

	Requirement	Recommendation
M1. Safety guards	<p>1. All moving parts must be shielded by wire mesh which is durable and strong, and of a mesh size small enough to prevent children's' hands and arms passing through. The guards should be permanently secured by locks and electrically earthed.</p> <p><i>When visiting verify the above and in addition:</i></p> <p>2. Mesh guards must be in use at all times; they must be locked in place or otherwise secure, and earthed.</p>	
M2. Manifold	<p>1. Head loss. The manifold is the piping or ducting which carries water from the penstock to the turbine inlets and runners. It must be designed so as not to introduce large additional head losses. Two suggested rules of thumb for verifying this are:</p> <ul style="list-style-type: none"> a. do not allow the velocity of the water in the penstock to increase as it passes through the penstock, b. flow velocities in manifold straight pipes should not exceed 3m/s; flow velocities in bends of up to 45 degrees should not exceed 2.5m/s; flow velocities in bends up to 90 degrees should not exceed 2m/s; all changes in velocity should preferably be performed in tapered pipe sections. <p><i>When visiting verify the above and in addition</i></p> <p>2. Check all components carrying high water pressure (the manifold and parts of the turbine) for leaks. Leaks can in some cases be accommodated in the power house, but because they may lead to expensive damage, they should be corrected immediately.</p>	
M3. Manifold valve	<p>1. A manifold valve is a valve at the foot of the penstock and start of the manifold which stops water flowing in the penstock. A manifold valve is required in all cases except:</p> <ul style="list-style-type: none"> a. where it is possible to quickly and safely, and routinely, divert water away from the turbine runner or the penstock mouth in order to shut down the turbine (for example on some low head sites it may be as quick and easy to divert water at the penstock mouth as to close a valve) b. if the guide vane of a crossflow or propeller closes off the flow sufficiently c. if a jet deflection system is fitted to a Pelton d. if a multi-jet Pelton has valves on every branch of the manifold <p>2. Location. It must be located inside the power house and be easily accessible.</p> <p>3. Rating. It must be rated for maximum penstock pressure.</p> <p>4. The valve must be of a slow closing type (gate rather than butterfly) or have apparatus which reliably prohibits fast closing, such as:</p> <ul style="list-style-type: none"> a. fitting of a second, much smaller, valve in parallel with the main manifold valve; this is padlocked in the open position and kept open when the main valve is closed b. a gearing mechanism to ensure very slow closing 	

M4. Pressure gauge	<p>1. A pressure gauge should be available in the power house to read water pressure just before it enters the turbine. After long periods such a valve cannot be relied on to give accurate readings. Nevertheless it is useful as an indication of the penstock filling to full capacity. To take accurate readings of head, a calibrated pressure gauge should be brought to site to replace the installed gauge or a calibration carried out on the installed gauge. A procedure for calibration should be described in the operator manual.</p> <p>2. The gauge should read approximately half-scale at gross head.</p>	
M5. All turbines	<p>1. Balancing. The turbine runner must be statically balanced before commissioning; it is recommended that large crossflow runners are dynamically balanced.</p> <p>2. Design features. The turbine must be of a design which performs efficiently and reliably in site conditions at minimum cost.</p> <p>3. Interior access. The turbine must be easy to dismantle in situ to allow inspection of jets and runner, and to allow removal of debris from the jets and other parts. The runner must be removable in situ.</p> <p>4. Auto shut-down. An automatic runner shut-down is required to protect bearings and synchronous generators from run-away speeds (unless the generator is banded to withstand overspeed and certified by the manufacturer).</p> <p>5. Air-access. If the turbine is of a type which demands good air access to a free jet then it may be wise to see that the turbine installation instructions ensure that air flow is not restricted for instance by tailwater.</p> <p>6. Water seals on turbine shafts. Non-contact seals are highly recommended. Labyrinth seals or stuffing boxes can be used. Rubbing seals which cannot be regularly adjusted should not be used.</p> <p>7. Bolts securing the turbine/generator base-frame to the floor and runner inspection bolts must be removable and not subject to corrosion seizure. To ensure this the design must ensure that water is drained away from these bolts.</p> <p>8. The design must ensure that the turbine exhaust water departs efficiently from the runner. For instance if two runners are used a single Pelton shaft ensure that the gap between is sufficient to allow exhaust water to escape (3 bucket widths minimum).</p> <p><i>When visiting verify the above and in addition:</i></p> <p>9. If the turbine is of a type which demands good air access to a free jet check it is installed so that air flow is not restricted for instance by tailwater.</p> <p>10. The installation must allow access to all sides of the turbine and space to dismantle it, and access for greasing and maintenance tasks should be demonstrated.</p> <p>11. Paintwork must be kept in good condition to avoid corrosion.</p> <p>12. If a turbine flow measurement weir is included in the power house design, take flow readings and note turbine/generator efficiency. Use weir equations and the salt-dilution method to check calibration of the flow measurement weir. If no weir is fitted, use the salt-dilution method between forebay and tailrace to measure flow.</p> <p>13. Check that the auto shut-down system works.</p>	

	<p>14. Turbines must be tested for run-away speed conditions in cases where no auto shut-down is fitted. This test must be clearly understood to be part of the manufacturers liability for fitness for purpose and should be undertaken by the manufacturer in the presence of the authorising engineer as part of the commissioning procedure.</p> <p>15. Check retaining bolts and runner inspection bolts are protected by grease from corrosion and are well drained.</p> <p>16. Always check runner alignment. In the case of Peltons and crossflows, rotate the runner and make sure that it is correctly mounted on the shaft and accurately aligned with the nozzles or water inlet jet.</p> <p>17. In the case of a Pelton turbine, also check splitter ridge and notch radius tolerances while rotating the runner. The axial tolerance on the splitter ridge and the radial tolerance on the bottom of the notch in neither case should exceed +/- 0.3% of the PCD.</p>	
M6. Turbine case design	<p>1. Turbine steel casings should have adequate thickness. Webs or ribs are usually necessary as stiffeners to reduce vibration and noise, which can occur with large flat unsupported areas of steel.</p> <p><i>When visiting verify the above and in addition:</i></p> <p>2. The turbine should not be noisy nor vibrate in a way that threatens progressive damage. The turbine should not make so much noise that it is uncomfortable to work near it for long periods. (Noise indicates inadequate panel thickness or stiffening, and/or a misdirected jet of water, or possibly operation above optimum speed causing water to overshoot the runner; in the latter two cases power inefficiency will be apparent. A propeller turbine may be noisy and inefficient if cavitation is occurring in the draft tube).</p> <p>3. In cases where bearing alignment and jet accuracy depends on adequate tolerances in case fabrication, the case should be checked for squareness with a rule, string, and a square.</p>	
M7. Turbine/generator base-frame	<p>1. The turbine and generator must be mounted on a single steel fabrication, the base frame, which is set into or fixed to the powerhouse floor (separate fixings are avoided in order to avoid tension stresses occurring in the concrete floor). This can be fabricated from angle iron or channel section. A base frame can be omitted if the turbine and generator are close-coupled, that is their own frames are rigidly connected to each other's.</p> <p>2. It is recommended that the turbine and generator be fixed securely to the base frame in a workshop before installation to achieve correct positioning. This can avoid problems with bearing alignment and belt tensions during operation. The runner must be easily removable on site.</p>	
M8. Bearings	<p>1. Position. Crossflow turbines must be centrally mounted between bearings; Peltons and Propellers can be either centrally mounted or overhung.</p> <p>2. On larger machines, bearings must be selected and maintained to provide a service life of 10 years. On smaller machines a service life of 5 years is acceptable.</p> <p>3. Bearings must be properly aligned, either by use of self-aligning types or by machining of the bearing housings. There must never be more than two bearings on one shaft. Poor alignment will cause bearing failure and will be</p>	

	<p>evident in the first year of operation of the turbine. The mandatory one-year warranty should be invoked to ensure that bearing failure costs are covered by the contractor, and to ensure correct alignment is established.</p> <p><i>When visiting verify the above and in addition:</i></p> <p>4. With the bearing housing open, check that the bearing housing is one-third full of clean grease.</p> <p>5. Check that the bearing turns freely. (It is rarely the case that a check with a feeler gauge is possible. If it is, use the gauge to ensure that the rolling element clearance is within the manufacturer's tolerances. If the bearing rattles then it is worn, or in the case of adjustable types, it needs to be adjusted).</p> <p>6. When the turbine has run for some minutes, touch the bearing housing. If it is over-heating, it is likely that the bearings are damaged or severely worn and should be replaced.</p> <p>7. When the turbine has run for two hours, place your hand on the bearing housing; if it is too hot to allow you to keep your hand there, the temperature will be over 60 degrees C. This usually indicates that the bearing housing contains no grease or contains too much grease. In the case of some arrangements it may indicate that the bearing is adjusted with too small a clearance or that the two bearings are positioned with excessive axial thrust relative to each other.</p>	
M9. Drive system	<p>1. The mounting of pulleys on shafts must be done in a way which avoids any danger of progressive fretting damage. Taper-lock bushes are recommended.</p> <p>2. The pulley diameters used must not be smaller than recommended by belt and generator manufacturers, in order to prevent over-tensioning of the belt and over-loading of bearings.</p> <p>3. Pulleys and belts must be sized according to their manufacturers' procedures. Synthetic belt materials are recommended for all schemes, and must be used on all except very small schemes. It is important to remember that synthetic belts require high tensions, so that only more expensive bearings and shafts capable of accommodating high tensions can be used, and the drive system will demand more careful maintenance.</p> <p>4. To maintain cost-effectiveness drive ratios should normally be less than 3:1, although ratios of up to 4:1 are acceptable on smaller schemes. It is advised that higher ratios are not used, as they are likely to present expensive problems with pulley and bearing alignment; higher ratios also imply larger bearings and thicker shafts as tensions are greater.</p> <p>5. In the case of synthetic flat belts, the smaller pulley is usually crowned, to stop the belt slipping off.</p> <p><i>When visiting verify the above and in addition:</i></p> <p>6. Belt tensions should be checked to ensure that they do not exceed recommended values.</p> <p>7. With the turbine running, the drive system should be checked to ensure that the belts do not slip or, in the case of flat belts, progress across the pulley.</p> <p>8. Belts and flexible couplings should be inspected for any degradation such as cracking or stretching, and for alignment.</p>	

	<p>9. In cases where direct drive couplings are used, the alignment must be checked.</p>	
M10. Tools	<p>1. The power house should be fitted with a set of tools as detailed in the operators' manual.</p> <p>2. It is highly recommended that tool locations are silhouetted on a tool display board such that it is immediately apparent if a tool is missing or in use. (Experience shows this usually works better than a locked-chest approach).</p> <p>3. For larger schemes a lifting hoist should be available in the power house.</p> <p>4. The inclusion of a rechargeable battery-powered lantern in the tool collection is recommended, and this should be always charged or charging.</p> <p>5. To test for correct alignments and runner and case tolerances, the basic tools are a steel rule, a tape measure, some string, a square, feeler gauges, a dial gauge, and a spirit level.</p> <p>6. Checking alignments and tolerances of belts and turbines is straightforward, using mainly string and steel rule, and possibly also a square.</p>	
M11. Log-book and maintenance manual	<p>1. The power house must be equipped with a log-book to a format in accordance with the maintenance training manual.</p> <p>2. A maintenance manual appropriate to the installation must be in place.</p> <p><i>When visiting verify the above and in addition:</i></p> <p>3. The log book must be available for inspection and used regularly and accurately. It is recommended that the log book location is silhouetted on the tool display board in the same way as the tools.</p>	

