
Drill holes for securing the side-plate around each lip. Clamp a block of wood under the lip to prevent the metal from bending. Spot-weld or rivet the two angle brackets into position after drilling (10mm holes for M8 bolts to allow a small degree of adjustment).

7.2 Side-Plate



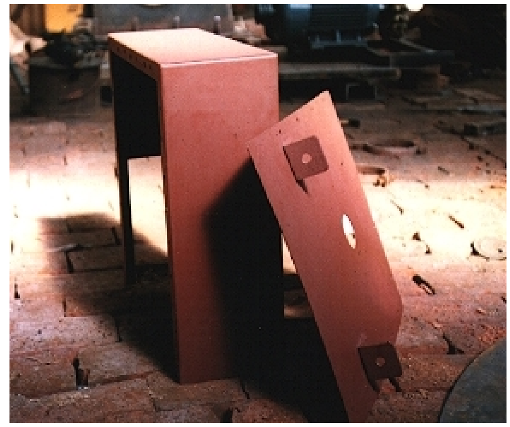
Cut the (2mm) plate to size to size and check that it slides into the case. It should be flat to ensure a good seal around the edges. Mark positions for centre hole and fixing points then drill to appropriate size. Nuts are welded on to the inside of the plate at the fixing points around the edges. These allow the bolts to be threaded through from the outside and screwed tight. Drill out centre hole (10mm greater than diameter of hub extension on runner) Use a trepanning tool, a large hole saw or drill several small holes and file away to a circle. Clean up all burrs with a file and emery cloth. Mark position of angle brackets and spot weld on. If necessary, check the location of the support brackets by loosely assembling with the other components first. Cut the strips of gasket rubber to length (25mm wide), mark positions of holes and punch out. Glue into position.

7.3 Pipe-Flange Seal



Mark out position of flange over the side-plate. Drill four fixing points. Mark the gaskets where the fixing points are and remove circles of material (e.g. 10mm dia.) using a leather punch. Drill holes in the PVC pipe flange and attach flange and gasket to plate with M6 bolts. Push the bolts through from the outside of the plate to prevent the excess threaded lengths from interfering with the generator. An additional gasket or piece of rubber can be positioned on the outside betw een the plate and generator to dampen any vibration when the turbine is operating. Cut a piece of PVC pipe almost the length of the hub extension. The length of this pipe section should be adjusted so that it reaches from the PVC flange to the hub when the runner is in position. Drill a drainage hole underneath the pipe seal. A the runner rotates, any water which finds its way along the hub shaft extension will be flung off and collect on the plastic pipe. It can then run out through the hole. If the hub is located on the shaft by a grub screw rather than a key and keyway, then this hole can be used to tighten the grub screws and so should be positioned accordingly.

8 Final assembly



It is wise to assemble and disassembled the components during fabrication as a check that each part has been made correctly. When complete it will be necessary to coat all steel components with several layers of waterproof paint to prevent corrosion. This includes the base frame, nozzle, case and turbine hub. The turbine buckets will also benefit from a surface treatment such as painting even if they are made from aluminium or bronze. This will help to minimise the surface friction and improve efficiency.

A gasket is also required between the side plate and turbine case and similarly between the nozzle plate and turbine case. Soft tyre inner tube rubber is excellent gasket making material. The holes for bolts should be cut out of the rubber using a leather punch or similar tool. The gasket can be glued into position using a contact adhesive once the paint is dry.

The nozzle can be aligned by eye as shown opposite. Important considerations are that it is 90° to the turbine shaft and strikes the runner tangentially on the p.c.d. line. This is usually in the centre of the buckets. Some horizontal movement of the runner should be possible by sliding the generator fractionally backwards or forwards in order to centre the nozzle and bucket splitter ridges. Vertical adjustments are made (altering the operating p.c.d. of the runner) using the slotted nozzle mounting points on the bracket.

The simplest method of aligning the nozzle and runner is to look through the nozzle before connecting to the penstock. A torch is useful to illuminate the runner if the case is already in place. The splitter ridge should be directly in the centre of the hole. Aligning the nozzle with the p.c.d. is more difficult but can be found with experience. One method of finding the optimum point when the penstock is connected to the turbine at the site is by making small adjustments to the vertical position and measuring the power output. The nozzle is tightened in place when the point which gives the maximum power at fixed head and flow is located. The power output can be measured directly if a ballast metre is fitted. Otherwise using a hand–held tachometer the rpm's can be measured from the fan end of the turbine shaft. The point where the rpm's are highest is the optimum point for the nozzle. The frequency is also proportional to the rpm's so this can be used as an indicator if it can be measured perhaps using a multi-meter.