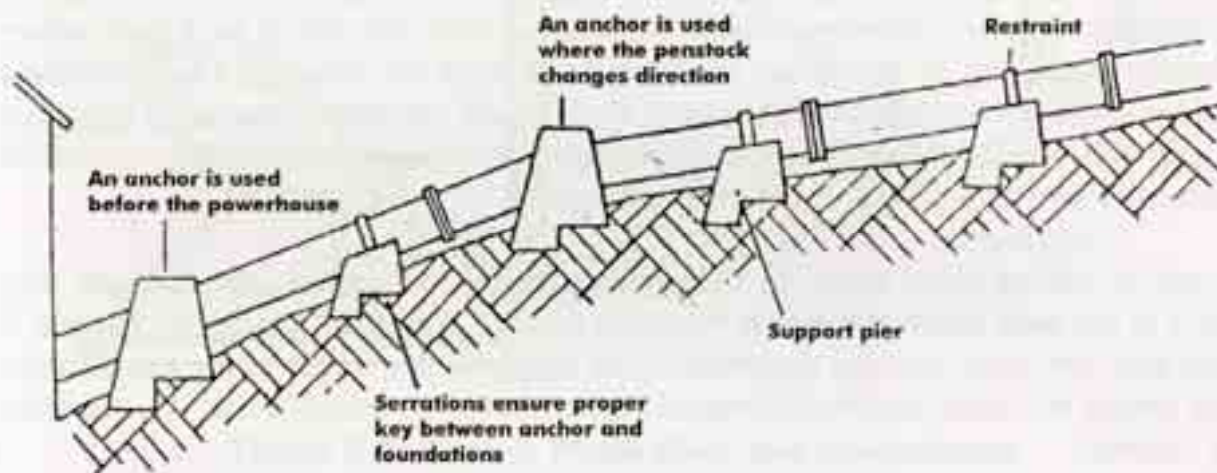


# Chapter 3

## The Penstock and Allied Structures

### 3.1 The Penstock Pipe

The penstock carries water from the forebay, which is an open tank, to the nozzle of the turbine at high velocity and under pressure (Figure 3.1). Thus considerable pressure may develop within the penstock towards the lower end. The penstock is usually made of mild steel, equal lengths of pipe with flanges on both sides are bolted together. Unflanged pipe lengths can also be welded at the site if such facilities exist. In low head schemes, the penstock can also be made from HDPE pipe.



**Figure 3.1: A Typical Penstock Installation with Support Structures**

Damage may be caused to the penstock by falling rocks, corrosion, sinking of the support structures, people, misalignment at the time of installation, landslides, and even freezing of water inside the pipe. The damage can be in the form of such things as cracks and leakage, removed or broken bolts, formation of rust, and bending. The damage should be inspected carefully. The exact location and size of any cracks causing leakage should be pinpointed. Any bending of the pipe resulting from sinking of support piers and anchor blocks should be checked. The penstock surface should be inspected to determine the extent of loss of paint, rusting, cracking, or other such damage. The pipe should also be inspected to check whether it has been dented or become deformed; it may have become oval, for example.

Both the nature and the source of any damage should be determined before undertaking any repairs. If the pipe is leaking, for example, it is necessary to determine whether the leakage is caused by a worn out gasket, loose or missing bolts, cracks at the weld, or holes formed by some other agent such as a falling stone. Different types of repairs are needed for each of these cases.

If a joint is leaking, then it is likely that the gasket is worn out. The joint should be opened by removing the bolts and the gasket replaced. Usually, the same size and type of gasket (flat rubber gasket or o-ring) should be installed as that removed. However, if the pipe length has changed due to subsidence, then a thicker or thinner gasket should be used.

If the leakage is caused by a crack, the area where the crack or a hole has appeared must be cleaned properly, removing all the rust or paint with the help of emery paper, and then welded. Before welding, water should be removed from the pipe and the surface properly dried. Welding can only be done at the site if welding equipment (whether electric welding or gas welding) is available there, which is usually not the case. If the crack is large, it is usually necessary to remove that section of the pipe and take it to a place where proper welding can be carried out. Small cracks or holes can be plugged by wrapping a rubber sheet around the pipe and fixing it in place with the help of clamps as described earlier. This is generally only a temporary arrangement, however, and welding may still be necessary since it is likely that the crack will expand.

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Loose or missing bolts should be tightened or replaced as soon as possible with new ones of the same size and material. If leakage persists, the gasket should be changed. If this does not work, then the alignment of the penstock may be out or the gap between the flanges may have become too large; the expansion joint should be checked, adjusted, or repaired.

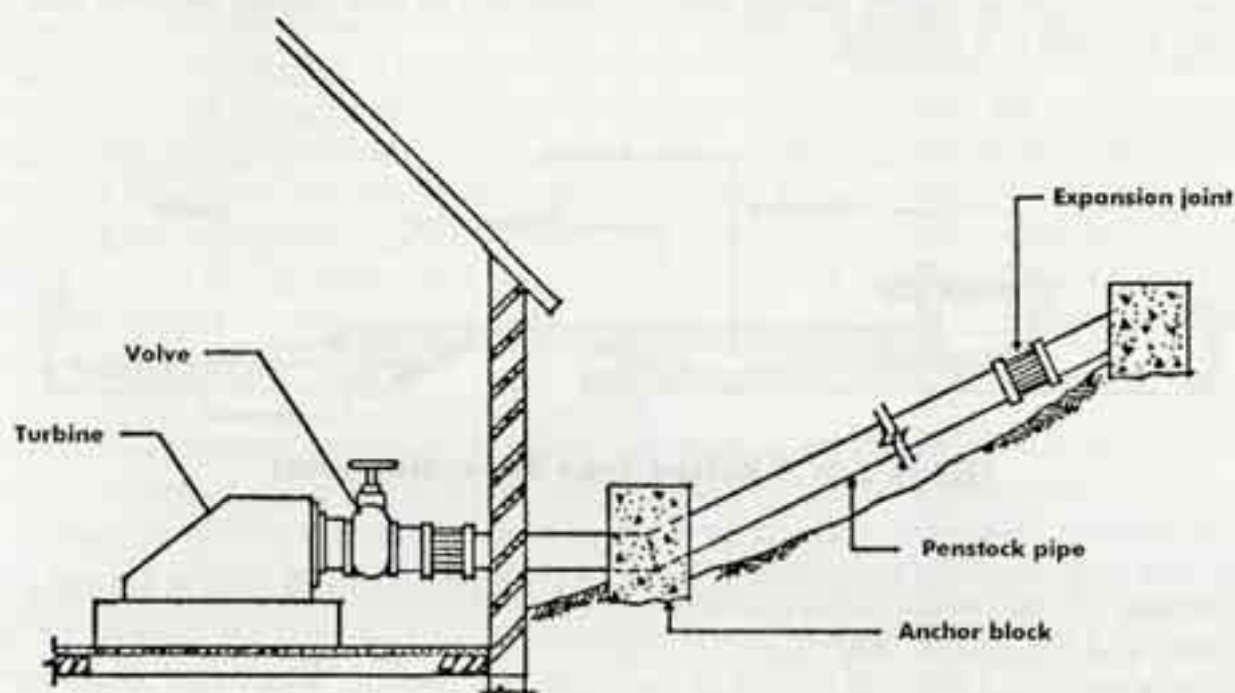
Small bends or dents in the pipe caused by such things as falling rocks can be left unrepaired after ascertaining through inspection that the damage (especially a bend) is not causing severe stress to the joints. If necessary, the surface should be polished and repainted to prevent rusting.

HDPE penstock pipe may develop cracks as a result of excessive bending or such occurrences as cattle walking over the pipe. Small cracks can be plugged using a rubber sheet and clamps. If the crack is very large, it should be repaired by cutting out the cracked portion and fitting a new piece by heat welding. The plate used to melt the edge of the HDPE pipe can be heated using charcoal or even good quality firewood. The plate must be heated to 220°C, and this can be checked with thermo-chrome chalk. A chalk mark on the plate turns from white to brown within five to 10 seconds if the temperature is correct. If the colour changes in less than five seconds, then the plate is too hot; if it takes longer than 10 seconds then it is too cold.



### 3.2 Support Structures for the Penstock

Support structures include support piers, which allow some axial movement of the penstock, and anchor blocks, which do not allow any kind of movement in any direction. Support piers are mostly made from cement-stone masonry and plastered with cement mortar, whereas anchor blocks are almost always made from concrete (Figure 3.2). In some cases, the support piers may also be made from dry stone masonry or some other cheaper materials.



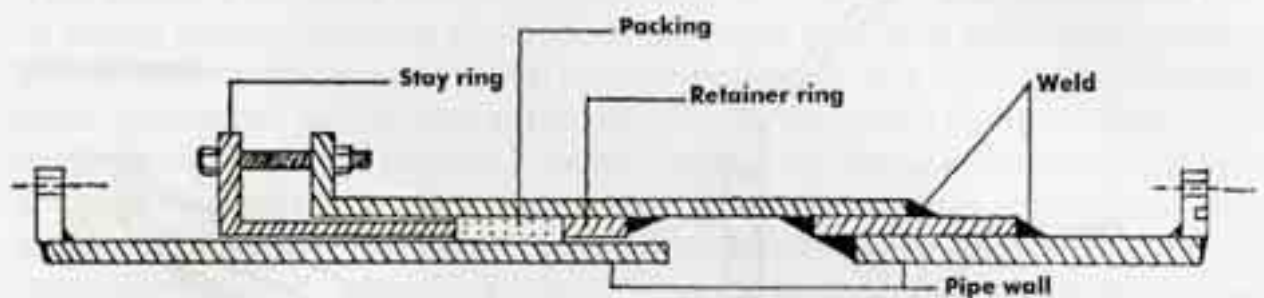
**Figure 3.2: Anchor Block Near the Powerhouse**

Damage may be caused to support structures by such things as subsidence of land mass, landslides, standing water in the vicinity of the foundations, and unstable ground. The damage can be in the form of sinking or erosion of the base, sliding of the whole structure down the hill, and breaking or cracking of the plaster and masonry.

The damage must be inspected and assessed properly. Usually, cracking or breaking of the masonry can be repaired by removing the damaged sections and reconstructing them. If the whole structure has sunk, it should be completely dismantled, including the foundation, and rebuilt after ensuring that the original levels at the points of support for the penstock are reached. Temporary supports should be provided for the penstock near the construction points before dismantling. The area must also be inspected for any drainage problems; for example, water may be accumulating. If necessary, drainage channels should be built and the ground levelled to provide an adequate slope to ensure that water drains away quickly from the structures.

### 3.3 Expansion Joints

The main function of expansion joints is to allow axial movement of the penstock pipe caused by changes in the ambient temperature. If this natural expansion were to be prevented it would induce undue stress in the penstock. The most common type of expansion joint consists of two pieces and is bolted (or in some rare cases welded) to the flanges of the lengths of penstock pipe (Figure 3.3). When the pipe expands or contracts, one piece of the expansion joint slides over the other. Leakage is prevented by inserting a suitable sealing packing that is compressed to stop leakage with the help of bolts provided in a stay ring.



**Figure 3.3: A Bolted Type Expansion Joint**

Damage may be caused to the expansion joint by misalignment as a result of sliding or bending of the anchor block or lateral movement of support piers, or jamming of the moving parts as a result of rusting or over-tightened packing. Sometimes, axial movement of the pipe can also cause serious damage to the expansion joint, especially when the gap between the two pipe ends is already very large and there is a possibility that one piece of expansion joint may slide out of the other entirely.

The most common type of damage is jamming as a result of rusting, misalignment, or damaged sealing packing, resulting in leakage, or loss or bending of the stay ring bolts. Sometimes if the gap provided between the two penstock pipe ends at the time of installation was less than needed, the two ends of the pipe inside the joint may touch or even press against each other when the pipe expands, causing damage not only to the expansion joint but also to the anchor blocks.

If the expansion joint has jammed, it should be disassembled. The mating/sliding surfaces should be scrubbed with emery paper or a wire brush and greased. The underside of the packing which slides over the pipe end should not be greased.

If the expansion joint is leaking, but the pipe is not misaligned and the gap between the two ends of the pipe is correct, then extra turns of packing rope of the same size may be



added. Sometimes, leakage can be stopped by just tightening the bolts of the stay ring to compress the packing further. If the packing is badly worn, it should be replaced with new packing after dismantling the joint and cleaning the surfaces. Usually, a jute rope with a square cross-section is used as packing material. If extra packing is to be added or replaced, the stay ring should be removed and the original packing taken out and new packing inserted after cleaning the surfaces. The number of turns of packing depends upon the pipe length that it needs to cover (usually between 20-30 mm). Reassembly of the joint is described below.

Sometimes, the gap between the two ends of penstock pipe within the expansion joint may need to be adjusted. If the gap needs to be increased, then remove the expansion joint and cut off the appropriate length of the inner pipe over which the packing rests. Decreasing the gap is difficult since it actually means adjusting the whole length of the penstock pipe. This can only be done by dismantling the pipe section completely and replacing the length with a specially made longer piece. If the adjustment needed is small, in the order of five to 10mm, then one or more rings can be added at different flanges of the pipe lengths downstream from the expansion joint and gaskets provided on both sides of these rings.

Misalignment between the two pipe ends can cause a lot of damage, not only to the expansion joint but also to the anchor blocks or even the whole penstock pipe. Thus it is necessary to remove any misalignment as much as possible. Sometimes misalignment can be removed by putting some kind of packing between the penstock pipe and the support pier saddle in order to raise the penstock at that point. Sometimes the groove in the pier may be deepened by chiselling to lower the level of the penstock pipe at that point. Sometimes, if it is really necessary, two (or more) pipe lengths can actually be bent slightly to adjust the misalignment; but this is very difficult precision work which should only be undertaken in a properly equipped workshop where the extent of the bending can be controlled and measured.

To reassemble the expansion joint, proceed as follows. Clean and grease the mating/sliding surfaces, change the packing, and tighten the bolts slightly. Assemble the stay ring in position and fit one part into the other, pushing it fully in (minimum gap). When the assembly of the expansion joint is complete it can be fitted to the flanges of the two penstock pipe ends. Adjust the length as necessary to reach the two flanges and tighten the bolts of the flanges after fitting new gaskets. Tighten the bolts of the stay ring slightly to compress the packing. Fill the penstock with water and tighten the bolts of the stay ring just enough to compress the packing until there is no leakage from the joint. Do not over tighten. Over-tightening can damage the packing and jam the expansion joint.

For most repairs it is necessary to dismantle the expansion joint. This means separating the joint from the pipe ends by removing the bolts at the flanges and on the stay ring and separating the two parts.