Chapter 5
Installing the Electro-Mechanical Equipment

5.1 Machine Foundations

Depending on the design, separate machine foundations may be constructed for each machine or one foundation platform may be sufficient for all the machines. For smaller electricity generation units, a single foundation block is usually built for both the turbine and generator, which are then fitted on to a single baseframe. The baseframe is then fitted to the anchor bolts cast in the foundation block.

For MHPs with milling machinery, it is cheaper to have separate foundations for each machine since the machines are more spread out and having a single foundation block for all of them would not be practical. The actual construction of the foundations for the machinery is described in Chapter 4.

5.2 Machinery Installation

Once the concrete in the foundation is fully cured, the machines should be fitted to the baseframe on the foundation block. The machines installed should be level, and this is checked with a spirit level on the machine shaft. If the machine is not level, place shims under the footplates to raise the appropriate part of the baseframe or the machine until it is level.

5.3 Alignment

The power from the turbine is transmitted to the generator or other machinery by direct coupling (Figure 5.1) or a belt drive (Figure 5.2). Before the machines are run, the pulleys (for a belt drive) or the shafts (for direct coupling) must be aligned properly. Incorrect alignment will lead to loss of power, belt slippage, vibration, and reduced life of the bearings. In extreme cases, the shaft could also break as a result of excessive metal fatigue.

5.3.1 Direct Drive

In direct drive systems, the shafts of the turbine and generator (or other machines) should have minimal positional or angular misalignment. These two types of misalignment are shown in Figure 5.3.

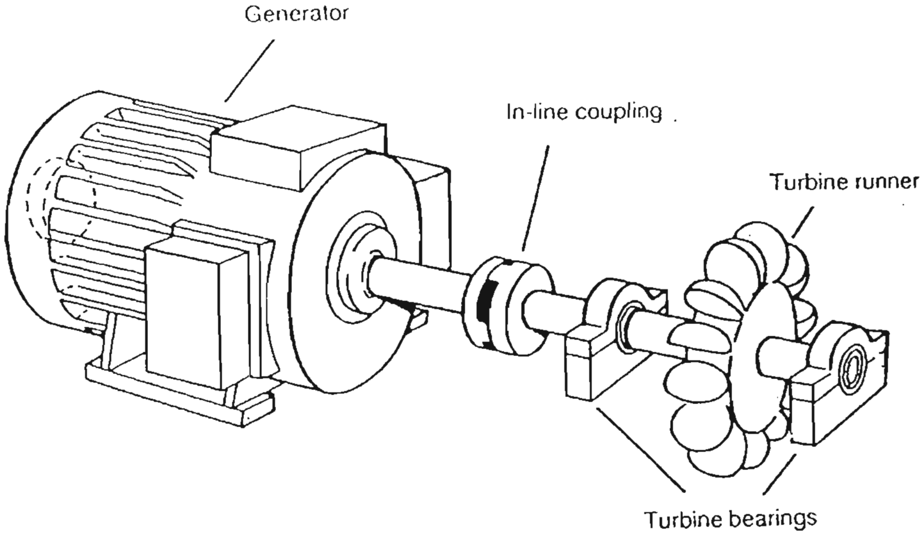

Figure 5.1: Direct Drive Turbine and Generator System

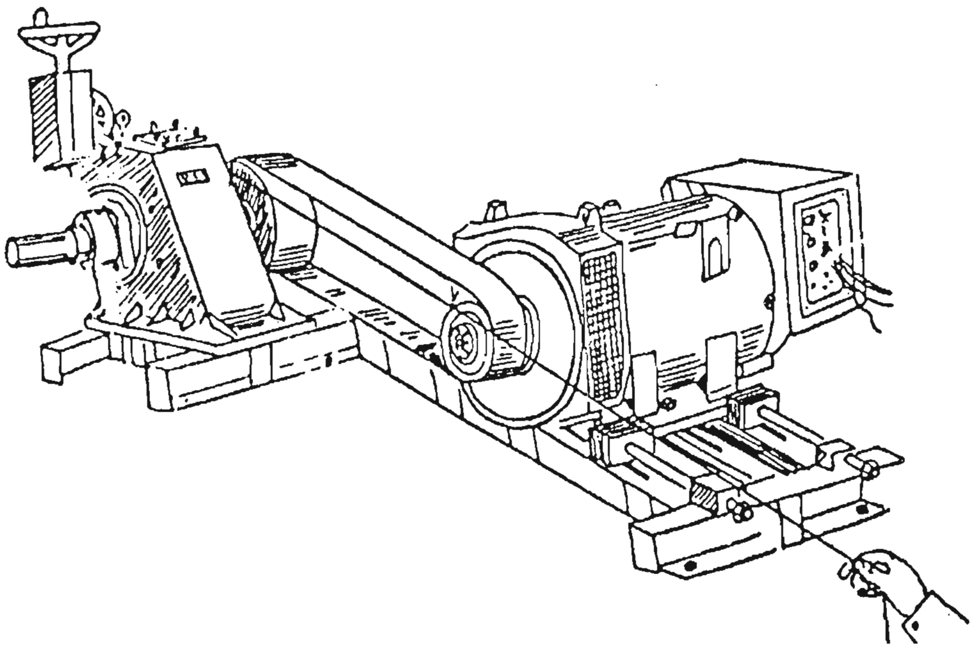

Figure 5.2: Turbine and Generator Coupled through a Belt Drive

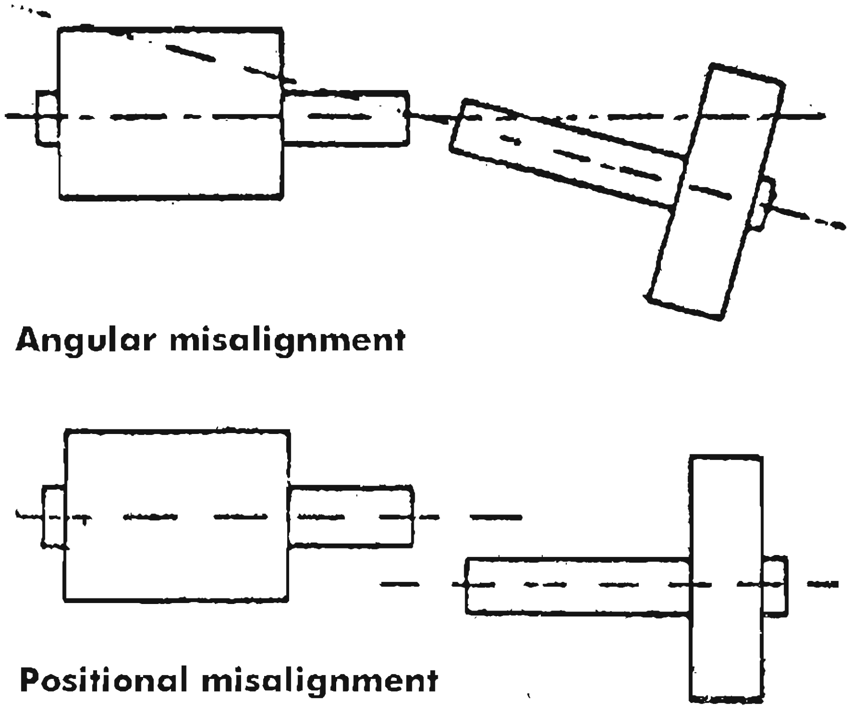

Figure 5.3: Angular and Positional Misalignment

Some generators are provided with adjusting screws to adjust the alignment. These can be used to reposition the generator until the required level of alignment is reached.

A straight edge placed on one of the shafts can be used to check the alignment initially as shown in Figure 5.4. Any gap between the two shafts will indicate how the shafts are misaligned and the machine can be moved in the appropriate direction to achieve alignment.

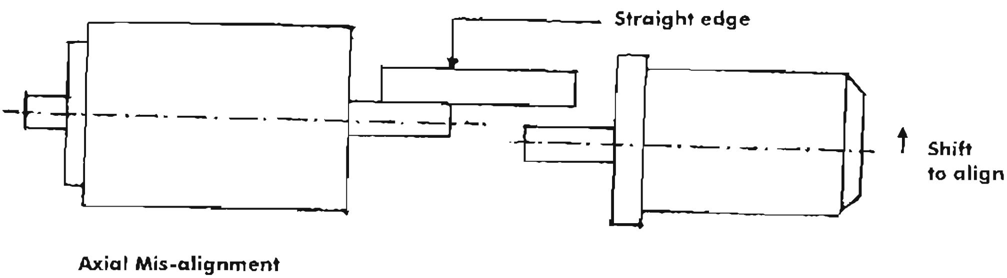

Figure 5.4: Using a Straight Edge to Check Alignment

Adjustments in height are made by adding or removing shims between the generator feet and the baseframe. While some angular and horizontal misalignment can be removed by repositioning one or both machines, it is usually not possible to align them completely. Quality flexible couplings should be used to accommodate any residual misalignment, but every effort should be made to minimise it.

5.3.2 Belt Drives

For belt drives the alignment is simpler since only angular misalignment needs to be rectified, i.e., the two shafts should be parallel. The alignment is checked by stretching a thin string along the edges of the turbine and generator pulleys as shown in Figures 5.2 and 5.5. The machines are moved in the appropriate direction until the pulleys are in line with each other.

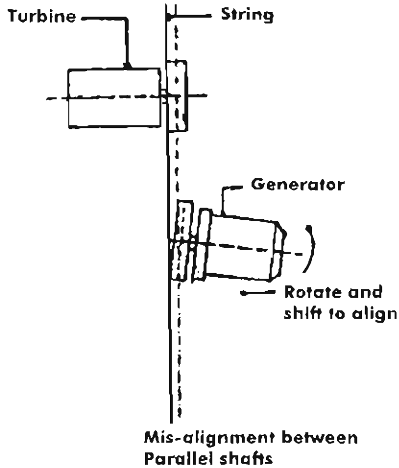

Figure 5.5: Aligning a Belt Driven System

5.4 Installation Procedure for the Penstock

Penstock installation is usually carried out from the powerhouse to the forebay. After the turbine has been installed, the adapter nozzle/manifold is assembled. Then the valve (if fitted) is attached. The valve, since it is heavy, will need to be supported. Then the first piece of the penstock (usually a bend) is attached to the valve while both are firmly supported.

The first anchor block is normally built just outside the powerhouse wall enclosing the first piece (the bend) (Figure 5.6). Sections of penstock pipe are then connected one after the other up to the forebay.

5.4.1 Joining and Adjusting Steel Penstocks

There is usually some discrepancy between the initial measurements (which may not have been very accurate) and the actual length needed for the penstock. Adjustments in the length of penstocks are made by casting the bends or penstock pipes in the concrete of the anchor blocks after the penstock has been laid. If the bends or pipe sections to be embedded are cast in before the penstock pipe is laid, then it becomes difficult to make any adjustments (see Chapter 4).

The penstock lengths are joined together at the flanges until the location of the second anchor block is reached. The section or bend to be embedded is then attached to the

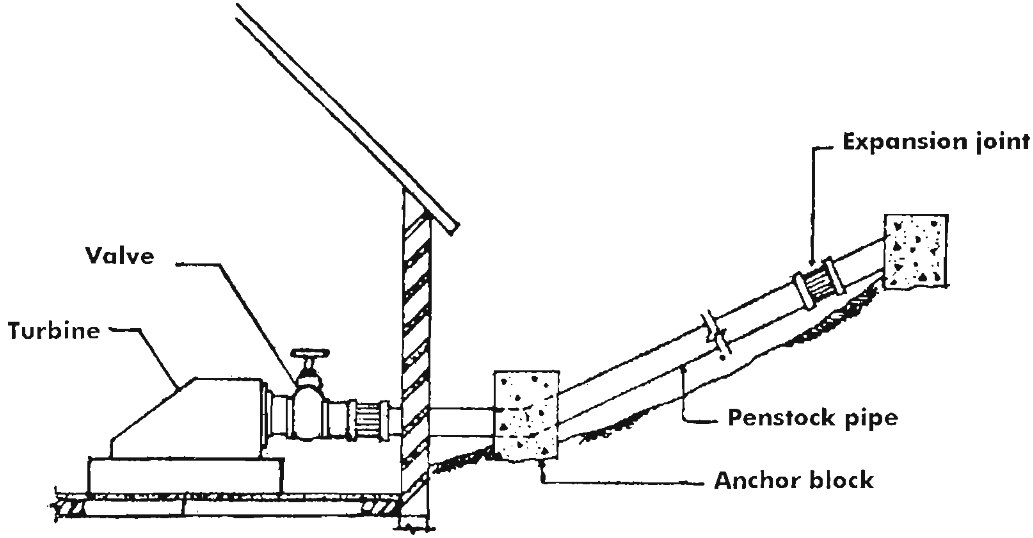

Figure 5.6: Cross-section through a Powerhouse and Anchor Block

penstock while supported by temporary supports. In this way, the whole penstock can be joined together up to the location of the entry into the forebay, while propped up by temporary supports. When the penstock is fully joined, the support piers and anchor blocks should be completed (Chapter 4).

The forebay should be constructed after the penstock has been laid and the supports completed. This will make it possible to shift its position if necessary to accommodate any small differences in penstock length or alignment.

Steel penstock lengths are joined together by bolting the flanges on the lengths. A flat rubber gasket at least five mm thick, or an O-ring gasket, is used to make the joint leakproof. In some rare cases, penstock lengths may also be welded together if adequate equipment and qualified welders are available at the site.

5.4.2 Joining HDPE Penstocks

Penstocks made of HDPE (high density polyethylene) are joined together by butt welding the pipe ends. A hotplate is used to melt the ends so they can be joined together. The procedure for joining HDPE penstock lengths is as follows.

- The ends of the pipes are cut at right angles with a hacksaw and smoothed and levelled using a flat file. When the two ends are placed face to face, the gap at any point should not be greater than one millimetre. If the gap is larger the ends must be smoothed until the gap is reduced.

- The hotplate is heated to about 220°C. A white thermo-chrome crayon is used to determine the temperature. When the hot plate is marked with the crayon the mark should turn brown in about five seconds. If it takes longer, the plate is not hot enough. If it takes less time, the plate is too hot.
- The hotplate is then slipped into a teflon envelope (the teflon envelope prevents the HDPE from sticking to the plate) and held between the pipe ends which are firmly pressed against it (Figure 5.7). When the pipe is properly heated there will be a lip of molten plastic around the perimeter of the pipe ends. This lip should be of the same size all around the pipe.

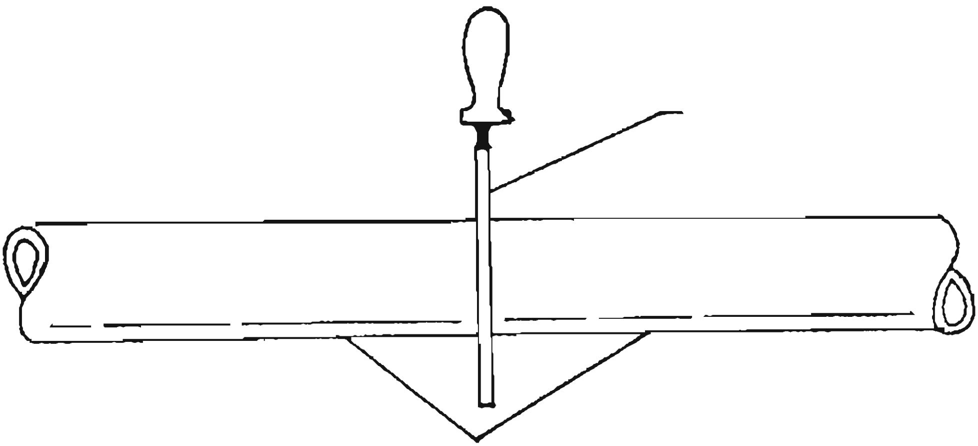

Figure 5.7: HDPE Pipe Ready for Making the Joint

- The plate is removed from between the pipe ends and the ends are pushed together. While joining the ends, the contact must be even and the alignment perpendicular. Once the melted ends touch each other they must not be separated and realigned. The pipe ends are pressed firmly but not excessively (Figure 5.8). The joined pipe should then be laid on level ground with no stress to the joint for about 15 minutes. If necessary, supporting packing should be laid underneath the pipe at appropriate locations to maintain alignment and reduce stress.
- The joint is tested by flexing it. It is also examined visually to ensure that there are no cracks or discontinuities. A proper joint is as strong as the rest of the pipe and

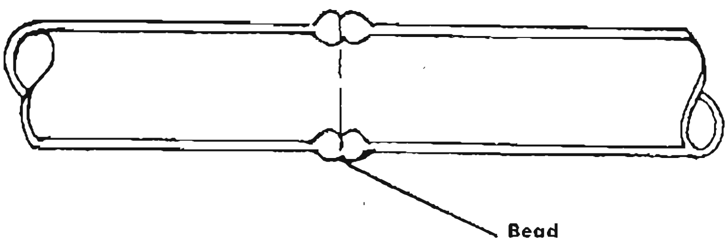

Figure 5.8: HDPE Pipe with Bead after Joining

cannot be cracked or broken apart. After joining a convenient length, the pipe is lowered into the trench and carefully joined to the pipe already in the trench.

5.4.3 Laying Buried Penstocks

HDPE pipes should always be buried since ultraviolet rays from sunlight accelerate deterioration and decrease the useful life of the pipe. Sometimes steel pipes are also buried, especially the welded types.

It is not necessary to build support piers for buried penstocks. Additional anchor blocks are usually not needed after the first block since the weight of the backfill is sufficient to restrain the penstock.

The penstock route is finalised and marked out using pegs driven into the ground and the penstock trench dug. The penstock trench must be even, without any protruding stones. The bottom should be filled with a layer of sand or fine soil around 100mm deep. The penstock is then laid along the trench and tested. Then the trench is backfilled as shown in Figure 5.9.

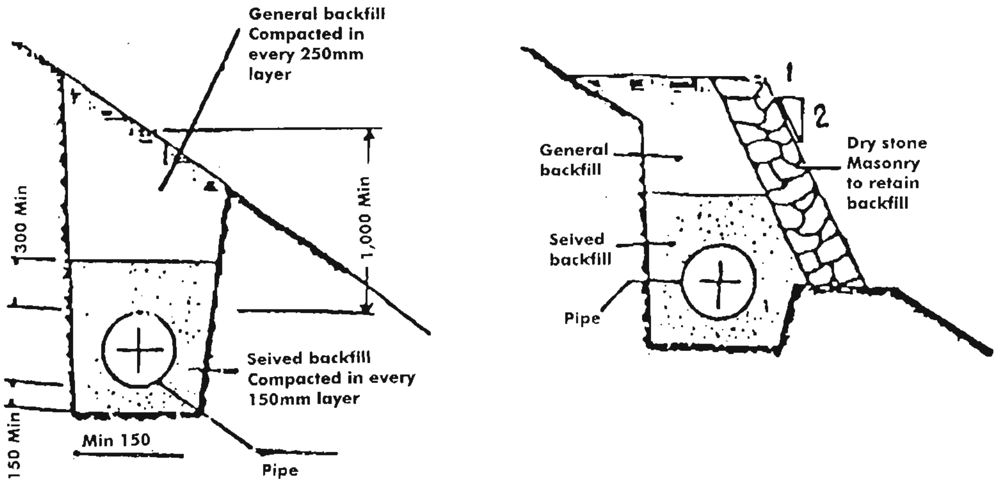

Figure 5.9: Section Through Pipe Buried in Different Ways

5.4.4 Fixing the Penstock with Support Piers and Anchor Blocks

The support piers and anchor blocks are completed after the penstock has been laid and properly aligned.

Construct the support pier masonry until it reaches the level of the penstock. The base plate and anchor bolts should be cast into the concrete or plastered into the top of the support pier. At least one third of the pipe diameter should be submerged in the support pier. To prevent damage to the pipe, a bitumen sheet is placed between the penstock pipe and the metallic base plate fixed to the support pier (Figure 5.10).

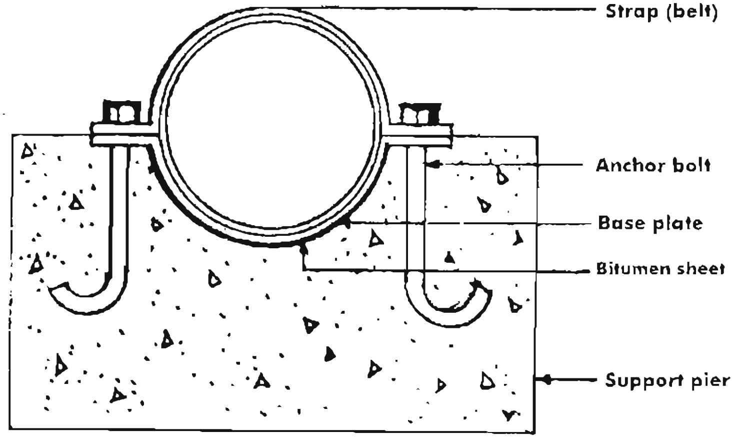

Figure 5.10: Cross Section through a Support Pier

Anchor blocks are normally made of concrete, unlike the support piers which are normally built of stone masonry. The concrete should be poured in the form after the bend or other part of the penstock has been properly positioned. The centre of the bend should be at the centre of the anchor block. Check that the correct bend is used and that the alignment is correct. The bend should have steel rods 12mm in diameter welded to it in order to improve bonding to the concrete.

5.4.5 Installing Expansion Joints

An expansion joint is designed to take up expansion of the penstock caused by variations in temperature. A typical expansion joint is shown in Figure 5.11. Expansion joints are usually placed just below anchor blocks. Normally, one expansion joint is provided between two anchor blocks.

When installing an expansion joint, the temperature at the time of installation must be taken into consideration, so that the minimum gap is maintained when the pipe expands fully, as a result of the highest possible temperature rise, and the maximum gap is not exceeded when the pipe contracts fully (Figure 5.12). The temperature of the penstock may be higher or lower than the ambient temperature, depending, for example, on whether the sun is shining directly on the penstock The gap (G) at the time of installation of the expansion joint should correspond to the gap required for the actual penstock temperature, and related extent of expansion, at this time.

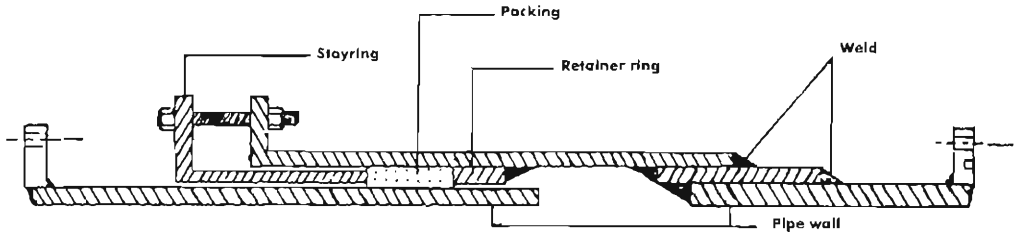

Figure 5.11: Welded Type Expansion Joint

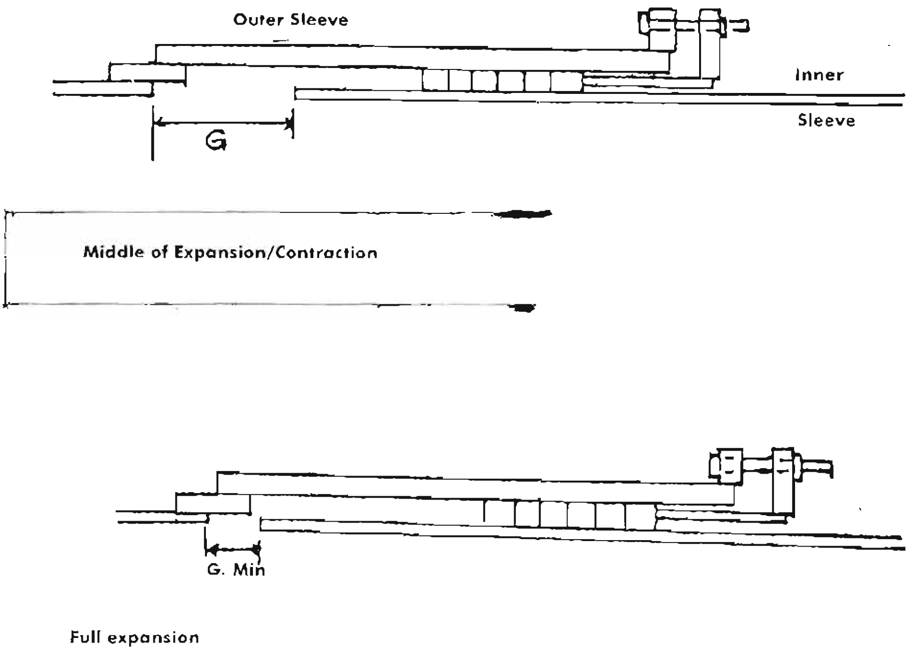

Figure 5.12: Expansion Joint Positions during Installation

For example, if the expansion joint is installed at a time when the penstock temperature is the highest expected, then it must be assembled in the fully expanded position. This will allow the pipe to contract when the weather gets colder.

For temperatures in between, the position of the pipe should be set in proportion to its deviation from the minimum or maximum temperatures. For example, if the surface temperature of the pipe is halfway between the maximum and minimum temperatures then the joint should also be set in mid position. The following example explains the procedure further.

Example

Consider a site where the maximum expected temperature of the pipe is 35°C and the minimum is minus 10. At installation time, the pipe surface temperature is 15°C. The maximum expansion that the joint can accommodate is 50mm. A minimum gap of 10mm must be maintained under all conditions. The length of the pipe between two anchor blocks is 40m.

Since the pipe temperature at present is 15°C, the gap (G) set between the two pipe ends must be such that it maintains allowable G_{max} and G_{min} at lowest and highest temperatures (Figure 5.12). This value of G is determined as follows.

$$
\begin{aligned}
G_{min} &= 10mm \\
G_{max} &= 10 + (35-(-10)) \times C \times L \\
&= 10 + 45 \times 12 \times 10^{-6} \times 40 \times 1000 \\
&= 10 + 21600 \times 10^{-3} \\
&= 10 + 21.6 \\
&= 31.6mm
\end{aligned}
$$

where,

C is the coefficient of expansion for mild steel and
L is the length of the pipe.

This value is acceptable since it is less than the full extension of the expansion joint.

Now the gap (G) at the time of installation is given by

$$G = \frac{T_{max} - Ta}{T_{max} - T_{min}} \times (G_{max} - G_{min}) + G_{min}$$

where,

T_{max} is the maximum temperature of the penstock
T_{min} is the minimum temperature of the penstock
T_a is the temperature of the penstock at the time of installation

$$G = \frac{35-15}{45} \times 21.6 + 10$$

$= 19.6mm$

Therefore, the gap between the pipe ends should be about 20mm when the expansion joint is installed.

5.4.6 Positioning the Pipe in the Expansion Joint

The procedures for setting the expansion joints as they are being installed are different for a bolted type design and a welded type design.

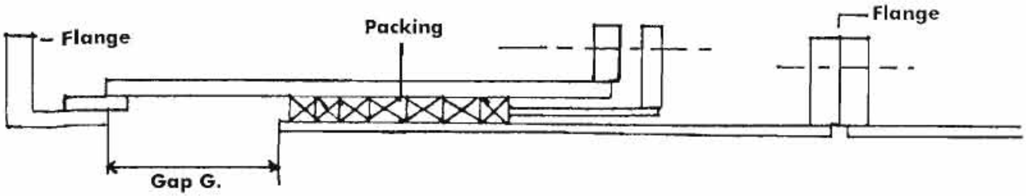

Figure 5.13: Setting the Gap in a Bolted Type Expansion Joint

Bolted Type Design

The distance between the flange of the expansion joint and the end of the pipe is small; thus the gap is accessible and can be measured easily (Figure 5.13). After the correct gap has been set by moving the pipes axially, the packing is put in place and the stay ring tightened. The next length of penstock pipe is then bolted on to the expansion joint.

Welded Type Design

In a welded design setting the gap is more difficult because it is not accessible and cannot be measured directly. The set-up is shown in Figure 5.14. The gap 'G' is the difference

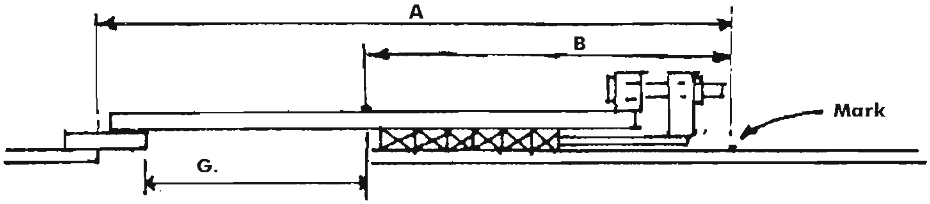

Figure 5.14: Setting the Gap in a Welded Type Expansion Joint

between the lengths 'A' and 'B'. The expansion joint flange is then positioned over this mark and the stay ring tightened.

5.4.7 Installing the Packing

Ensure that the place where the packing will be placed is clean and greased or oiled. Squeeze one end of the packing rope into the gap between the inner and outer sleeves. Mark this point so that the number of turns of packing can be counted. The packing should be pushed firmly with a suitably sized piece of wood until it reaches the retaining ring. Continue placing the first round of packing firmly against the retaining ring. Repeat until about five turns have been completed and then cut the packing rope. Place the stay ring against the packing and tighten the bolts.

5.5 Controls and Instrumentation

If an electronic load controller (ELC) is fitted, the controls and instrumentation are an integral part of the ELC panel. All the meters should be adjusted to zero. All connections should be checked to ensure that they are tight and correctly done. The ballast load should be 20 per cent more than the maximum output of the generator, and its resistance should be checked to ensure that it is functioning properly and that there are no short circuits.