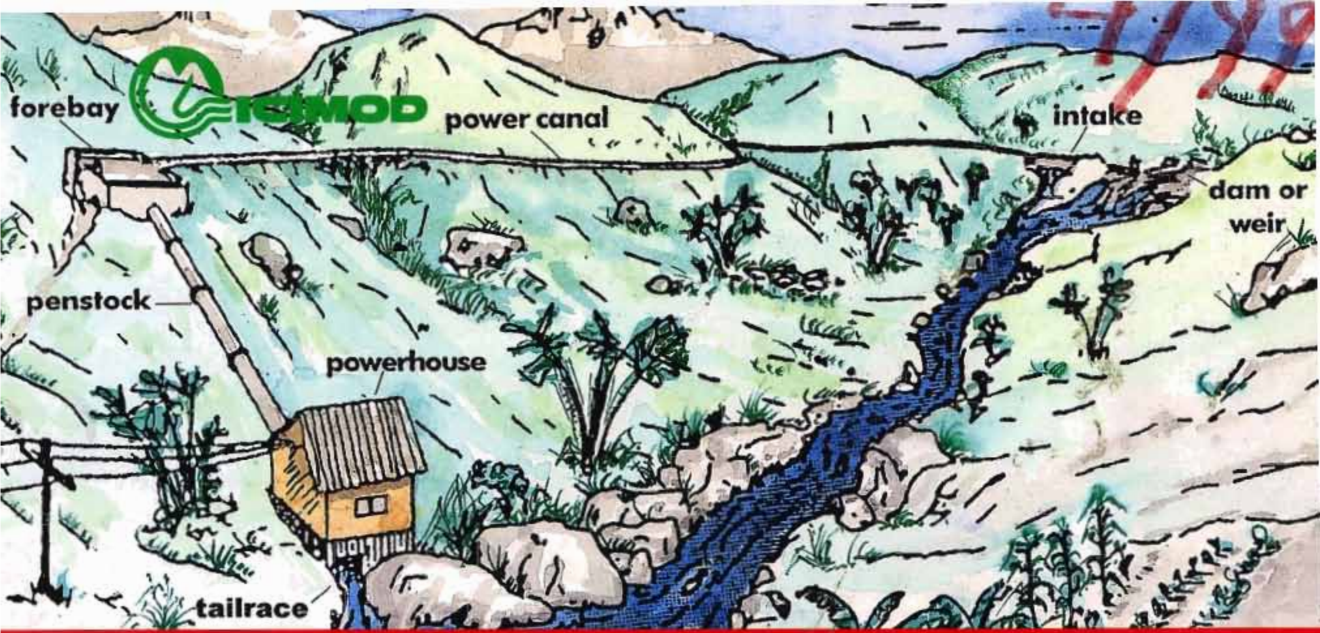
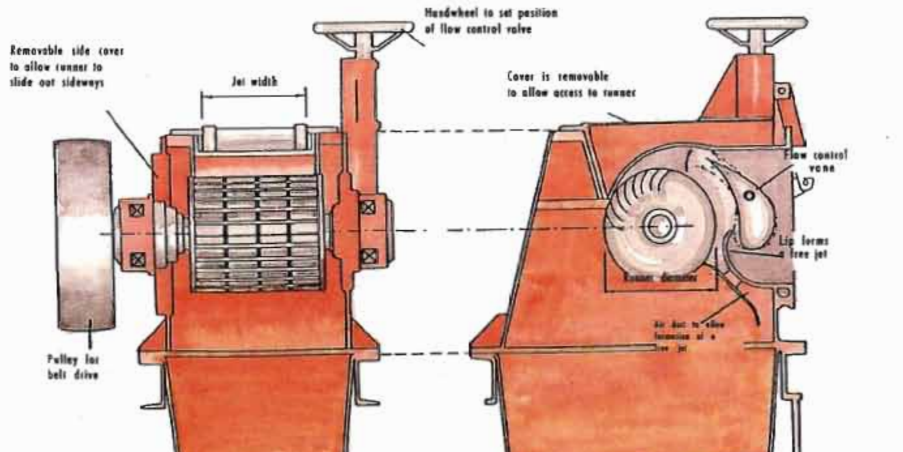


Installation and Commissioning Manual for Private Micro-hydropower Plants



International Centre for Integrated Mountain Development
Kathmandu, Nepal
1999

Installation and Commissioning Manual for Private Micro-hydropower Plants

Prepared by
DCS - Technology Development
P.O. Box: 8, Butwal, Nepal

Revised by
Anwar A. Junejo
Ajoy Karki
Girish Kharel

International Centre for Integrated Mountain Development (ICIMOD)
Kathmandu, Nepal
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Preface

Private or community owned and managed micro-hydropower (MHP) schemes are now accepted as viable, least-cost options for many under-developed and inaccessible mountain areas in the Hindu Kush-Himalayan (HKH) region. Local entrepreneurs and/or communities are likely to initiate, manage, operate, and maintain such plants themselves. The technology is simple and low cost. However, the implementers/surveyors, designers, manufacturers, installers, and other technical people involved are usually not highly qualified and may lack the necessary expertise in their respective fields. Therefore, institutional arrangements and properly designed and implemented inputs are needed for these groups of professionals (both implementers and operators/managers) in the form of training opportunities, manuals and guidelines, back-stopping back-up support', maintenance and repair facilities, and know-how support. Without such inputs, the performance and viability of many plants may be less successful than hoped.

With these needs in view, ICIMOD decided to develop and disseminate a series of four information manuals for MHP schemes on site survey and layout design, manufacture, installation, management and operation, and maintenance and repairs. The manuals have been prepared as part of a project entitled 'Capacity Building for Mini- and Micro-hydropower Development in Selected Countries of the Hindu Kush-Himalayan Region, Phase II'. Like its predecessor, the first phase, the project has been generously supported by the Norwegian Government. The project has been designed and implemented by ICIMOD in the HKH regions of Pakistan, India, and Nepal, in collaboration with suitable focal agencies in each country.

The current manual focusses on the installation, commissioning, and handing over of MHP plants to owner-managers. The target group includes installers and/or supervisors of the installation process. Since these people may have limited formal education and technical qualifications, an attempt has been made to keep the contents simple and brief. However, there is always a problem of balance between simplifying so far that the information is no longer useful, and the information being so complicated that those who need it are unable to use it. An attempt has been made to achieve the optimum balance.

The original version of the manual was prepared by DCS-Technology Development, Butwal, Nepal, and has been revised by the project coordinator, Dr. A. A. Junejo, and two consultants, Mr. Ajoy Karki and Mr. Girish Kharel. The revision is based on the recommendations of an Experts' Consultation organized by ICIMOD in February 1998, as well as on some suggestions from other experts. DCS did a very good job in collecting the basic information and compiling it in one place; while the consultants rewrote some chapters to improve the contents and cover some additional topics. The Coordinator and ICIMOD are grateful to DCS and the consultants for their contribution.

This manual is probably the first of its kind on the subject aimed at this particular target group. Although every effort has been made to make it useful for the target group, it is quite possible that some important aspects have been overlooked, or some information not provided in the most effective way. We would very much welcome receiving any comments and suggestions for improvements or additions for subsequent editions from users of the manual, experts, and institutions concerned with MHP.

After necessary modifications these manuals will be translated, published, and distributed in India, Nepal, and Pakistan to prospective users and beneficiaries and relevant institutions. It is also hoped that some training agencies will find the manuals to be useful supporting material for their training programmes.

Anwar A. Junejo
Coordinator MMHP Project
ICIMOD, November 1998

Abbreviations and Acronyms

MASL	:	Metres above sea level
CGI	:	Corrugated galvanized iron
ELC	:	Electronic load controller
GI	:	Galvanized iron
HDPE	:	High density polyethylene
HKH	:	Hindu Kush-Himalayas
MHP	:	Micro-hydropower
SWG	:	Standard wire gauge

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Chapter 1
Introduction

Many areas in the Hindu Kush-Himalayan (HKH) region are little developed and inaccessible; and people live under difficult conditions with much drudgery and deprivation. At the same time there is increasing degradation of existing resources and the environment. Energy, considered to be the crucial ingredient for development, both social and economic, is in short supply. And this is particularly true for useful forms of energy such as electricity. Development of appropriate energy resources and systems and improving access will be crucial for the development of such areas. As a result of the difficulties associated with distribution and transportation, it is preferable to develop and use local energy resources in projects that can be initiated and managed/operated by the local populace without outside intervention.

The power or energy of flowing or falling water, available in most remote and underdeveloped mountain areas in the micro-hydropower (MHP) range of 0.2 to about 100kW, can meet local needs in a simple, convenient, environmentally friendly, and relatively cheap way, provided appropriate inputs and methodologies are adopted and implemented. Experience in many developing countries has clearly shown the viability of this renewable and environmentally friendly resource in such places. However, it has also become clear that properly designed and implemented inputs, such as training manuals on various aspects and back-up support, are vital for the success of such programmes. Another important prerequisite is involvement; the beneficiaries or communities involved should play a leading role in the whole process of planning, fund-raising, decision-making, survey, installation, and management and operation. Without this complete involvement of the beneficiaries, the chances for long-term success of the plant are not very high.

1.1 About this Manual

After extensive studies, consultations, and analysis of the current situation in the HKH region, ICIMOD decided to develop three training programmes and a series of manuals aimed at the professionals involved in the implementation of private MHP schemes at the grassroots' level[1]. Four manuals are being prepared to cover the following aspects of setting-up and running MHP plants in remote areas, particularly in the HKH region.

[1] Private' is taken here to mean any plant set up independently of a central authority such as the government or an electricity utility. It includes schemes developed by local entrepreneurs as well as those set up and owned by local communities, whether or not they are supported by an agency grant.

- Site Survey and Layout Design
- Installation and Commissioning
- Operation and Management
- Maintenance and Repair

This manual is one of this series and covers all aspects of installation, from packing and transportation of the equipment to the site, to commissioning and handing over the plant to the owner-manager(s). The intended target group are private sector installers who may have some experience of installation, but who have little formal training in this special area. Such people will be able to use the current manual to improve the installation process and as an aid in dealing with specific problems and other aspects of installation. The manual has deliberately been kept as simple as possible to provide the maximum benefit to those in need; even so the installer should preferably have some technical qualification, for example a certificate or diploma in a relevant engineering trade, so that he[2] can understand the technical aspects fully. Clearly, it is impossible to cover all aspects of installation for all types of sites and equipment within one manual. However, an effort has been made to cover most installation aspects for micro-sized plants, especially up to 50kW in capacity. Some plants may also have agro-processing or other equipment within the powerhouse. Installation of such equipment has not been covered in this manual since it is a separate subject. Instructions for installing and commissioning such equipment are usually provided by the manufacturer.

The information provided in this manual is intended to help installers improve their capabilities even without extensive supplementary training. There is no doubt, however, that maximum benefit will be obtained from the manual if the installer is first able to participate in a proper training course in which this manual is used as a training manual.

There are three main components in the installation process in addition to packing and transporting the equipment to the site safely: construction of the civil engineering structures, including the weir, intake, canal, forebay, powerhouse, and tailrace; electro-mechanical installation of the turbine, generator, valve(s) and penstock; and installation of the transmission lines. This manual focusses on the installation or construction and testing and commissioning of these components.

[2] Note: Throughout this manual the term 'he' is used to refer to the installer whether male or female.

Chapter 2
Planning and Preparation for Installation

Considerable planning and preparation will be necessary before the equipment is transported to the site for installation. Information must be gathered and the equipment needed at the site identified. This is unlikely to be the first visit of the installers to the site. At least one or more of the team members should already have travelled to the site and the main village where the team has to stay and have established contacts with the local lead persons. Therefore, travelling to the site should not pose a problem. However, the route for transporting the equipment may be somewhat different than that used for people; some equipment may have to be airlifted and then manually transported, for example. The best time for travel, transportation, and installation of equipment should also be considered. The rainy season, harvest time, festival time, or very cold or hot seasons will not be suitable for working at the site. It can take between two weeks and six months to complete the installation, depending upon the size of the plant, the remoteness of the site, and whether it is an easy or difficult scheme.

Briefly, the installation process will include the following.

- Packing and transporting equipment and materials to the site and storing them there
- Finalisation of the sites for the weir, intake, power canal and its sub-components (desilting basins, spillways, crossings), forebay, penstock and powerhouse (These will have been demarcated during the surveys.)
- Measurement and minor adjustment of locations of some components such as the base of the turbine, the forebay, and the intake mouth
- Construction of all civil structures — including foundations for the turbine, generator, and agro-processing equipment — and construction of support piers, anchor blocks, and such like
- Installation of the penstock pipe and accessories
- Installation of the turbine, generator, agro-processing units (if provided), and coupling/drive systems
- Installation of the transmission and distribution wires
- Testing and commissioning (starting, testing, measuring output, resolving defects)
- Training the managers and operators
- Handing over the plant and certification

Sometimes, most of the civil construction work will have been completed before equipment arrives at the site. In other cases, however, it may be convenient to complete the civil work and the installation of the electro-mechanical equipment and transmission system at the same time in a prescribed sequence.

If for some reason the installation work has to be discontinued, adequate planning will be necessary to prevent damage to the components already installed or constructed and to the remaining equipment and materials; and this includes the cement, which can easily be spoiled as a result of exposure to rainwater or humidity. Similarly, newly constructed civil works, such as earthen canals, may have to be protected from damage during the monsoon rains or from other occurrences.

Usually, two or three persons; who together have the necessary expertise, will travel to the site. But they may not all stay all the time. The main expertise needed is in the fields of:

- site assessment and survey (to assess geophysical features and changes since the last survey and make some measurements of distances);
- civil construction;
- installation of electro-mechanical equipment, including the penstock;
- laying transmission lines; and
- commissioning and testing.

Information should also be collected and verified regarding availability and cost of skilled and unskilled labour and construction materials. In addition, the location of the nearest adequate workshop (with, for example, welding facilities or other tools), health care centre, and communication facility should also be identified in advance, if possible.

2.1 Tools and Other Materials for the Site

A comprehensive list must be prepared of tools and instruments to be carried to the site that may be needed during the installation. The list should also include materials to be transported. It is best to prepare a proper checklist (see Annex 1 for an example).

Furthermore, all the drawings of the parts and components with the installation instructions must also be carried to the site. These include the weir, intake, canal, forebay, penstock route, powerhouse, the mechanical components (such as trash racks and expansion joints), and the specifications and construction details for the various foundations. The decisions regarding construction materials, that is what needs to be carried and what can be acquired at the site, should also be made in advance (these include such things as doors and windows, corrugated iron sheets, wooden beams, and steel bars). Some of this material can be provided or acquired by the communities involved. In fact, completion of most of the civil work can and should be the responsibility of the beneficiary communities or the entrepreneur.

It is usual that some land and length measurements have to be carried out again. It may be necessary to measure the length of the penstock more accurately. Or the penstock length may need to be adjusted by a few centimetres, necessitating measurement of the length, and possibly raising or lowering of the base of the turbine or forebay. Similarly, a few surveying tools, for example, an Abney or Dumpy level, will be needed to mark out the construction of the power canal, intake, and weir.

Chapter 3
Transportation of Equipment to the Site

Actual transportation of the equipment is usually not the responsibility of the installers. However, they may sometimes be called upon to advise. Transportation of the equipment to the site also includes proper packing, planning the transportation, and storage at the site until installation is complete. Packing is an important part of the process. It should ensure that the equipment is protected from the effects of weather; that pilferage, loss, and damage during transportation and storage are minimised; and that the equipment is easy to carry. In most cases, the equipment will have to be carried manually for anything from a few metres to many kilometres (in Nepal it could mean a walk of a few days). Therefore, the packages have to be of appropriate size and weight. An experienced and trained porter can carry up to 60 kg for long distances on a mountain trail; and a horse or mule can carry up to 80 kg. But this would also depend on how difficult or dangerous the trail is (steepness, width, slipperyness). Many components (e.g., penstock pipe sections) need not be wrapped, while others, like the generator, have to be wrapped in polythene sheets or similar material to protect them from rain. Smaller items should be packed together, others (e.g., the turbine) may have to be disassembled and packed or they will be too heavy to carry. The penstock and other items more than three metres long may also be difficult to carry. All these aspects should be given due consideration when planning the packaging and transportation. Disassembled parts of items may have to be marked so that they can be correctly reassembled later.

It is usually expensive and inconvenient to pack larger units, such as the generator and turbine, in wooden cartons. However, smaller and delicate items, such as electrical instruments, electronic load controllers (ELC), switches, and insulators for transmission, may be packed in wood or cardboard cartons using adequate anti-impact material such as foam and plastic sheets or similar materials to protect them from rain. In some countries, e.g., Nepal, the traditional method of carrying a heavy load is on the back; whereas in Pakistan, for example, people carry packages on their heads. The maximum dimensions suggested for packages to be carried by these different methods are as follow.

Carrying method	SuggestedMaximum Dimensions (cm)		
	Length	Width	Height
On the back	50	50	120
On the head	50	50	40

Heavier and larger packages should be carried on the back if experienced porters can be found. Sometimes, heavier items can also be carried by two or more persons by fastening the item to a wooden pole of appropriate thickness which is supported on the shoulders. In this way, heavier loads (up to 100 kg) can be carried by two people. Table 2.1 shows the average maximum sizes and weights that can be carried by a single person or animal and by other transport systems.

Table 2.1: Permissible Weights for Transportation of Goods

Mode of Transport	Carrying Capacity	Remarks
Porter	60	On back
Horse	80 kg	30 kg each side
Mule	40 – 60 kg	30 kg each side
Truck	8 – 10 tonnes	Up to 5 one tonne units if crane available for loading
Helicopter	0.5 – 4 tonnes	Depends on type
Plane	2 – 10 tons for hilly areas	Depends on type

3.1 Storage at the Site

Usually, it is necessary for equipment and other materials (e.g., cement) that have been transported to the site to be stored there for some time. An appropriate location has to be found for this purpose. Some items must be stored indoors under lock and key, while other heavier equipment can be kept outside but properly covered. Items, such as penstock pipe lengths (flanged or unflanged), can be stored outside but preferably covered with waterproof sheets. If possible and safe, the heavier equipment may actually be stored at the site (e.g., penstock, turbine, generator, trash racks); while other lighter, more delicate, and expensive items should be stored at another place inside, for example, in a house or school (e.g., the ELC, control panel, transmission wires, insulators). Special attention should be paid to the storage of cement since it can go hard in even a few days if exposed to excessive humidity. Cement should be properly wrapped in plastic sheets during transportation and indoor storage.

The following factors should be considered when selecting a storage site and storing the equipment and materials.

- Adequate space must be available both indoors and outdoors.
- The place should be as near to the actual site of installation as possible to avoid extra expenditure and possible damage resulting from repackaging and transporting.
- There should be no possibility of pilferage or damage by trespassers, or of damage as a result of rain, snow, animals, falling rocks, landslides, or other eventualities.

Chapter 4
Construction of the Civil Structures

4.1 Site Inspection and Preparation

Based on the detailed design, the locations of the various MHP structures should be verified and then clearly marked at the site. This includes placing centre line pegs along the headrace and penstock routes and along the boundary of other structures such as the settling basins, forebay, anchor blocks, and powerhouse.

At this stage the layout design should already have been finalised and no changes should be necessary. However, a final survey should be carried out to verify that, since the design phase, there have been no changes in the site that might necessitate relocation of structures. The layout should only be changed if there have been major geological changes such as landslides, along the headrace or penstock routes.

The site preparation should include clearing the route from the intake to the tailrace. Shrubs and other vegetation should be uprooted if they are likely to obstruct the construction work. If some structures are to be located along cultivated fields, these fields should be left barren before commencing the construction work. The area required during the construction phase will be larger than the actual area that the various structures will eventually occupy. This is because adequate space is needed for labourers to work freely, for storing construction materials such as stones and sand, and for dumping excavated soil.

4.2 The Construction Sequence

The construction of the scheme should start from the most critical location, i.e., where a slight misalignment or improper orientation may result in significant expenditure for remedial measures. Usually the machine foundation in the powerhouse is the most critical location. This is because, once the machine foundation anchor bolts are set in concrete, the turbine and generator locations cannot be readjusted. Therefore, the machine foundation should be constructed first. Then work should commence on the installation of the penstock pipe from the machine foundation to the forebay. Except for the last 300mm in height, the support piers can be constructed as the penstock installation work progresses upstream, including expansion joints at given locations as per design. The pipe is first supported by temporary stonework, wooden planks, or other materials. The final height of the piers should be adjusted once the entire pipe length has been installed so that the pipe can be properly aligned and bending stresses avoided when it reaches the end point in the forebay. The anchor blocks should also be completed after the entire penstock pipe length has been installed. This is because once the anchor blocks are constructed, the penstock pipe cannot be readjusted.

The forebay is usually located on an elevated terrace (flat area) on a steep slope above the penstock. Sometimes excavation of the location is required to provide a sufficient area for the forebay. If this is the case, then it could affect the length of the penstock pipe. Hence, the forebay should be constructed after the penstock pipe reaches this structure.

Once the machine foundation, penstock, and forebay have been constructed, the logical sequence is to continue the construction work upstream to the location of the intake. If the construction work is carried out in this sequence, there will be less chance of misalignment or errors in the elevation of the structures. However, if the survey work has been accurate enough, and the staff at the site are well experienced, some construction work on the higher structures can be carried out concurrently with other structures. For example, different portions of the headrace canal and the settling basins can be constructed concurrently. However, it should be noted that if, for example, the elevations of the headrace canal do not match and the downstream section is higher, remedial measures will be costly.

Construction work at the intake, in particular for the diversion weir, should normally start after all other structures have been completed. This is because the flow cannot be diverted for power generation until all other structures are ready. Furthermore, there may be additional risks from floods if work at the intake and weir is completed prior to the onset of the monsoon but other structures are still incomplete. Some retaining work along the intake bank can be carried out concurrently with construction of other structures, provided that the MHP scheme can be commissioned prior to the onset of the monsoon rains.

4.3 Machine Foundation, Powerhouse, and Tailrace

4.3.1 Construction of the Machine Foundation

Figure 4.1 shows a typical machine foundation pit with reinforcement bars. The foundation for the machine should be constructed as follows.

- Demarcate the floor area of the powerhouse and the location of the machine foundation according to the design plan.
- Excavate the machine foundation pit to the required depth and compact the floor using a manual ram. If the pit base is not a rock, then a 250mm stone soling should be provided above the base.
- Excavate the tailrace section inside the powerhouse before commencing the concrete work for the machine foundation. This will prevent any misalignment developing be-

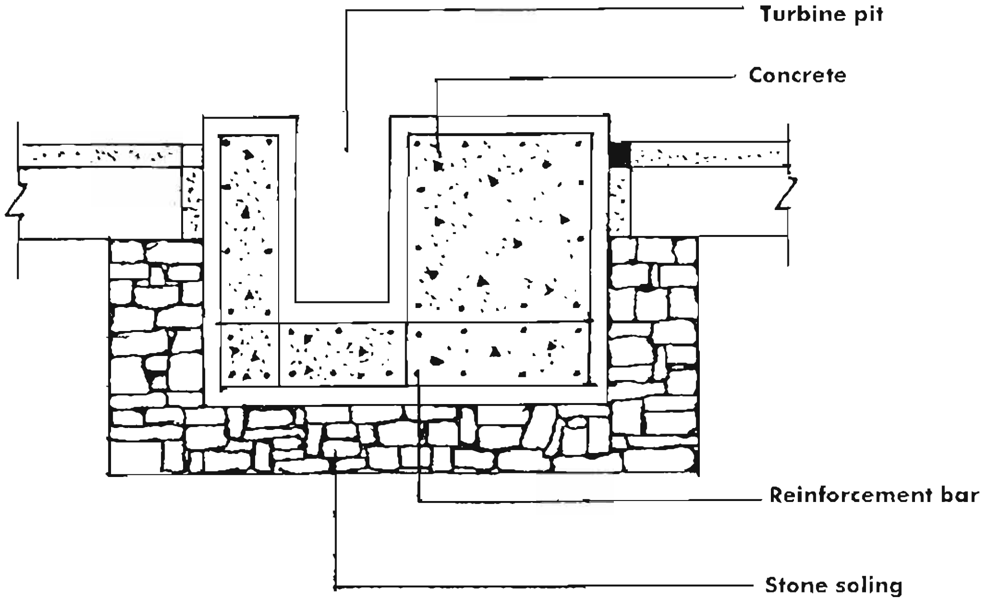

Figure 4.1: A Typical Machine Foundation Pit

tween the machine foundation and the tailrace. (If the tailrace is excavated at a later stage, a gap of about a week should be left after the construction of the machine foundation to allow the concrete to cure.)

- Place formwork around the periphery of the excavation and arrange the reinforcement and anchor bars for the base frame as specified in the design. If wood is expensive, dry stone walls can also be used for the formwork. Unlike wooden formwork, dry stone walls need not be removed. The threaded ends of the anchor bars should be greased and then covered with clean pieces of cloth or plastic sheets so that they are not damaged while pouring the concrete. Sometimes the base frame can also be welded to the reinforcement bars and cast into the foundation.
- When the formwork and reinforcement of the machine foundation have been put in place, prepare the concrete mix at the required ratio (usually 1:1.5:3 cement, sand, water, aggregate) and then pour it up to the generator/turbine base frame level. Concreting work is discussed further in the next section.
- Manually compact/vibrate the poured concrete using long steel rods. Once the required level is reached, place the base frame for the machines on the concrete so that it fits snugly over the anchor bars (the holes in the base frame are in line with the anchor bars), then tighten the anchor bolts. The base frame must be level, and this should be checked constantly (using a 'spirit level') while tightening the bolts. Note that the lie of the base frame can only be adjusted while the concrete is still wet.
- Protect the newly poured concrete structure from direct sun and rain for at least 24 hours.

- The concrete is cured by keeping it moist, usually by gently pouring water on the concrete structure. Curing should start 24 hours after the construction of the machine foundation and continue for at least a week. An uncured concrete structure will not gain full strength. During hot and dry weather it may be necessary to pour water on concrete structures twice a day (mornings and afternoons) to ensure that they gain full strength.
- Wait at least seven days after completion of the construction before removing the formwork from the machine foundation.
- Once the machine foundation and the tailrace section in the powerhouse are complete, work on the powerhouse walls and roof can commence. As a result of the confined space, it may not be feasible to construct the powerhouse structure, machine foundation, and the tailrace section concurrently.

4.3.2 Preparation of Concrete

The quality of cement, sand, and aggregates for concrete work should be as follows.

- Cement used for concrete and masonry work should be fresh and preferably less than six months from the date of manufacture. Cement that has been stored over a long period loses strength significantly.
- The sand for concrete work should be granular, clean, and free from organic materials and soil. Sand mixed with soil or organic material should be thoroughly washed before use to remove these and other water-soluble materials.
- The aggregates for concrete work should be collected either from quarries or riverbeds, or prepared by crushing stones. Aggregates need to be hard, angular, and non-porous.
- Concrete should never be mixed directly on the ground. It should be mixed on a clean and watertight platform (such as a tightly paved stone surface), or some other adequate surface.

The process of mixing concrete is as follows.

- Mix dry cement and sand thoroughly until the colour is uniform.
- Add the required volume of coarse aggregates on top of the cement-sand pile and mix the entire mass again so that the aggregates are uniformly distributed.
- Make a well in the dry concrete mix, gently pour in the required amount of water, and turn the mix thoroughly. Ensure that water does not seep away from the mix. If there is too little water, the concrete may be too hard to be poured properly and voids may form. Equally, excess water weakens concrete, leads to shrinkage cracks, and decreases the density. A water:cement ratio of 0.5 (25 litres of water per 50 kg of cement) should be used for manually mixed concrete.
- The concrete mix should be poured on to the structure within a few hours of its preparation. Concrete stored overnight loses significant strength and should never be used.

Figure 4.2 illustrates the right and wrong methods of pouring concrete on masonry or other structures. Concrete should not be prepared in separate lumps or poured from high above the structure under construction.

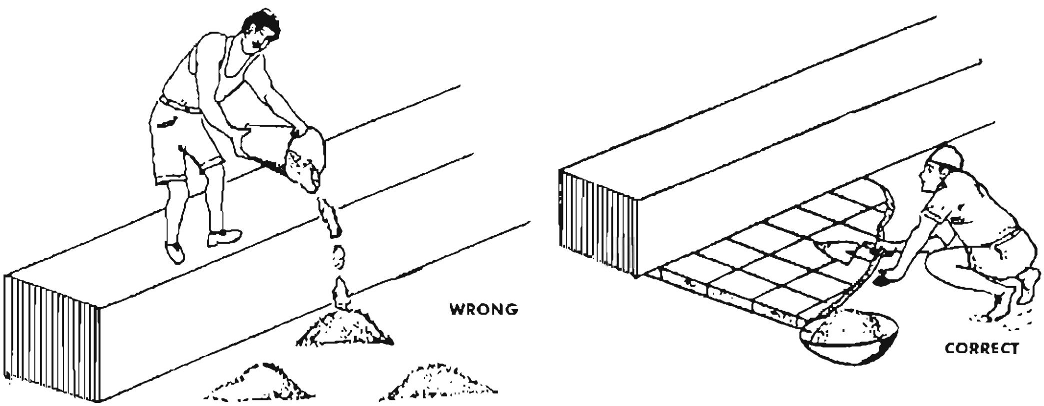

Figure 4.2: Pouring Concrete

4.3.3 Construction of the Powerhouse

As discussed in the layout design manual, the powerhouse structure should be similar to that used for local houses since this will be much easier to construct. In the HKH region, this usually means constructing the walls from 450mm thick stone masonry in mud mortar. The construction of the powerhouse structure is as follows.

- Demarcate the plan of the powerhouse at the proposed site as specified in the design. Then mark the excavation lines for the construction of the foundation and the walls. This is done by placing pegs along the inside and outside wall edges of the powerhouse. These pegs should then be joined with powdered lime, ash, or thin rope. Note that, to optimise the space in the powerhouse, the length or width should be at right angles to the final length of the penstock pipe.
- Excavate the foundation for the walls along the lines prepared above to the desired level (usually 1m) and compact the ground using a manual ram.
- Construct the front and side walls of the powerhouse. Generally the back wall involving the penstock should be constructed after the penstock installation is complete so that there is no interference between these activities. It is also easier to bring in electromechanical equipment, such as the turbine and the generator, if one wall is left open. During the construction phase the walls should often be checked with a plumb line to ensure that they are vertical. Doors and windows should be placed at appropriate locations.

- Construct the back wall after the turbine and the generator have been fixed on the machine foundation and the installation of the penstock is complete.
- Once the powerhouse walls have reached the desired height (about 2.5m), place the wooden trusses and roof according to the design, e.g., using corrugated, galvanised iron (CGI) sheets.
- Use only seasoned wood for doors, windows, and trusses.

4.4 Civil Works for the Penstock

4.4.1 Penstock Pipe Installation

The civil work for the penstock involves installing the pipe and constructing the support piers and anchor blocks as specified in the design layout. Both the latter must be located on original firm soil and not on backfill. The procedure is as follows.

- Clear all vegetation along the penstock route and mark the centre line by fixing a tight string. Mark excavation lines for the support piers and anchor blocks.
- Fix the turbine together with the manifold and gate/valve (if provided) to the machine foundation.
- Start the installation of the penstock from the machine foundation and proceed upstream This is usually the more convenient method and avoids any misalignment between the penstock and the turbine housing. Since the turbine needs to be firmly fixed to the machine foundation, there is almost no tolerance at this end after the machine foundation has been constructed. In contrast, any minor deviation in the pipe position can be adjusted easily at the forebay wall. A further reason for starting at the lower end and working up is that the pipe sections below the expansion joints can slide down if the installation proceeds downstream from the forebay. The installation is started by connecting the first link of the penstock (usually a bend) to the turbine manifold.
- Install the expansion joints at the required locations as specified in the design layout (i.e., downstream of the forebay and anchor block locations). Tightly pack jute (or similar fibre) inside the expansion joints during the installation process to prevent leakage during the operational phase.
- Construct the support piers at the required locations as the pipe installation work progresses upstream, but leave construction of the last 150 to 300mm of the height of each pier until after the entire penstock pipe has been installed. This allows for some adjustment of the pipe at the end. During the installation process, temporary dry stone walls can be used to balance the penstock on top of the unfinished support piers.

The construction of the support piers involves first excavating the ground to the required shape as per the drawings. Once the required foundation depth is reached (usually 300mm at the downstream face and the value dictated by the slope at the upstream face) the earth should be compacted using a manual ram. The piers should be constructed of stone masonry in 1:6 cement mortar, as discussed below.

4.4.2 Cement Masonry Work

The following steps are recommended for stone masonry in cement mortar.

- Stones should be washed and kept immersed in water for a day prior to construction. Dry stones do not adhere well to cement mortar and thus reduce the strength of the masonry.
- The ratio of the mortar for the construction of support piers should be not less than 1:6 cement to sand.
- Use good quality sand and cement as described in sections 4.3.1 and 4.3.2 and follow other relevant instructions in these sections regarding pouring time, protection from sunlight, and curing.

4.4.3 Anchor Blocks

As mentioned above, anchor blocks should only be completed once the penstock pipe installation work is complete. The following procedure should be used to construct the anchor blocks.

- As with the support piers, first excavate the ground according to the design. Once the required foundation depth is reached, compact the earth using a manual ram. Note that the excavation and compaction work should be done as the pipe installation proceeds.
- Prepare the concrete (usually 1:3:6 with 40% plum) by mixing cement and sand aggregates to the required ratio. Place the specified number of reinforcement bars of the given size (usually 3 bars of 10mm in diameter) as shown in Figure 4.3. The concrete prepared should be poured at the anchor block location and the plums should be placed evenly through the block. Either wooden planks or dry stone walls can be used for the formwork depending on the availability of wood at the site. Once the concrete work has been completed, the blocks should be cured for about a week. It is recommended that a final check be carried out on the penstock pipes and the expansion joints to ensure that there are no errors before pouring the concrete.

4.5 Construction of the Forebay

Generally the forebay should be constructed after the installation of the penstock is complete. The construction of the forebay involves the following.

- Mark the excavation lines for the forebay at the proposed location according to the design, as described above.

- Excavate the ground to the required depth and shape. Note that it is important to check the floor elevation after excavation but before construction. If errors are found in the elevation after construction work has commenced (the forebay is higher than the headrace canal upstream, for example), remedial work can be expensive.
- Compact the earth surface using a manual ram after completion of the excavation work.

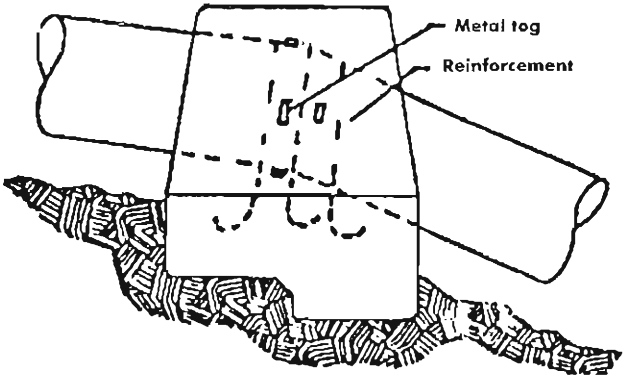

Figure 4.3: A Typical Anchor Block

- Construct the structure according to the design. The forebay and other water retaining structures are usually built using stone masonry in 1:4 cement mortar (see Section 4.4.2). Once the cement mortar has been prepared it should be used within two to three hours.
- If possible the inside faces (water retaining surfaces) should have dressed stones as this minimises the thickness of plaster required.
- As the masonry work proceeds, install the gates, flush pipes, and spillways at the given locations according to the design.
- After completion of the gates and masonry work, plaster the water retaining surface (i.e., the inside surface) of the forebay. An approximately 12mm thick 1:2 cement mortar layer is recommended for the plaster.
- Once the construction of the forebay is complete, it should be cured as described earlier. If there is a delay between completion of the masonry work and plastering, then the structure should be cured for another four days after completion of the plaster.

4.6 The Headrace Canal

Once the canal type (or types of different lengths) has been selected and the sizes worked out, the actual construction procedure involves the following stages.

- Setting out of the course of the canal and marking the centre line with pegs
- Preparing the bench for the canal
- Fixing the excavation lines
- Excavating the canal
- Constructing/lining the canal

4.6.1 Setting Out the Canal

Before setting out the canal, first ensure that all necessary equipment and manpower is available. The equipment used for the detailed survey work, for example an Abney level or a theodolite and a tape, is usually sufficient for the construction and for setting the specified slope of the canal bed. A transparent water-filled tube can also be useful for checking the level of the canal bed at various locations as the construction progresses.

The canal is set out as follows.

- First place pegs along the headrace canal route. Depending on the topography, such pegs should generally be driven into the ground at 5-20m intervals along the route. Pegs should be placed more closely at bends as well as at other important locations such as drops and the beginning and end of crossings.
- Place some intermediate pegs or reference pegs just outside the canal path. The differences in elevation between the reference pegs and the canal route pegs can be calculated using a levelling instrument. These pegs will serve as reference levels for the excavation work. An alternative possibility is to paint marks on exposed rocks just outside the canal path and calculate their relative elevations.

4.6.2 Preparation of the Bench

The bench of the canal is a strip of land of uniform width and slope along the hillside side of the canal. It is like a road of generally constant width and slope at the level of the top of the canal. The bench should be prepared as follows.

- Excavate a strip of land of even width along the path of the pegs placed along the canal route. If there is a possibility of material being washed down by rain from the slope above, or of small landslips being deposited directly in the canal, increase the width of the bench such that it is larger than the finished canal top width. This extra width is called the berm and stops debris or water coming down the hillside from entering the canal. Any such excess water should be channelled away from the canal through a proper drainage system. If it is not possible or practical to drain all the excess flow away, the flow can be allowed to enter the canal at a predetermined and properly constructed location such as near a spillway. The berm can also be used as a walkway for people or for workers during construction. Generally, a berm width of 300 to 500mm is sufficient along the uphill side for people to walk and for construction work. The slope of the bench should be the same as the slope of the canal section. Where there is a change in the canal slope (in the design), the bench slope should change accordingly. The bed slope of the bench should be verified using a levelling instrument. The elevation of the canal at different locations can be calculated using the intermediate pegs placed outside the canal path.

Once the initial elevation at the intake has been fixed, the subsequent elevations for the canal route can be calculated from the distances and bed slopes. The initial elevation can be estimated using contour maps of the area or measured with an altimeter. Another method is to carry the trigonometric points established by the survey department, but this may require more time and resources.

The absolute elevation figures (i.e., the exact elevation above sea level) need not be very accurate but the differences in elevation between the canal bed and the intermediate pegs should be accurate, since it is these differences that determine the slope of the canal.

The following is an example of an elevation calculation.

The designer has recommended a slope of two per cent for a certain canal section. The topographical map of the area indicates that the elevation at the intake is around 1,400 metres above sea level (MASL).

In this case the first peg placed at the intake area can be assumed to be at a level of 1,400masl. If the second peg is to be placed 20 m (horizontal distance) downstream, the bench elevation here should be

20 m x 2.0/100 = 0.40 m lower than the intake, that is at
1400m - 0.40m = 1,399.6masl.

The subsequent differences between the heights of intermediate pegs (i.e. reference points) can be noted in sequence using similar calculations.

4.6.3 Fixing the Excavation Lines

Once the canal bench has been prepared, the excavation lines need to be set out as described below.

- Place pegs to mark the centre line and the top and bottom edges of the canal (for trapezoidal sections). Note that, in the case of a lined canal, the position of the excavation line for the top and bottom edges should be calculated as the distance of the final edge of the canal from the centre plus the width of the side walls.
- Join the pegs using thin ropes. Then mark the lines along the ground for the centre line and top and bottom edges (five lines for trapezoidal sections) using powdered lime or ash. When a canal has a rectangular section the top and bottom edges lie above each other, and three parallel lines are sufficient for the excavation work.
- Check the dimensions against the design specifications continuously during this process.

4.6.4 Excavation of the Canal

This consists of excavating the canal with the required shape and slope according to the design. The main steps are summarised in the following section.

- For a rectangular canal, start the excavation from the sides down to the required depth.
- For trapezoidal sections, start the excavation along the lines for the bottom edge and dig down vertically to the required depth. Then excavate the sides with an even slope to meet the line for the top edge at the limit of the excavation. In this way, you will arrive at the required trapezoidal shape. This method of excavation minimises the use of construction materials and the need to backfill. This is important since the side walls of a trapezoidal cement masonry canal are more likely to crack if constructed on backfill. It is helpful to prepare a wooden frame, using rectangular sticks matching the trapezoidal cross-sectional shape of the canal, and to use this to check the shape as the excavation progresses.
- Check the canal bed slope frequently using a levelling instrument. Note that an inaccurate slope can be very costly. If the slope is less than required, the canal will not have the capacity to convey the design flow. Similarly, if the slope is steeper than required, the velocity may exceed the maximum value for the canal type and start eroding it.

4.6.5 Construction of the Canal Lining

Once the excavation work is complete, the construction of the canal lining can start, if part of the design. All that is required for an earthen canal is to trim the side walls and bottom anywhere where the excavation work has been poor. If a masonry-lined canal has been chosen, it will be necessary to collect stones, dress and size them, and place them along the excavated surface according to the design.

The following points should be noted when constructing stone masonry in cement mortar canal lining.

- The minimum thickness for bed and side walls should be 150mm. Thinner walls require more stone work for the lining (dressing and sizing) and may not have the required strength. This also applies to stone masonry in mud mortar linings.
- Since the canal is a water retaining structure, the ratio used for the mortar should be not less than 1:4 cement to sand.
- Use 1:2 cement to sand mortar for any plaster work. The plaster should be about 12mm thick (~1/2 inch). Plastering is expensive and should only be applied where really necessary, to prevent leakage for example.
- The instructions given in Sections 4.3.1 and 4.3.2 for this type of construction should also be followed.

4.7 The Construction of the Settling Basins and Spillways

The construction of the settling basin is similar to that of the forebay. Since the function of the settling basin is to remove the sediment from the flow, more than one of these structures may be required if the headrace canal is long (more than about 300m) and unlined. The flow in a long, unlined canal can erode the bed and side walls and increase the sediment load, which then needs to be removed.

Generally at least two spillways are required for an MHP scheme. The first one should be located immediately after the intake to divert excess flow during floods. If there are any chances of the headrace canal being blocked by landslides from above, intermediate spillways should be provided along the canal route. One spillway should always be incorporated at the forebay to divert the design flow in case of valve closure at the powerhouse (e.g., during emergencies). A spillway may also be required at the settling basin if there is a possibility of excess flow reaching this structure during floods.

Spillways can be constructed as part of other structures, such as the settling basin or the forebay, or as independent structures just for spilling the (excess) flow. They are simply openings (with or without a gate) along the top wall sections of the structure or canal that divert any excess flow.

The basic steps in the construction of a settling basin are as follow.

- Demarcate the excavation lines for the settling basin at the location shown in the design and then excavate the ground.
- Compact the earth surface using a manual ram.
- Then construct the structure as per the design. The settling basin is usually lined with stone masonry in 1:4 cement to sand mortar. Construction of cement masonry structures is described above.
- If possible the inside faces (water retaining surfaces) should have dressed stones. This minimises the thickness of plaster needed.
- Install the gates, flush pipes, and spillways at the required locations as the masonry work proceeds.
- After completing the gates and masonry work, plaster the water-retaining surface with a 12mm thick layer of 1:2 cement to sand mortar.
- Once the construction of the settling basin is complete, the channel that diverts the flow from the spillway should also be constructed if required.
- Follow the instructions provided in Sections 4.3.1 and 4.3.2 for this type of construction.

4.8 Intake Structures

At the intake, the flood protection walls and mouth should be constructed first as shown in the detailed drawings. Such work may require diverting the flow towards the opposite river bank The weir should not be constructed until all other work at the intake is complete. Depending on the design flow and the nature of the weir (temporary or permanent) this too may require diverting the river flow temporarily towards the opposite bank. The construction work is easiest when the water level in the river is low and the water is not too cold.

4.9 Retaining Structures and Stabilisation

Small potentially landslide prone slopes can be stabilised with dry stone walls, masonry walls, or gabions. Gabions are usually the most suitable and economical way of stabilising slopes in MHP projects. The construction of gabions requires a skilled person who is able to weave the boxes using galvanised iron (GI) wires. Gabion boxes can be made in different sizes, depending upon the requirement.

The following wire sizes are recommended for gabions for MHP projects.

Mesh size:	80mm x 100mm
Mesh wire:	9 SWG (3.66mm)
Selvedge wire:	6 SWG (4.88mm)
Binding wire:	11 SWG (2.95mm)

The assembled gabion box should be tightly packed with stones. It is better to use dressed stones on the outside surfaces of the gabions. Once the boxes are filled, the cover should be closed and tied using the selvedge wire. Note that gabions should be placed in such a way that the lengths are parallel to the flow.

Table 4.1 can be used together with Figure 4.4 as a guideline for selecting the width of the gabion wall for the height of soil that it needs to retain.

Table 4.1: Gabion Sections for Retaining Walls

Wall height required, H (m)	Width, W (m)
1	1
2	1.5
3	1.5
4	2
5	2
6	2.5

Terracing and plantation are also suitable methods for stabilising small areas prone to landslides on hillsides at MHP sites. The method of terracing is shown in Figure 4.5. Terraces are constructed on landslide prone areas with an overall slope of less than 30°. Dry stone walls should be used for the vertical face of the terraces. These walls retain the soil while allowing surface water to drain out.

Terraces also help to reduce the surface erosion since the surface water can be diverted by constructing small drains. Note that dry slopes are more stable than saturated ones, and that landslides generally occur on wet slopes.

Planting grass or shrubs that have deep root systems (such as bamboo or Napier grass) on terraces also contributes towards the stability of slopes. However, fast growing trees that do not have deep root systems should be avoided since they may fall during storms as a result of their own weight.

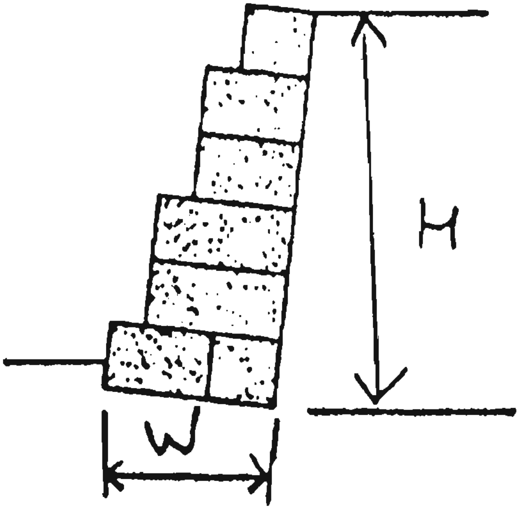

Figure 4.4: A Gabion Retaining Wall

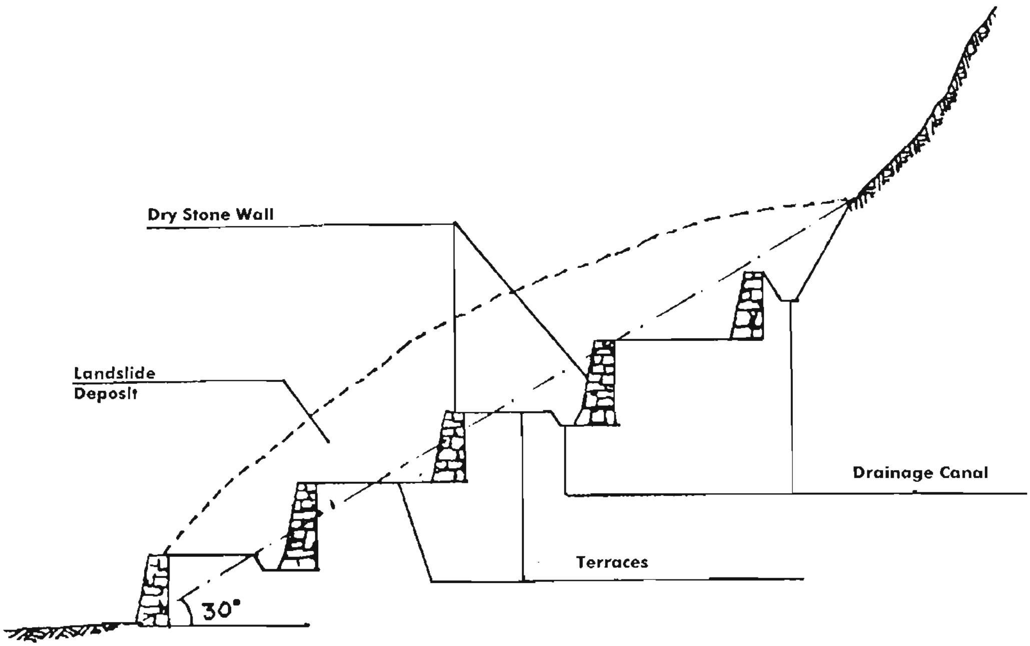

Figure 4.5: Use of Terraces to Stabilise Slopes

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.

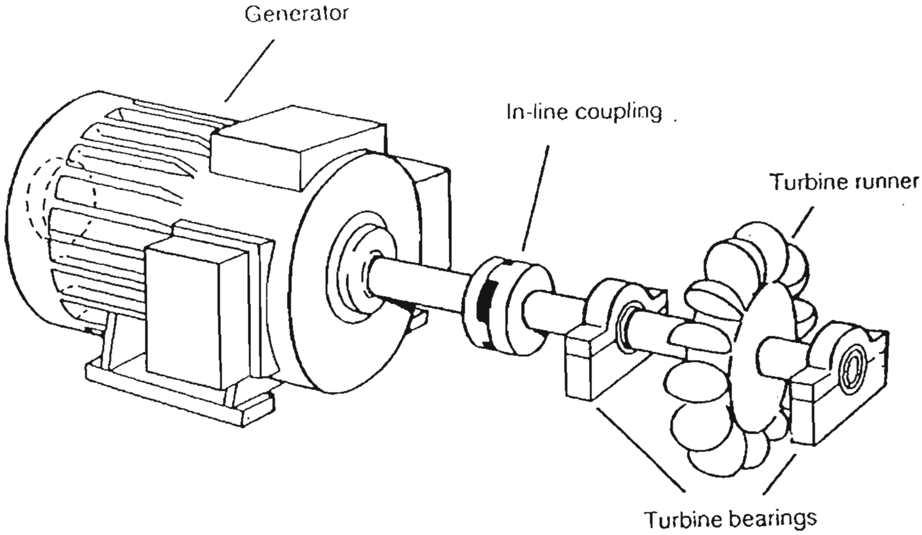

Figure 5.1: Direct Drive Turbine and Generator System

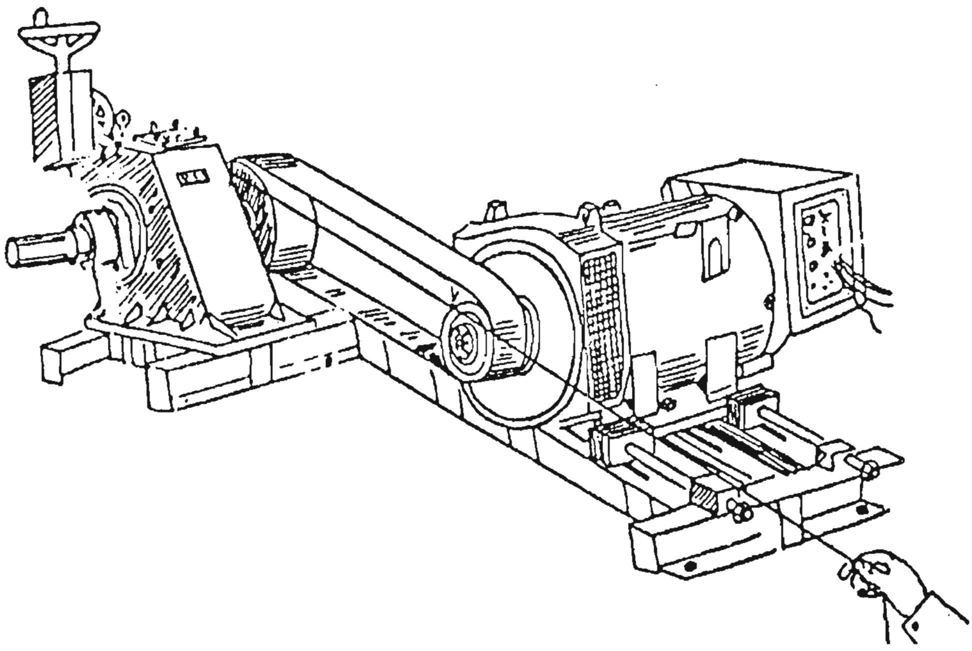

Figure 5.2: Turbine and Generator Coupled through a Belt Drive

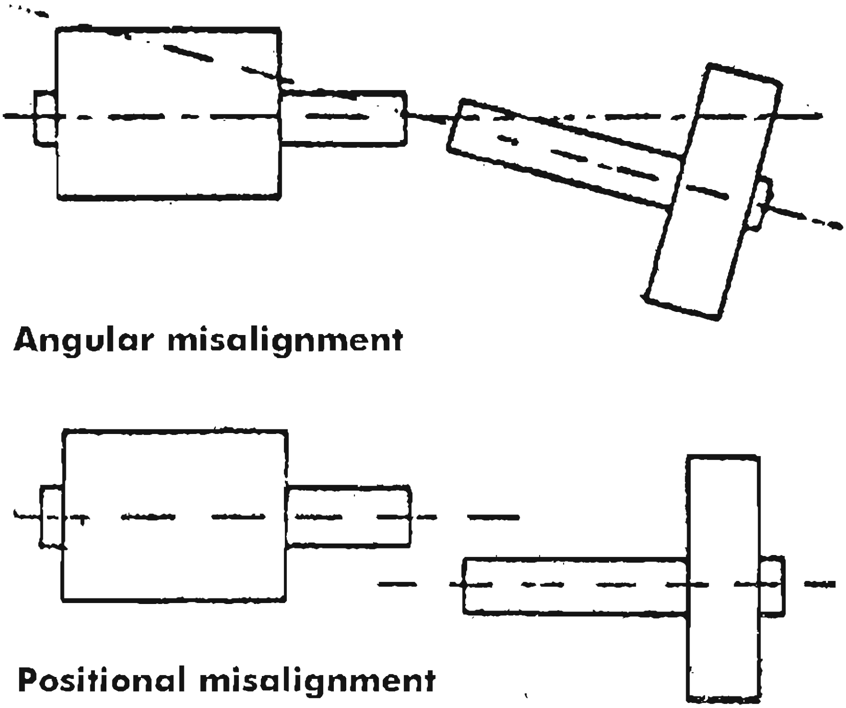

Figure 5.3: Angular and Positional Misalignment

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.

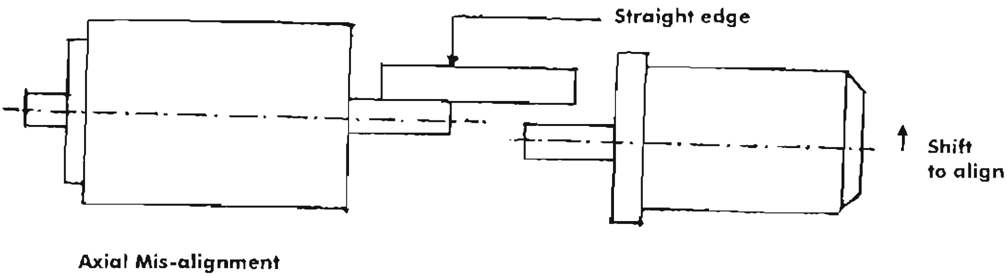

Figure 5.4: Using a Straight Edge to Check Alignment

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.

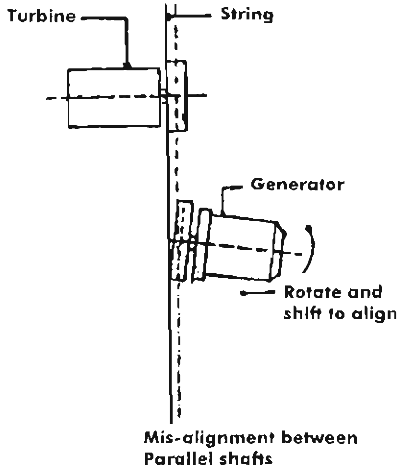

Figure 5.5: Aligning a Belt Driven System

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

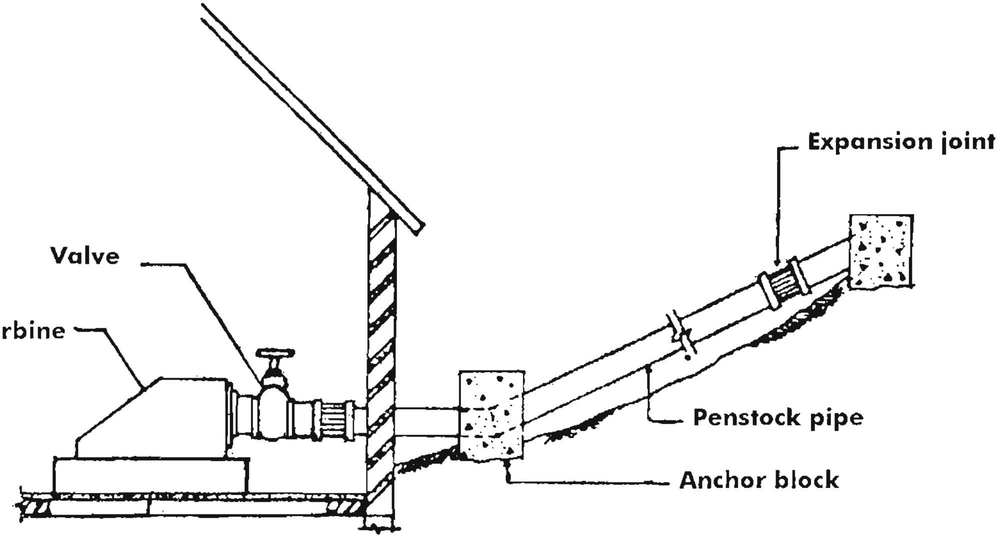

Figure 5.6: Cross-section through a Powerhouse and Anchor Block

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.

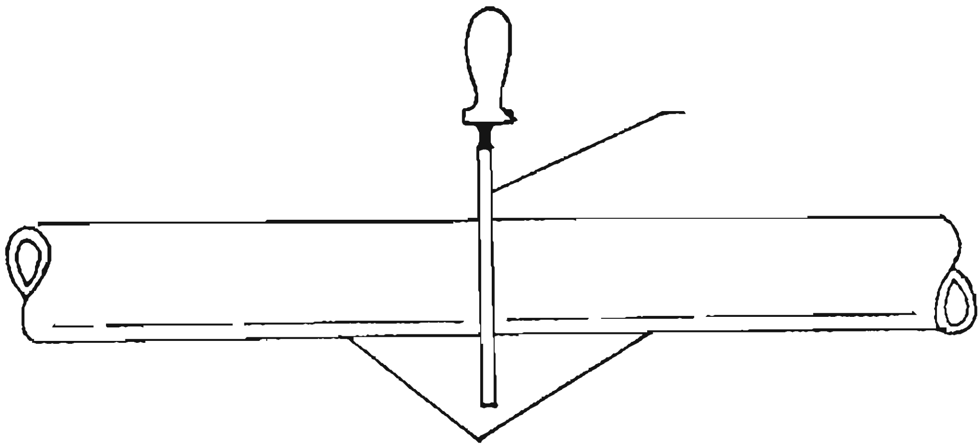

Figure 5.7: HDPE Pipe Ready for Making the Joint

- 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

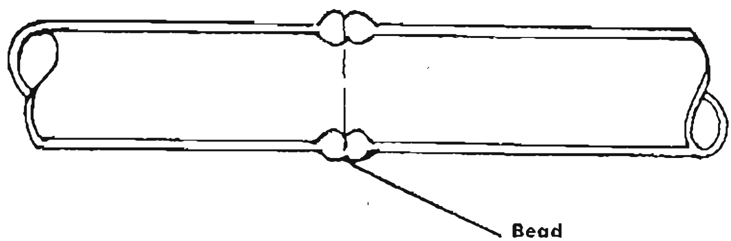

Figure 5.8: HDPE Pipe with Bead after Joining

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.

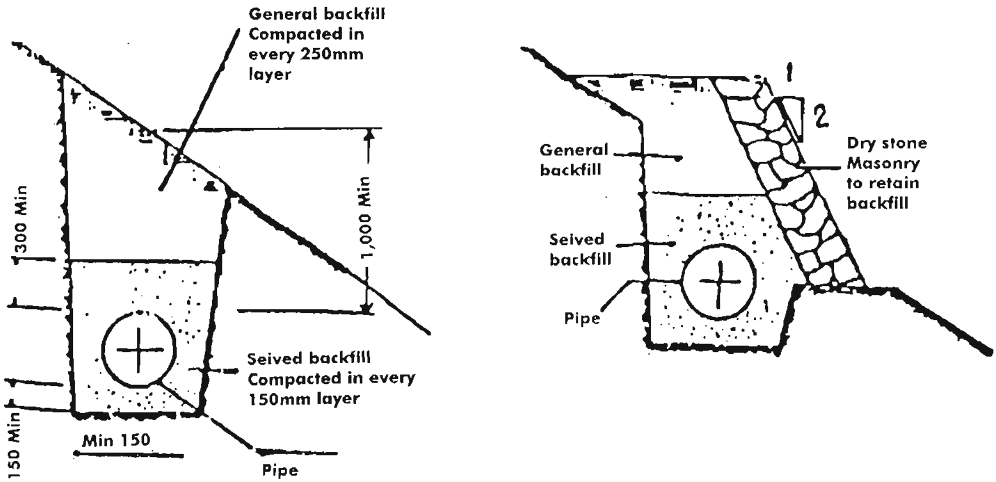

Figure 5.9: Section Through Pipe Buried in Different Ways

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).

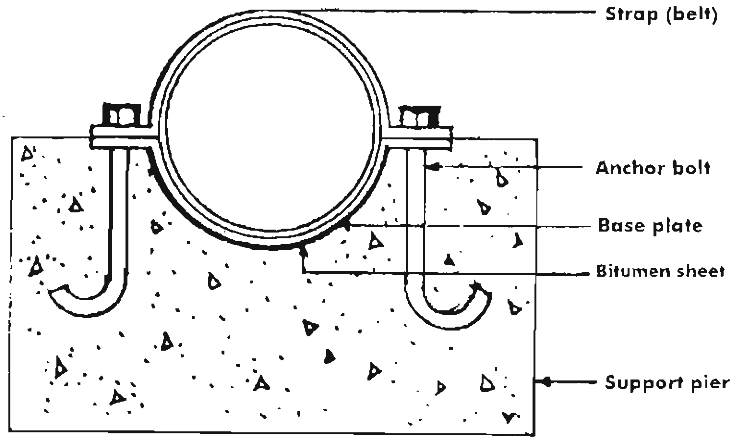

Figure 5.10: Cross Section through a Support Pier

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.

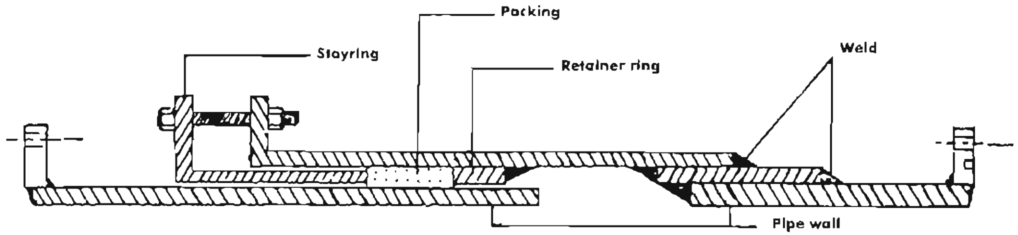

Figure 5.11: Welded Type Expansion Joint

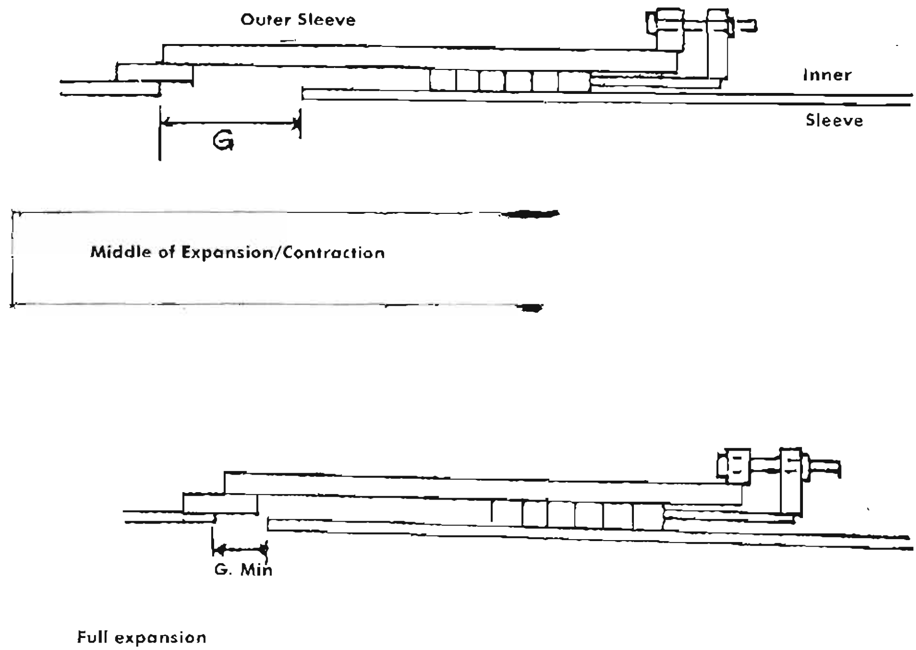

Figure 5.12: Expansion Joint Positions during Installation

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.

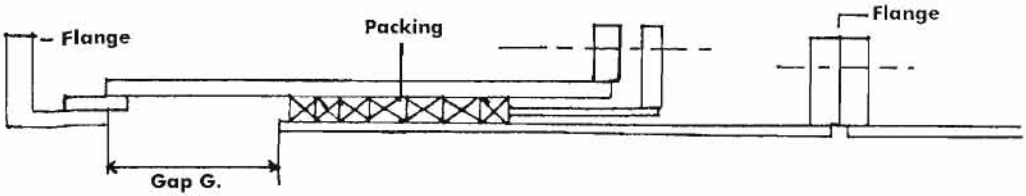

Figure 5.13: Setting the Gap in a Bolted Type Expansion Joint

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

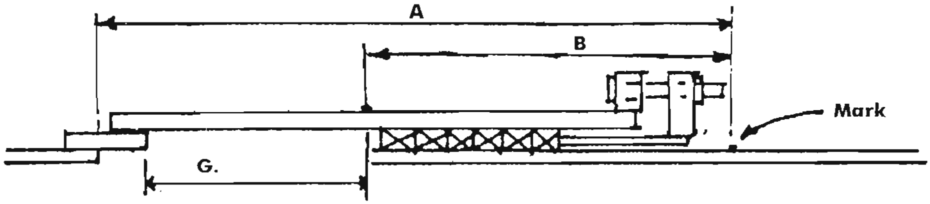

Figure 5.14: Setting the Gap in a Welded Type Expansion Joint

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.

Chapter 6
Installation of Transmission Lines

6.1 Steps before Installing Transmission Lines

It is usually necessary to resurvey the transmission route and plan for difficult features and obstructions such as landslide zones, gulley crossings, trees, ground clearance, and cultivated land.

- Choose a short straight route.
- Calculate the number of poles required for the given length and use pegs to mark the location of the pole pits.
- If wooden poles are proposed in the design then select straight hardwood poles.
- The poles should be buried about one metre deep in the ground. Bitumen paint should be applied to the portion to be buried to prevent rotting.
- The specifications for the poles for different types of transmission are shown in Table 6.1.

Table 6.1: Specifications for Wooden Poles

Type of Transmission/ Pole Specifications	Single Phase 220V	Three Phase	11 kV
Height of poles	6m	7m	8m
Diameter of poles	125 mm	150 mm	175 mm
Ground clearance	4.5m	5m	6.3m
Spacing of poles			
- For transmission	30 – 35m	30 – 35m	50m
- For distribution	25m	25m	

6.2 Installation Procedure

- Clear the path of the transmission route.
- Dig holes in the ground for the poles and fix accessories (e.g., D-iron clamps and insulators) on the poles. The spacing between the insulators is shown in Figure 6.1.
- Insert the pole base in the pit (Figure 6.2) ensuring that after erection the pole will be in line with the other poles and vertical; check verticality with a plumb bob
- Fill the pit with earth and stones and compact well.

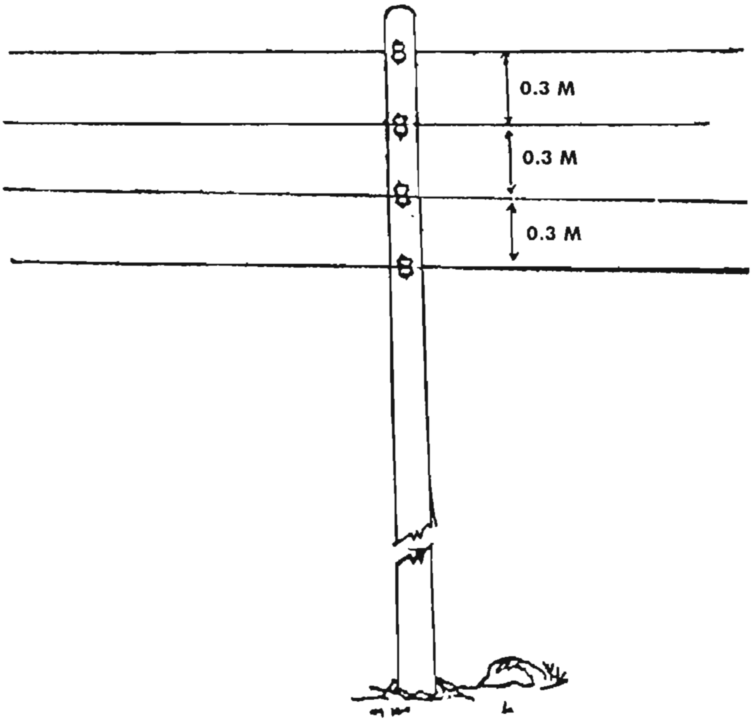

Figure 6.1: Spacing of Conductors at the Pole

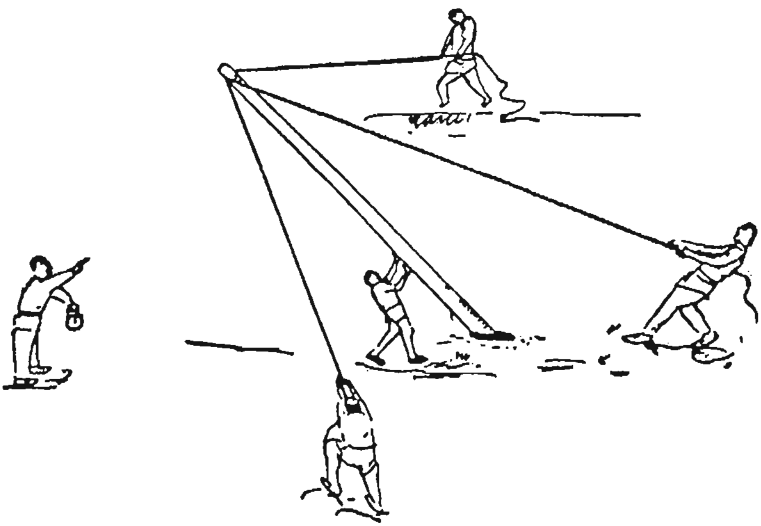

Figure 6.2: Erection of Poles

- Install stay wires on the poles at every bend, on the first and last pole, and on poles with a jumper (Figure 6.3).

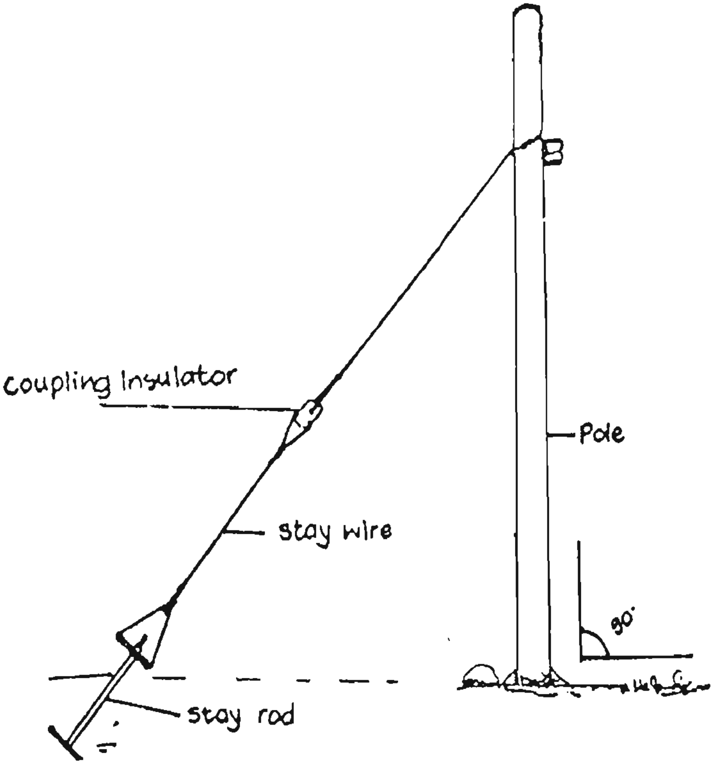

Figure 6.3: Erection of Stay Wires

After all poles have been erected, commence installing the wires. Start to unroll the wire and lift the end up to the pole carefully; the wire should not be overlapped during pulling (Figure 6.4). Generally, pulling of the wire can be started from the powerhouse; but if this is in a valley and the route is uphill (vertical slope), then pulling may be started from uphill and the wire run down towards the powerhouse.

- Lines are generally pulled using portable manual wire puller machines with a capacity of two tonnes.
- When pulling wires, make them tight enough so that they do not sag heavily or swing and touch another wire. The spacing between the wires should be uniform. Normally, the spacing should be about 0.5m per 50m pole spacing.
- The wire sag should be observed visually from some distance (about 50 metres); the extent of sag should be the same between all poles (Figure 6.5). The sag in the cable can be measured using a level but this will not be possible in all cases.

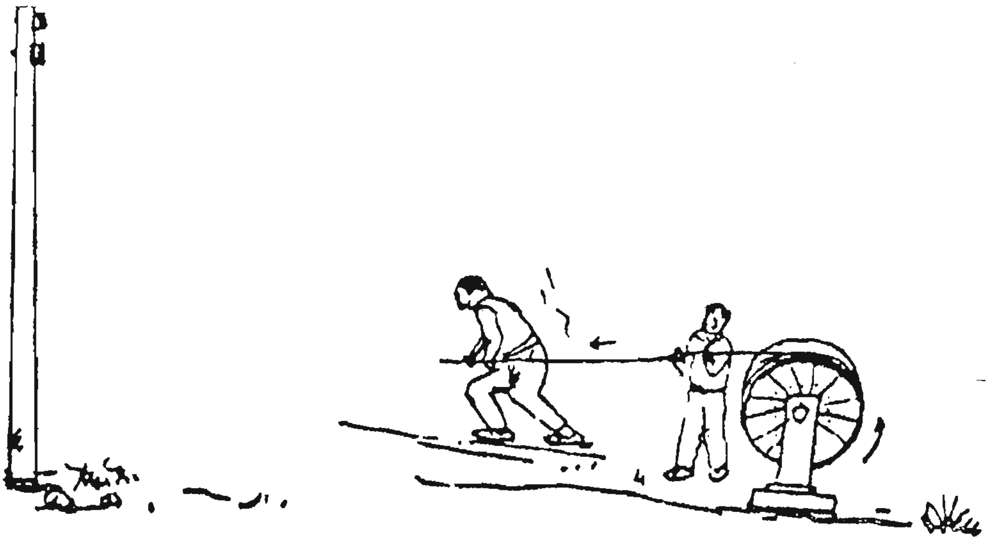

Figure 6.4: Unrolling Wire

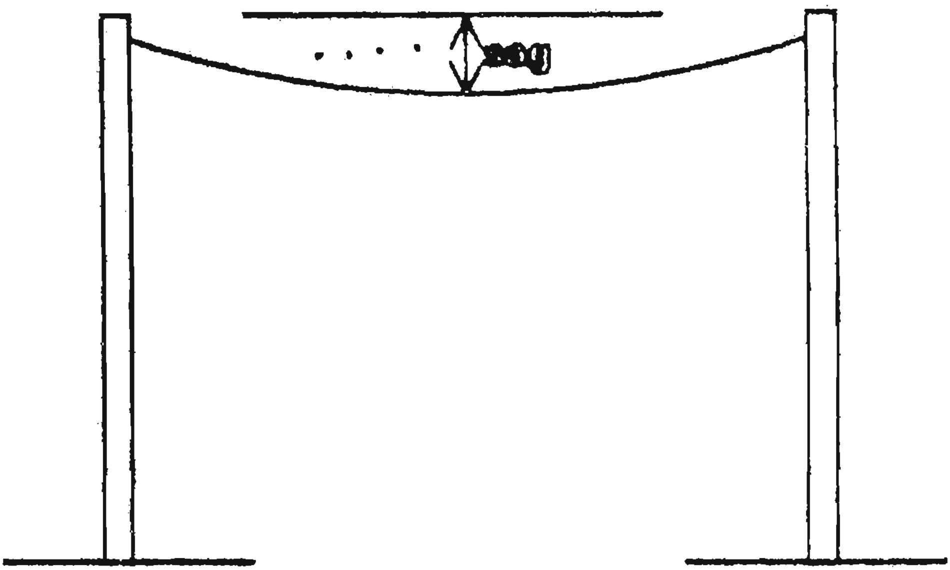

Figure 6.5: Spacing of Sag

- Excessive tension on the conductor should be avoided as it could cause it to break.
- During installation of transmission lines, the ends of two wires can be connected using the following procedure (see also Figure 6.6).

  - Open all strands of both ends of the conductors.
  - Bring the two ends together, overlapping by at least 300mm, and twist each strand together with one from the opposing conductor.
  - Wrap the twisted strand lengths around the joint and pass the last strand underneath another strand to give the joint a smooth, tight, and unbreakable finish.

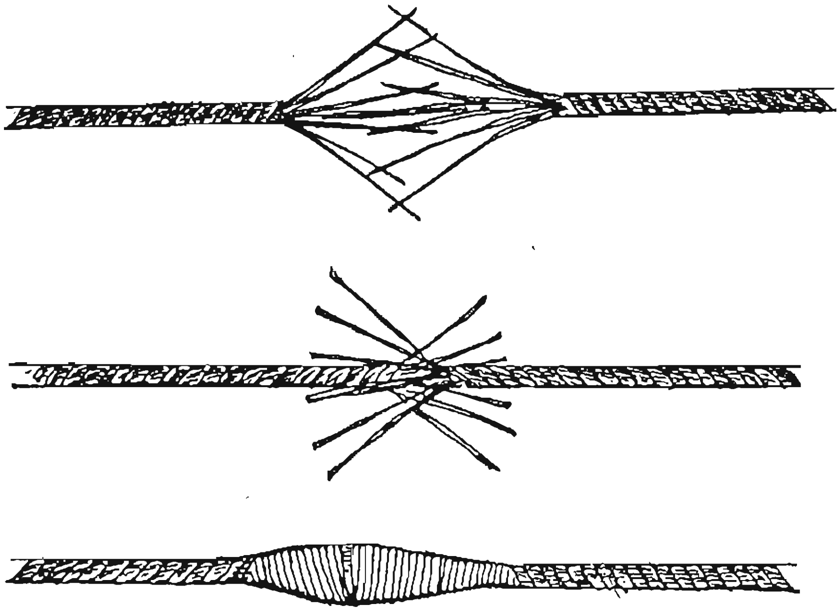

Figure 6.6: Method of Joining Wire Ends

- Safety belts should be used during the installation of transmission lines, and the installers should be informed about the safety aspects.
- After the transmission lines have been erected, all the routes should be checked for such things as ground clearance, road clearance, compaction of pole pits, and position of stay wires.
- Anti-climbing devices and 'Danger' boards should be installed on each pole.

6.3 Installation of Distribution and Service Lines

Distribution lines bring power from the transmission line to the service wires supplying the consumers. The installation procedure for distribution lines is similar to that for transmission lines. If the lines pass through a village, it is necessary to make sure that there is appropriate ground clearance and that the lines are a sufficient distance from the houses. Stay wires should be installed wherever necessary.

The service line brings electrical power from the distribution line to the premises of individual consumers. This wire can be pulled by hand from the pole to each house. Normally flat, twin-sheathed solid aluminium conductors are used, so excessive tension in the wire should be avoided. The wire should be fixed to the pole and connected to the distribution line by wrapping it around it three or four times. It may also be tied to the pole to avoid excessive stress at the joint.

6.4 Earthing

Earthing is the process of providing a path to earth for excessive electricity and voltage caused by short circuits or lightning, and thus preventing damage to equipment and people. There are two basic systems for earthing.

- System earthing means connecting the neutral points of generators and transformers to the mass of the earth.
- Equipment earthing means connecting the outer casing or supporting structure of live electrical equipment to the general mass of the earth.

Earth connections should be provided at the following points.

- The neutral of all the power systems such as the generators and transformers
- The earth terminals of each lightning arrester
- The frames of such components as the generator, motor, ELC, ballast, transformer, and control/instrument panel
- All metal casings or coverings containing or protecting any electric supply or apparatus
- The armouring of underground cables
- The metallic poles and towers of overhead lines

System and equipment earthing should be separated by a minimum distance of ten metres.

A good earth should have very low resistance and should thus be made in an area where the ground is normally moist, for example, near a canal. Salt and coal can be used to further reduce earth resistance.

6.4.1 Earth Electrodes

The earth electrode is a plate or pipe of copper or GI driven into the ground and connected to an electrical system or piece of electrical equipment. The number and type of earth electrodes required per installation depend upon factors such as the type of soil, the type and capacity of the installation or equipment, and the value of the required earth resistance. Plate electrodes should be used only when the current carrying capacity is the main consideration, as, for example, for the powerhouse earth. The approximate sizes of earth electrodes recommended for MHP installations are given in Table 6.2. The different ways of preparing and connecting earth electrodes are described below.

The earth should be connected with eight SWG wire (4.06mm diameter); copper wire for copper electrodes and GI wire for GI electrodes

Table 6.2: Recommended Sizes of Earth Electrodes

Conductor Type (to be buried vertically)	Size (mm)
Copper plate	600 long x 600 wide x 3.15 thick
GI plate	900 long x 900 wide x 3.15 thick
GI pipe	38 diameter x 2,500 long

6.4.2 Pipe Electrodes

The general arrangement for pipe earth electrodes is shown in Figure 6.7. Pipe electrodes should have an internal diameter of at least 38mm if made of galvanised iron and 10mm if made of cast iron and a length of at least 2.50m. They should be driven fully into the ground. Where rock is encountered at a depth of less than 2.50m, the electrodes may be buried inclined to the vertical but the inclination should be not more than 30 degrees off vertical.

Pipes or rods should normally be a single piece. If it is necessary to reduce the depth of burial of an electrode, this must be done without increasing the resistance. This is achieved by using a number of rods or pipes and connecting them together in parallel. The distance between two electrodes in such cases should preferably be not less than twice the length of the electrode.

The copper earth wire should be joined to a hole drilled in the top of the pipe and held tight with a brass nut and bolt. Before attaching, the earth wire should be scraped to ensure good contact between the wire and the pipe.

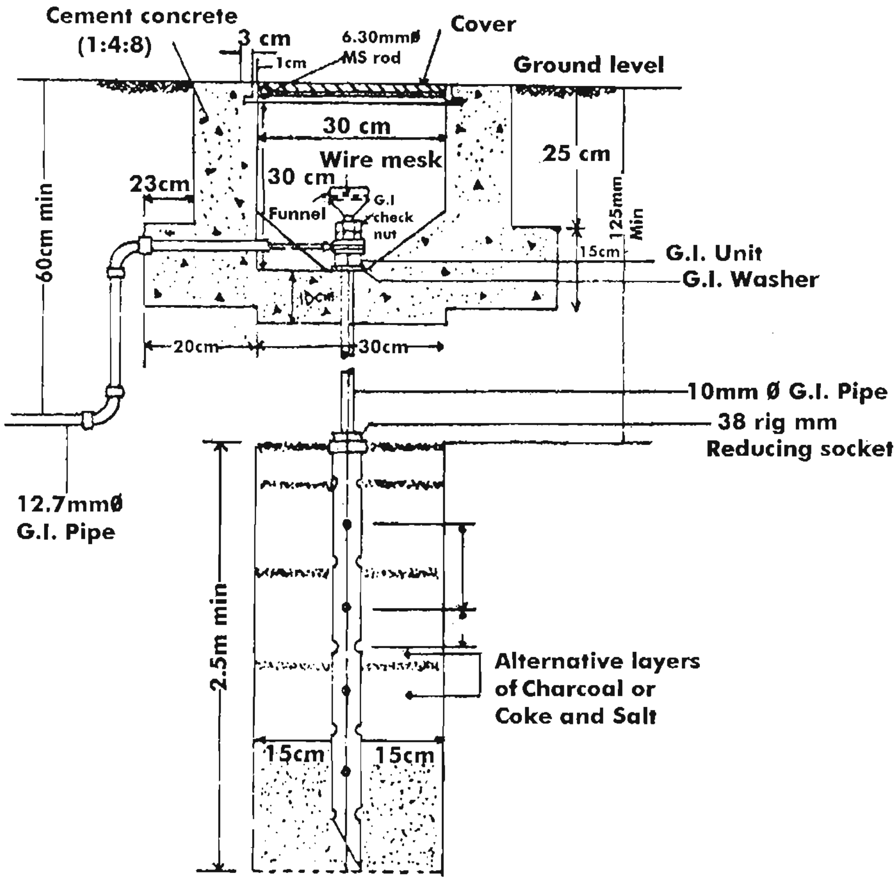

Figure 6.7: Typical Pipe Earth Electrode

6.4.3 Plate Electrodes

A typical arrangement for a plate earth electrode is shown in Figure 6.8. Plate electrodes can be made of copper or galvanised iron. The minimum recommended sizes are shown in Table 6.2. Plate electrodes should preferably be buried vertically so that the top edge is not less than 1.50m below the surface of the ground. The copper earth wire should be joined to a hole drilled in the top of the plate and held tight with a brass nut and bolt. Before attaching, the earth wire should be scraped to ensure good contact between the wire and the pipe.

If the resistance of a single plate electrode is higher than the required value, two or more plates should be used in parallel, the two plates being separated by not less than eight metres.

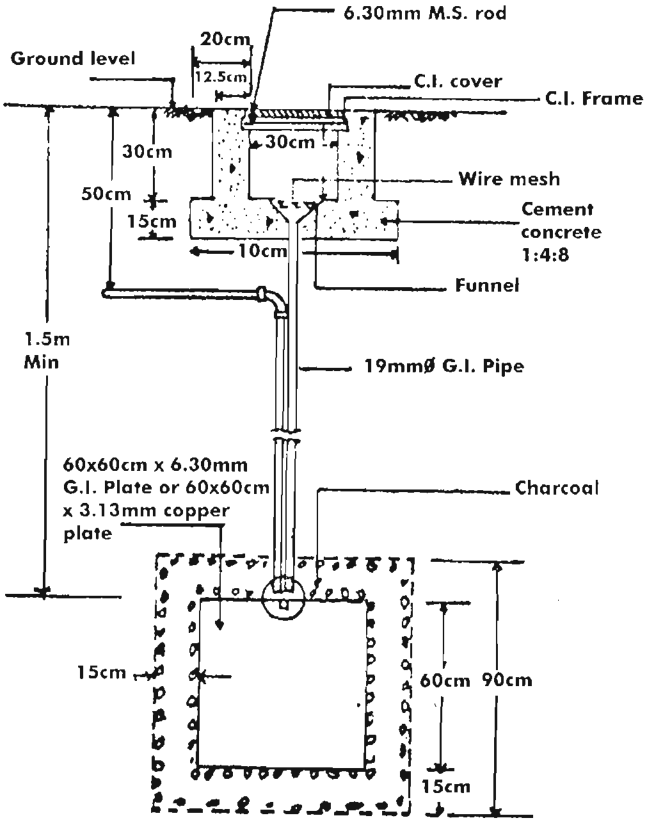

Figure 6.8: A Typical Plate Earth Electrode

6.5 Lightning Arresters

During storms, high voltage from lightning can come into contact with the transmission and distribution lines. If not prevented, this voltage will transmit across the coils of the generator and its body, causing a short circuit and damage. Therefore, it is necessary to provide earthing for this high voltage to discharge before it reaches the generator. This earthing is provided by a lightning arrester connected between phase and earth. In the case of three-phase transmission, a separate arrester is needed for each phase and the earth as shown in Figure 6.9. A 0.5kV lightning arrester will be sufficient for low-tension transmission, but a higher voltage rating is required for high-tension transmission.

The lightning arrester should be installed as close to the generator as possible, usually at the first pole outside the powerhouse. If the transmission line is more than a kilometre long, one lightning arrester should be installed for every kilometre.

6.5.1 Installation Procedure

- Check whether the lightning arrester is as per the specification.
- Mount a frame on the pole and fix the lightning arrester to it (Figure 6.9). If more than one lightning arrester is to be used, the distance between two arresters should be at least 100mm.
- There are two plates on the lightning arrester. Connect a wire from the plate marked 'earth' and bring it to neutral and to the ground and earth it. For the earthing procedure see Section 6.4. Connect a wire from the other plate and join it to the live part of the transmission/distribution system, i.e., the R, Y, and B phases.
- The last arrester on the transmission line should be within 1,000m of the farthest consumer.

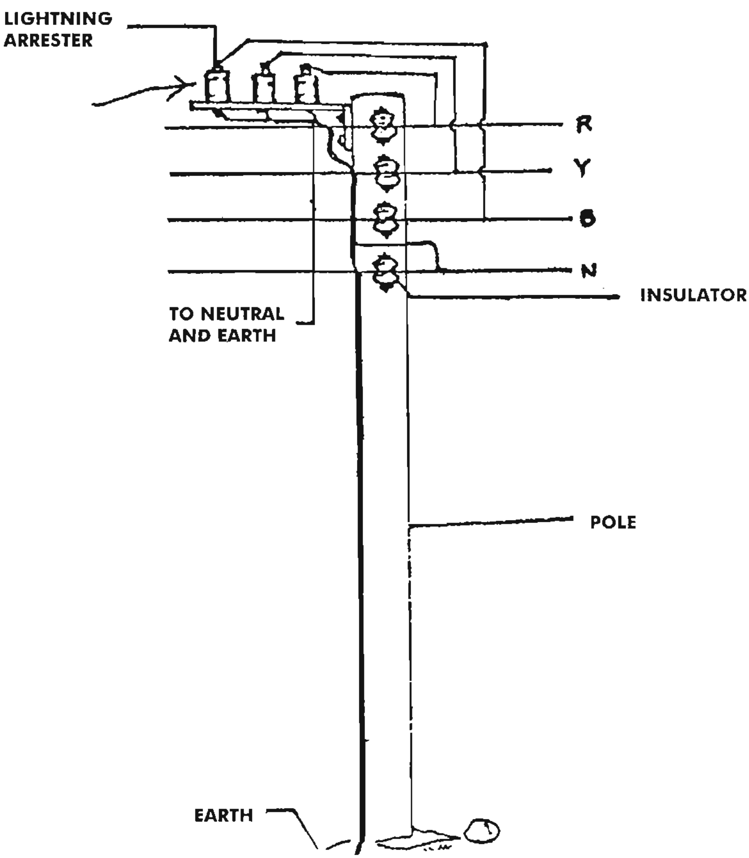

Figure 6.9: Installation of Lightning Arresters

Chapter 7
Commissioning and Testing

Commissioning and testing of an MHP provide a system for checking that all the components of the MHP are functioning properly as per the design and/or as specified by the supplier. The commissioning and testing procedure also provides a record of the operational status of the plant at start-up, which is a useful reference for the future. More practically, some problems may be encountered when the plant is operated for the first time. These problems, whether in the civil works or in the electromechanical equipment, must be removed completely, before the plant is put into normal operation.

7.1 Commissioning Procedure

The commissioning procedure should begin only after all the installation work has been completed and checked. The commissioning report must have a list of all the items to be checked or tested. A note should be made next to each item, specifying the condition, and whether this condition is satisfactory or whether it needs to be rectified. Similarly, the test results should show the data obtained, calculations of the results (e.g., efficiency), and whether or not these meet the specifications.

7.1.1 Cleaning the Penstock

Inevitably, some debris will have dropped into the penstock while it was being assembled. This debris must be removed before running the turbine, otherwise the turbine will be damaged.

The penstock valve should be closed and the penstock partly filled with water in order to flush the debris to the bottom from where it can easily be removed. The debris will collect behind the valve. The water should then be drained by opening the valve or turbine vane just enough to allow the water to drain very slowly. After the water has drained out, the debris can be removed in one of the following ways.

- If a gate valve is installed, by removing the top half which houses the spindle and gate
- By removing the valve (in the case of a butterfly valve) and/or turbine adapter
- By removing the turbine cover

7.1.2 Checks before Starting

Before starting the plant, the whole system from the weir and intake to the end of the transmission line must be inspected to ensure that there is no damage or possibility of break-up, especially in the canal. The following must be checked and/or carried out to ensure this.

Intake

- Intake and trashrack are clean.
- The intake gate operates properly.

Canal

- The canal is clear of all loose stones and dirt.
- There are no cracks or damage to the canal. Repair cracks or damage if any.

Desilting

- The flushing valve opens and closes properly.
- The desilting basin is clear of all debris.

Gates/Stoplogs

- They operate properly.

Penstock Supports/Anchors

- All nuts on the penstock straps are tightened properly.
- There is no damage to supports/anchor blocks, and the bases of the anchor blocks/ supports have not been eroded. Repair if necessary.
- The drainage arrangements around the anchor blocks/supports are not blocked or damaged. Repair if necessary.

Penstock

- All bolts are tightened properly.
- The penstock has not sagged at any point. Reconstruct support piers if necessary.
- The paintwork is intact. Repair if necessary.

Turbine

- The turbine is well mounted and in good condition.
- Corrosion protection and paint are ok.
- The ball bearings are well lubricated.
- The shaft is turning smoothly, there is no noise or vibration.

- The turbine-alternator alignment is ok.
- All the nuts and bolts are properly tightened.

Power Transmission

- The coupling is aligned properly, there are no loose bolts.
- The belt is aligned and tightened to the correct tension.

Alternator

- The alternator is well mounted and in good condition.
- Corrosion protection and paint are ok.
- The ball bearings are well lubricated.
- The shaft is turning smoothly, there is no noise or vibration.
- The turbine-alternator alignment is ok.
- There are no loose or untightened bolts.
- The ventilation system is not blocked.
- The stator windings to terminal are properly connected.
- All cabling is ok and fixed well.
- The nameplate has the correct information.
- The insulation resistance is ok.
- The continuity of each grounding circuit throughout the system is ok.

Control Panels

- Panels are properly fixed, doors and locks function properly.
- Paint is ok.
- Earthing is done properly, screws and terminals are tight.
- All cabling, connections, terminals, and wiring are ok and there are no loose connections.
- The general cabling layout is ok and there is no damage.
- Labels are well fixed, have the correct information, and are readable.
- Wiring diagrams are available.

Transmission/Distribution

- The resistance of all earthing systems is within the given limits (usually less than 5W).
- There is no excessive sag in any section.
- The ground clearance of all transmission lines is satisfactory.
- The lightning protection system is in place.
- The connections to the transformer are properly tightened.
- The transmission line is clear of trees and branches. Cut off any branches or trees that are too close (within 2 metres of the transmission line).

- All service wires are properly connected.
- All poles are undamaged, vertical, and fixed properly.
- All insulators are undamaged.
- All connections to the insulators are properly made.
- All joints and splices in the transmission are properly made.

After all the checks have been completed and are considered to be satisfactory, the waterways should be filled slowly with water to test all overflow systems and to test for slippage or leakage. All gates, stoplogs, and flushing valves must be operated in this situation to ensure that they function in their normal operating conditions. Check to see whether the penstock leaks.

This test should be carried out for a period of at least 24 hours while the canal remains full and some flow is spilling from the forebay. During this time the system must be monitored to check for any leakage of water from the canal and the forebay. Also check that no damage has been caused by the overflowing water.

7.2 Commissioning and Performance Tests

After all the above tests have been carried out the system is ready for commissioning.

Open the main valve or turbine valve SLOWLY to start rotating the turbine. The turbine should be allowed to run at a low speed, with the generator connected, while ensuring that there are no unusual sounds, vibrations, or behaviour.

If any unusual sound or odd behaviour is noticed then shut down immediately. The problem(s) should be investigated, identified, and rectified before the tests are resumed (e.g., misalignment, loose nuts/bolts, leakage).

Increase the turbine speed gradually until normal operating speed is attained. Allow the turbine to operate at this speed, with the generator excitation ON and with no load or a very small load, for about two hours. During this time, constantly monitor the equipment, particularly for excessive temperature rises in the bearings and alternator windings.

Increase the load on the machines in steps of 20 per cent until maximum output is reached. At every load step the system must be allowed to reach a steady state (i.e., there are no fluctuations, and flow and output are constant) and normal running condition before readings are taken.

While the machines are running, continue monitoring for unusual sounds, vibrations, and odd behaviour.

7.2.1 Performance Test

While operating the machines at different loads as described above, a performance test should be carried out by taking the readings of the machines and the outputs at different loads. The following should be measured and recorded.

The flow (if possible), pressure at the penstock outlet, turbine speed, bearing temperature, alternator temperature at different points, alternator voltage and current on all phases, exciter voltage, and current and voltage drop across transmission line lengths on each phase.

The different readings should be taken at steps of 20 per cent up to the rated power output of the plant. In cases in which an ELC is installed, the power output may be increased by increasing the water flow. The ELC automatically switches on the ballast to maintain the correct speed. The tests can be continued using the ballast load, but it is advisable to use an external load as this will provide visible evidence to the customer that the required output has been produced. For example, in a 10kW plant, ten 1kW heaters could be used; and for plants of 1-2kW, 10-20 100W bulbs could be used.

A sample format for the test results is given in Annex 2.

7.3 Rectifying Faults

During the commissioning tests, problems may be encountered in the functioning of the plant, or faults detected. The severity of any problems must be assessed and action taken as follows.

7.3.1 Serious Problems

Stop further commissioning work until the problem is fully rectified. Such problems are broadly of two types.

Safety related Any conditions which, if not rectified and the equipment is operated, could lead to injury, loss of life, or serious damage to the infrastructure and equipment of the plant.

Examples

- Inadequate spillway, which could result in erosion of anchor blocks or supports, or erosion of land.
- Transmission wires that can be touched by a person while standing on the ground.
- Any situation that causes electrical cables to overheat.

Operational. These are problems that prevent the full output of the plant from being produced and can have an adverse effect on the life of the plant in the long term if it continues to be operated.

Examples

- Blocked or restricted canal preventing the required flow being attained
- Rapid and high rise in temperature of bearings or generator windings
- Excessive vibration
- Resonance speed that is close to the operating speed

7.3.2 Ordinary Problems

These are the problems that can be rectified straight away or later and will not hinder the commissioning work which can continue.

Examples

- Minor leakage of water from the canal or pipe joints
- Minor misalignment that can be adjusted
- Damage to paint work where repainting is needed

After any rectification work on a component, the component must be tested before proceeding with the commissioning.

7.4 Endurance Test

After the performance tests have been completed, the equipment should be run continuously for a period of at least 24 hours at full load to find out if the machines are able to give continuous and trouble-free service. During this test the machinery should be continuously monitored for the following.

- Excessive vibration and noise
- Overheating of mechanical and electrical components
- Loss of output
- Deviations in frequency, voltage, and current

If any of the above problems occur, then the cause of the problem must be found and rectified before further tests are done or before the commissioning and handover are completed.

After completing the endurance test successfully, the plant is almost ready to be handed over to the owner-manager(s). However, it would be advisable for the owner-manager and operators to continue operation of the plant for an additional two to three days under the supervision of the installers. The plant should be started, stopped, load(s) applied/removed, and the flow varied, while continuously monitoring the output, instruments, and overall behaviour (noise, temperature, vibration, leakage). This will lead to more confidence about the performance of the equipment, and the plant operators will also have received some on-the-job training.

Chapter 8
Training Managers and Operators

The manager and operators for an upcoming plant should be selected and/or appointed by the community/entrepreneur before the process of installation begins, so that they can participate fully in the installation process. This will increase their knowledge about the names, shapes, characteristics, and functions of the various parts of the whole set-up in general and about the electro-mechanical equipment in particular. They should be taught through actual practice instruction and explanations and assembly and disassembly of various components (e.g., the bearing housing to check or replace a bearing). They should also be informed about what would happen if a unit was not handled or operated properly, and about what the signs of malfunction are. The testing and commissioning phase is particularly important since the installers will be starting, operating, and stopping the plant repeatedly, looking for the faults or problems and removing them. The manager and operator must be fully involved and asked to carry out some of the operations themselves (e.g., starting/stopping, disassembling components, carrying out alignment checks). Some such operations should be repeated for the sole purpose of training these people during the testing and commissioning phase, since this is probably the best opportunity. This training should be given high priority even if it means prolonging the process of testing and commissioning. Adequate training of managers and operators should be one of the clauses in the handing over certificate to be signed by the owner/ community leader taking over possession of the plant.

The following main features should be covered in this training.

- Starting and stopping procedures, including what to do if something goes wrong
- Applying and removing the load (all aspects of operation)
- Identification and names of various components, their functions, and operational characteristics
- Familiarity with most sections of the operations and maintenance manual
- Maintenance of all parts
- Basic fault diagnosis and repairs
- Cleanliness and safety
- Basic bookkeeping

The operator is almost like a bus driver. Even minor carelessness on his part may result in a serious breakdown and/or bodily harm. Therefore, the importance of conducting this training should be recognised by all concerned.

Chapter 9
Handing Over the Plant

The final step in the installation process is the handing over of the plant to the owners or the manager and community representatives. The installers must demonstrate to the recipients that the installation has been completed satisfactorily in accordance with the specifications provided; that the plant is producing the rated power and working satisfactorily in all respects; and that it is likely to perform satisfactorily in all respects in future. In addition, both the installer and the recipient must sign and keep copies of some formal documents related to the satisfactory performance, handing over, and guarantees for the future.

9.1 Completion Certificate

The completion certificate is usually needed by the installer to get the funds released from some funding agency, e.g., a bank; whereas the guarantee(s) from the manufacturers and the installers is needed more by the owner-recipient so that he can obtain services and parts to be replaced if something goes wrong during the guarantee period. These two types of document must be written in clear and precise language to avoid any ambiguity. Annex 3 shows a sample form for a completion certificate. This form contains the information needed for handing over and taking over the plant. The manufacturer/installer must also provide to the owners all drawings, catalogues, figures, sketches, maps, a copy of the feasibility study, and a well-prepared and useful operation and maintenance manual.

9.2 Guarantees

Two or more guarantees may have to be provided by the manufacturers, installers, and suppliers of equipment, depending upon where the equipment has been acquired and by whom.

The manufacturer(s), for example, should provide guarantees for a prescribed period (e.g., one year), that the equipment will be repaired free of charge including replacement of parts if the machine or a part/unit fails within this period; except if the failure is caused by improper or careless use or handling of the equipment by the operators. Usually, a guarantee is also provided for the parts or components obtained from the market or from other manufacturers, e.g., penstock pipes, bearings, bearing housing, couplings, and belts.

Similar guarantees should be provided for the civil works (if constructed by a contractor/ installer) and the transmission and distribution lines.

A sample guarantee document is shown below. This can be improved, modified, or re-written, to accommodate all the relevant components or units. The guarantee shown is for the turbine, generator, and coupling system, but other items can be added.

Guarantee

The following equipment supplied/manufactured by .... is hereby guaranteed by the undersigned for a period of 12 months from the date of hand over of the MHP plant. If it breaks down or fails to perform satisfactorily and produce the rated output, the supplier/manufacturer hereby undertakes to repair such parts and replace faulty parts free of cost, so that the equipment gives the rated outputs. This guarantee is void if the failure of a component is caused by improper handling or operation, carelessness, or an accident

1) Turbine (type) ....;kW capacity ....; dia. of rotor ....mm; bearings manufactured by .... (country) ....; shaft diameter ....mm, bearing housing ....(type, make, country).

2) Generator (type) ....; phase ....; rpm ....with brushes/ brushless.........; with/without AVR ....; manufacturer's name and country...........; capacity ....kVA

3) 2 Pulleys .... mm dia & .... mm dia; shafts ....mm dia. and ....mm dia., material ....; having .... grooves .... (type) key.

4) .... V belts .... (manufacturer and country), nominal length ....; x-section area .... mm^2, material ....

....

(Signature of guarantor)

Date: ....

Name: ....

Designation: ....

STAMP

Organization: ....

Address: ....

References and Further Reading

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Annexes

Annex 1: List of Tools and Other Materials Needed for Installation of an MHP scheme

Particulars	Required		Checked date	Tick when packed	Remarks
	Yes	No			
Mechanical					
Spanner sets (ring and open)					
Slide wrench					
Screwdriver sets (Philips and plain)					
Hammer					
Pipe wrench					
File set (round and flat)					
Steel ruler					
Measuring tape (30m)					
Levels (spirit & string)					
Hand drill machine					
Small bench vice					
Vice grip					
Allen key set					
Punches for making holes					
Grease gun					
Bearing puller					
Wire brush					
Hacksaw					
Emery paper (different grades)					
Paint brush					
Differential chain					
Dreep pin					
Square					
Portable welding machine					
Electrical					
Common pliers					
Nose pliers					
Wire cutter					
Line tester					
Safety belt for climbing poles					
Gas solder					
Crimping tool					
Wire puller					
Multi-meter					
Frequency meter					
Vibration meter					
Insulation tester					

Annex I Cont.......

Particulars	Required		Checked date	Tick when packed	Remarks
	Yes	No			
Civil					
Tri squares					
Crowbar					
String					
Mason's trowel					
Shovel					
Hammer					
Spirit level					
Chisel					
Pick					
Boring rods					
Abney level					
Theodolite					
Plumb bob					
Dynamite					
Other Materials					
Cement (quantity needed)					
Sealing materials					
Doors, windows					
Corrugated iron sheets					
Lintels					
Fuses (different sizes)					
Ballast heaters (if not available with ELC)					

Annex 2: Record Sheet for Performance Tests for MHP Turbine and Generator

Turbine type: Controller type: Rated output:								______ Micro hydro Project Efficiency/Output test results				Date: Test done by: Page ______ of ______		
S. No.	Load (kW)	Voltage, V (volts)			Current, I (amps)			Turbine opening (%)	Flow (l/s)	Turbine Speed (rpm)	Net head (m)	Power Output (kW) ($V_r \times I_r + V_y \times I_y + V_b \times I_b$)	Overall Efficiency
		R	Y	B	R	Y	B						
1													
2													
3													
4													
5													
6													
7													

Remarks:

Annex 3: A Sample Form for Handing Over and Taking Over an MMHP Plant (Completion Certificate)

To be completed by the authorised representative of the installer

A. General Information

Plant Name: .... Rated Capacity (kW): ....

Stream Name: .... VDC:.................. District:. ....

Plant Location (describe): ....

....

Owner's Name: .... Lead Person: ....

(Recipient)

B. Completion of Civil Works

Weir constructed Yes/No Type: .... Length (m): ....

Distance between weir and intake mouth (m): ....

Intake type: .... Size: ....(m)

Canal type: .... X-Section: .... Length (m): ....

Are length sections of different types? Yes/No. Description and length: ....

....

Design flow (l/s): ....

Control gate type and size: ....

Desilting basins No.: ....Size: ....

Construction types: ....Locations: ....

Flushing Systems: Yes / No. Number: .... Construction type: ....

Spillways: Number ....Construction type: ....

Gate provided? Yes / No Gate type and size: ....

Forebay size (L x W x H, m) ....

Trash rack type and size ....

Flush gate type and size ....

Spillway type and size ....

Desilting basin attached? Yes / No..............., Type and size ....

Penstock gate provided? Yes / No ....Type and size ....

Penstock Material .... Type .... Diameter(m) ....

Length ....Flanged pieces (No.) ....Thickness ....Vent pipe? Yes / No

Expansion Joints (No.) ....Type ....

Bends (No.) ....Type, description ....

Gross Head (m) .... Net Head (m) ....

Valve Provided? Yes / No Type ....

Manufacturer (name and address) ....

Powerhouse size (L x W x H) .... Construction type ....

Roof type .... Doors No........................ Windows No. ....

Tailrace type ....Length ....

Civil works completed satisfactorily? Yes/No

Any leakage, earth movement from or around any of the civil works? Yes/No

If yes, describe ....

Other problems during commissioning of civil works (describe): ....

....

To what extent were they overcome? ....

....

Test Results for Civil Construction

Flow measured in canal? Yes/No Flow (l/s) ....

Pressure gauge installed in penstock? Yes / No Pressure at full flow (kg/cm^2) ....

Weir performing satisfactorily? Yes/No If no, what needs to be done ....

....

Settling basins performing satisfactorily? Yes / No If no, what needs to be done

....

All flushing systems performing satisfactorily? Yes / No

If no, what needs to be done ....

....

Forebay and its accessories performing satisfactorily? Yes / No

If no, describe problem and solution ....

....

Penstock and its accessories performing satisfactorily? Yes / No

If no, describe problem and solution ....

....

C. *Installation of Electro-mechanical Equipment*

Turbine type .... Rotor dia. (m) .... Rated capacity (kW) ....

Rated speed (rpm) .... Runaway speed (rpm) ....

Bearing type .... Size ....Manufacturer ....

Test Results (Turbine)

Is turbine properly installed? Yes/No If no, describe problem and remedy.......................................

....

Was rated speed achieved? Yes/No If no, suggest remedy ....

Was rated power achieved? Yes/No If no, describe problems and remedies.

....

Any other problems? Yes / No Describe and suggest remedies ....

....

Generator

Type .... Single/three phase. Rated kVA .... Rated speed (rpm) ....

Rated voltage (volts)................... AVR? Yes/No Type..............................

Manufacturer and country ....

Generator properly installed? Yes/NoIf no, describe problem and remedy

....

ELC provided? Yes / No Type .... Manufacturer and Country ....

Coupling/pulley sizes ....speed ratio.......................................

Belt types and sizes..

Power transmission type (if different) ....

Control Panel instruments and number provided (details) ....

....

Main switch type .... Fuses, type and no. ....

Over-voltage cutout .... Over-current cutout ....

Earthing system (describe) ....

All instruments and indicators working properly? Yes / No

If no, describe problem and remedy ....

Test results (Generator)

Was rated electrical power achieved? Yes / No If no, describe problem and solution

....

ELC tested and operated? Yes / No MCB/MCCB operated & tested? Yes/No

Whole circuit tested within powerhouse? Yes / No

If no, explain problem and remedy ....

....

Any misalignment? Yes / No If yes, describe ....

Any vibration? Yes / No If yes, describe ....

Any high temperature? Yes / No If yes, describe ....

Any loose belts? Yes / No If yes, describe ....

Endurance test done? Yes /No Duration (hrs.) ....

If no, describe problem and remedy ....

....

Any problem during earthing continuity checks for generator, ELC, control panel? Yes / No

If yes, describe problem and remedy ....

....

Is frequency meter installed Yes / No If yes, frequency range (Hz) ....

Describe problem with frequency (if any) and remedy ....

D. *Transmission Line Installation*

Main transmission line length (m) ...... Wiring system single/three phase, three/four wires

Poles, No. ....Type ....Size (L x W x H) ....

Wire size ....Manufacturer ....

Lightning arresters, No. .... Type ....

Branch transmission/distribution lines, No. ....

	(i)	(ii)	(iii)
Lengths of each branch	....	....	....
Wire sizes	....	....	....
Single/three phase	....	....	....

Lightning arresters: No. .... Poles, No. ....Insulators, No. ....

Test Results

Have all wires been inspected/tested for proper installation including joining, continuity and resistance, sagging, etc.? Yes/No Describe problems (if any) and remedies ....

....

Have any other problems been noticed with wires, poles, nearby trees, buildings, or other? Yes/No Describe problem(s) and remedy (if any) ....

....

E. *Training*

Training conducted for prospective operators and managers during Installation and Commissioning? Yes / No If no, describe problem and remedy/If yes, give details..................................

....

Additional training conducted during the first supervised operational phase? Yes / No

If no, describe problem and remedy/If yes, give details ....

....

Describe the overall assessment of training, have personnel gained satisfactory expertise? ....

Level of expertise gained (tick)

Person Name	Satisfactory	Acceptable	Low	Negligible
Manager	....	... ...	...	...

Operator 1 ....

Operator 2 ....

Operator 3 ....

Describe reasons for low or negligible gains and suggest remedy..

....

F. *Overall Certificate of Satisfactory Completion of all Aspects of Installation Process*

Certified that all the aspects of the Installation process have been completed satisfactorily in accordance with the agreed specifications. All the defects and problems encountered during the commissioning phase have been removed and no problem is anticipated in future. This certificate applies to the following completed components.

Completed Components	Signature by Installer	Signature by Recipient
Civil works		
Electro-mechanical Equipment		
Transmission Lines		
Commissioning & Testing		
Training		

Certified further that all the relevant documents — including operations and maintenance manual, drawings, specifications (e.g., for bearings), maps/sketches, and feasibility/survey report: have been provided to the owner/manager/authorised recipient.

....

Signed by *owner, authorised community representative*

Date: ....

Name, Position, and Address ....

....

* 1 (Signed by Authorised Representative of Installers) Date: ....:

Name, Position, and Address..

....

* 1 Note. If different aspects have been completed by different installers (e.g., civil works, transmission lines) then they should all sign separately on a modified form.

Participating Countries of the Hindu Kush-Himalayan Region

Afghanistan	Bangladesh
Bhutan	China
India	Myanmar
Nepal	Pakistan

International Centre for Integrated Mountain Development
4/80 Jawalakhel, G.P.O. Box 3226, Kathmandu, Nepal

Telephone : (977-1) 525313
E-mail : distri@icimod.org.np
web site : http://www.icimod.org.sg

Facsimile : (977-1) 524509
: (977-1) 536747
Cable : ICIMOD NEPAL