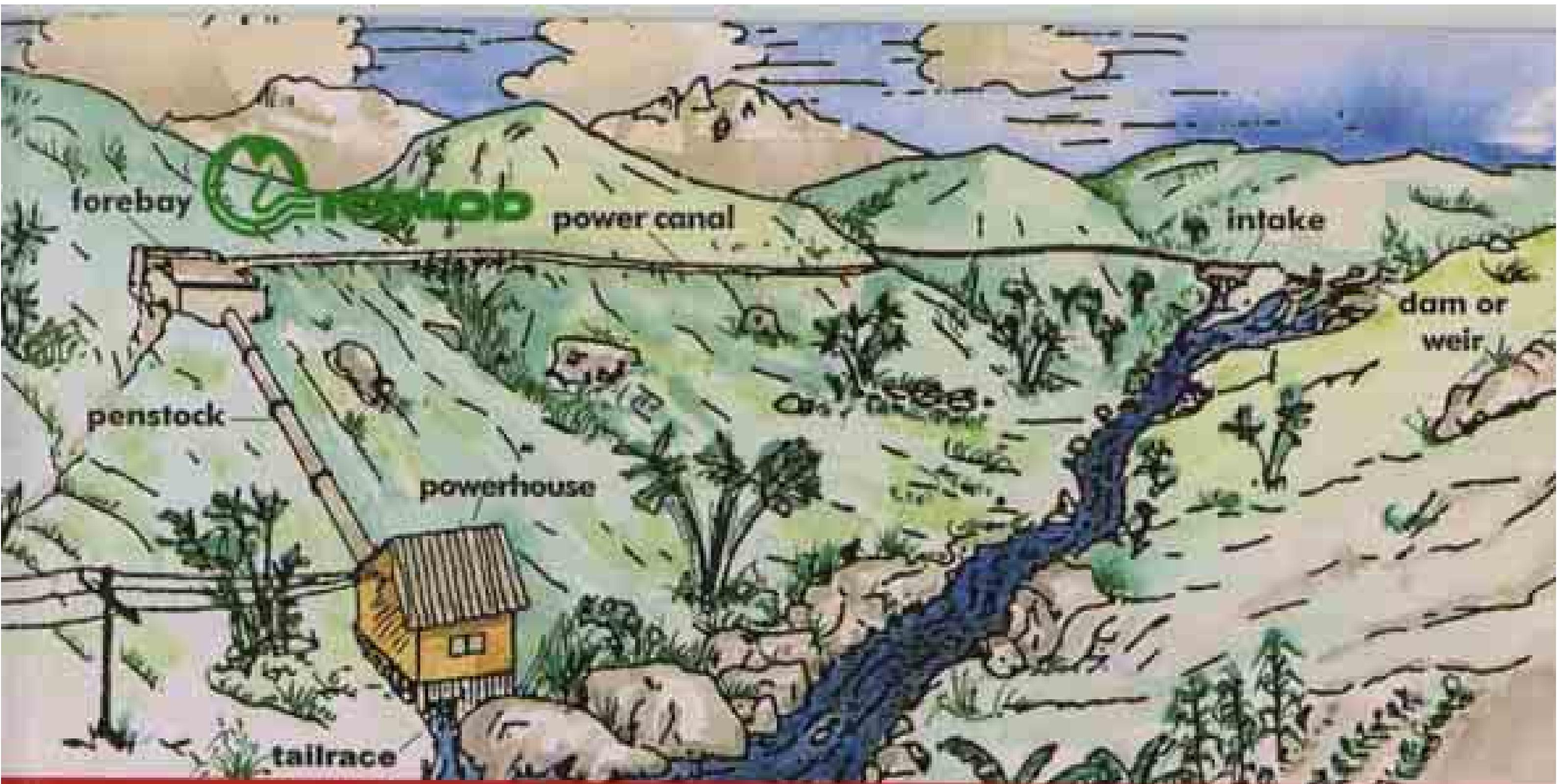
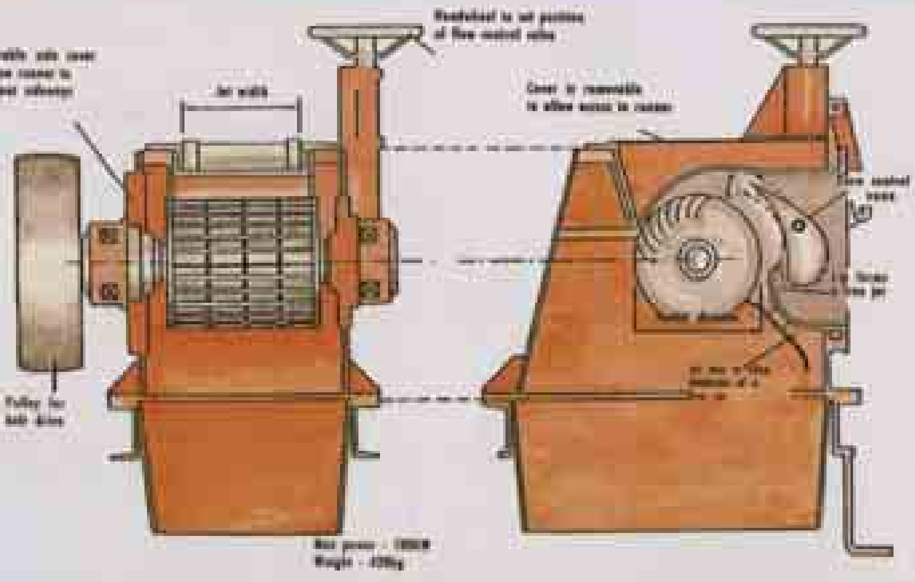


Maintenance and Repair Manual for Private Micro-hydropower Plants



International Centre for Integrated Mountain Development
Kathmandu, Nepal
1999

Maintenance and Repair Manual for Private Micro-hydropower Plants

Prepared by

Development and Consulting Service
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Preface

This manual has been prepared as one of a series of four manuals for the various groups of technicians and professionals engaged in the design, survey, feasibility study, manufacture, installation, management, operation, and maintenance and repair of private/community-based micro-hydropower (MHP) installations in the Hindu Kush-Himalayan region. The main reason for preparing the manuals was the felt and stated need of such groups for whom there are few opportunities for adequate training or advisory back-up. The lack of such opportunities and support is now recognised to be one of the main reasons why such schemes are less successful than hoped. At present, many schemes are being designed, installed, and operated by people who have not had sufficient opportunity to acquire the necessary skills.

The current manual is aimed primarily at managers and operators who have to carry out maintenance and minor repairs and organize major repairs in remote and under-developed mountain areas. It is hoped that this manual will provide some assistance to these professionals as a reference document. As the intended readers of the manual may have had a somewhat limited formal education, an attempt has been made to keep the contents simple. 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. We have tried to achieve the optimum balance.

All the manuals, including this one, have been prepared as a component of the project 'Capacity Building for Mini- and Micro-Hydropower Development in Selected Countries of the Hindu Kush-Himalayan Region - Phase II'. The project has been generously funded by NORAD and implemented by ICIMOD. The first draft of this manual was prepared by DCS -Technology Development, Butwal, Nepal and was revised by Dr. A. A. Junejo, the Project Coordinator of the MMHP project, with the help of field staff from DCS. DCS-Technology Development performed an admirable job in providing all the necessary information in one document and identifying a wide range of possibilities for damage and methods of repair. The revision was based on the recommendations of the Consultative Meeting of Regional and International Experts held in February 1998. ICIMOD is grateful to DCS and its field staff for their inputs and hard work.

This is a first attempt to produce and publish manuals such as these for user groups; and 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 MMHP. It is hoped that translated into the relevant languages, this manual will be a significant source of practical help.

Dr. Anwar A. Junejo
Coordinator, MMHP Project
ICIMOD

Abbreviations and Acronyms

ACSR	:	Aluminium Conductor Steel Reinforced
AVR	:	Automatic Voltage Regulator
ELC	:	Electronic Load Controller
HKH	:	Hindu Kush-Himalayas
IGBT	:	Induction Gate Bipolar Transistor
IGC	:	Induction Generator Controller
MCB	:	Miniature Circuit Breaker
MCCB	:	Miniature Coil Circuit Breaker
MHP	:	Micro-Hydropower
OVT	:	Over Voltage Trip
srpm	:	Revolutions Per Minute

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Chapter 1
Introduction

The energy needs of the people of the Hindu Kush-Himalayan (HKH) region are not being met adequately. Traditional energy resources, such as fuelwood, are dwindling fast, and more modern resources are difficult to provide as a result of the many constraints. The per capita energy usage in these areas is very low and not sufficient to support initiatives to improve living conditions, create employment and income enhancement opportunities, and contribute towards overall development such as infrastructural development. Suitable and reliable energy resources need to be developed and implemented in this area, keeping in mind the specific features of the mountain region, which differ significantly from those of the plains or even hilly areas nearer the plains. The level of development in this region is very low, the people are poor, access is difficult, the population is scattered, and awareness and know-how about machinery are limited. Energy sources and systems for these areas must be reliable, and, preferably, such that the local population can easily adopt and manage them without outside assistance. Micro-hydropower (MHP), which builds upon the traditional technology of water wheels (*ghatta*[s] or *gharat*[s]), is now recognised to be the most suitable, environmentally-friendly option, at least cost, for many such areas.

Private, community-based, and decentralised MHP installations are now meeting energy needs in many mountain areas in China, Nepal, and Pakistan to a significant extent. While appropriate support arrangements have been put into place in China, they are highly inadequate in Nepal and Pakistan. As clearly recognised during various meetings, consultations, and field studies, appropriate and adequate institutional support and interventions need to be designed and provided to the different professionals engaged in various aspects of MHP implementation. Without this support, the performance and viability of many MHP schemes are unlikely to be satisfactory. This is because these MHP schemes are designed, manufactured, and installed indigenously and are owned, managed, operated, and maintained by local people in remote areas.

The main needs identified were related to the improvement of quality and performance through development and dissemination of training programmes, manuals, standards and guidelines, back-stopping (provision of back-up support) for and advice to the managers/operators, and proper maintenance and repair systems for MHP plants. In order to try and fulfill these needs, ICIMOD has attempted to design and implement quality training programmes and to prepare and disseminate appropriate information manuals on various aspects of MHP implementation. In all, four such manuals, on site survey and layout, design and manufacture, installation, management and operation, and maintenance and repairs, have been prepared for technicians and owner-managers engaged in the implementation and operation of MHP plants in the HKH region. This manual is one of this series. These activities are part of a project designed and implemented by ICIMOD and supported financially by the Norwegian Government.

1.1 About this Manual

This manual is mainly intended for owner-managers and operators of private MHP plants who mostly have to rely on themselves or local technicians to identify any malfunctions in the equipment and to carry out subsequent repairs. ('Private' is taken here to mean all plants not owned or managed by a government body or a central electricity utility and to include community and entrepreneur owned plants.) Many of these owners or operators are unable to carry out repairs properly as a result of a lack of expertise and knowledge, of proper tools and instruments, and of workshops and allied equipment. The wide variety of equipment and different designs that exist in the HKH region are further impediments. (In Nepal alone, three distinctly different designs of crossflow turbines are being produced by manufacturers as a result of a lack of agreed standards or any form of supervision or coordination.) Nevertheless, most design concepts and many important components are the same. This manual is intended to provide the basic information needed for diagnosing and assessing malfunctions in MHP plants, deciding on the course of action for repairs, and carrying out many basic repairs, including assembly and disassembly, so that the owners/operators of such plants are able to carry out or organize repairs properly. Many repairs will still have to be referred to properly qualified and equipped technicians and workshops, and some suggestions for repairs at these places have also been included.

One of the keys to reliable operation is routine, preventative maintenance, i.e., regular inspection, lubrication, cleaning, and replacing of worn items; and responding to concerns identified during inspections immediately rather than waiting for machinery to break down before taking action. If minor repairs are not carried out in time, the plant may break down completely, resulting in significant additional cost, loss of income as a result of the delays in repairing the affected part, and possibly more damage to other more expensive parts.

One of the purposes of this manual is to provide a list of items for recommended appropriate, routine preventative maintenance for a typical MHP plant and to give details about how to implement it. Manufacturers' maintenance schedules and the periodic checks described in this manual must be carried out if the machinery installed is to give reliable service for a long time. Further information on regular inspection is provided in another manual in this series entitled 'Management and Operations 'Manual'.

Even when a preventative maintenance scheme is carefully implemented, occasional break-downs will still occur. Sometimes after repairing or replacing parts of the plant, difficulties may be experienced in getting the new component to function correctly. To assist in problem solving, many of the common problems encountered in MHP plants are listed in this manual, together with their causes and recommended corrective actions.

In some installations, agro-processing machines, such as oil expellers, rice hullers, and flour grinders are also driven by the MHP plant (either directly via an intermediate shaft or through electric motors). However, this manual does not cover the maintenance and repair of end-use machinery other than the electric generator.

Basically, the information provided in this manual is applicable to plants with a capacity of up to 100kW. However, plants larger than 50kW usually incorporate more safety related equipment and also need sophisticated tools and workshop facilities for repair. Therefore this manual is more relevant for smaller plants with a capacity of less than 50kW. Most of the private and community-owned plants in Nepal, Pakistan, and India fall within this range, and the manual should be of use for the more than 1,000 such plants that already exist.

Chapter 2
Maintenance and Repair of Civil Works

The civil works shown in Figure 2.1 are crucial components of MHP plants and vulnerable to natural mishaps such as rains, floods, or landslides. Routine maintenance schedules for these components are given in Chapter 6 and performance of routine maintenance is described more fully in the manual on 'Operation and Management'. This chapter is concerned with the non-routine maintenance and repairs of these civil structures. The term 'non-routine maintenance' is used to describe situations in which damage is not extensive and repair/maintenance is needed as a result of normal wear and tear or some minor mishap. The term 'non-routine repairs' refers to extensive repairs that have to be carried out as a result of major damage or breakdown.

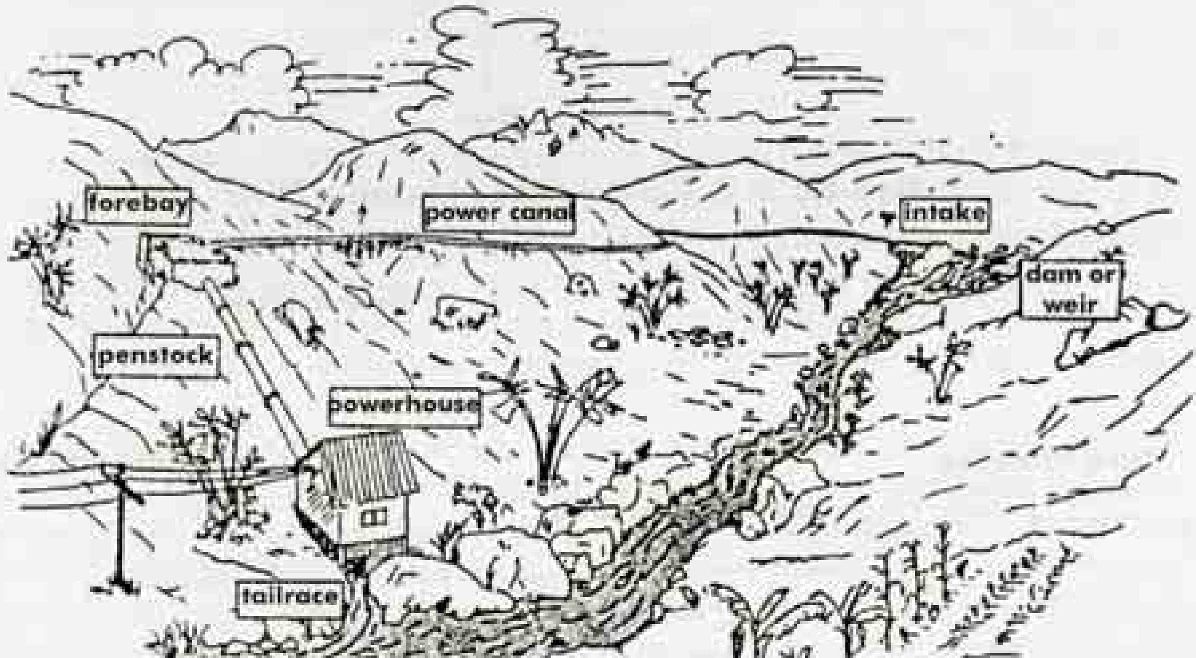


Figure 2.1: Civil Works and Other Components of a Typical MHP Scheme

2.1 The Weir or Partial Dam

The function of a weir is to maintain a constant water level to ensure that a constant flow enters the power canal all the year round, irrespective of low or high flow in the stream (Figure 2.2). A partial dam may have been built in place of a weir. This is usually a temporary structure made of mud and stones that diverts water into the intake mouth but does not extend all the way across the stream (Figure 2.3). A partial dam can be extended when the flow is low in the river and dismantled when flow increases in the stream, so that less water is diverted into the intake.

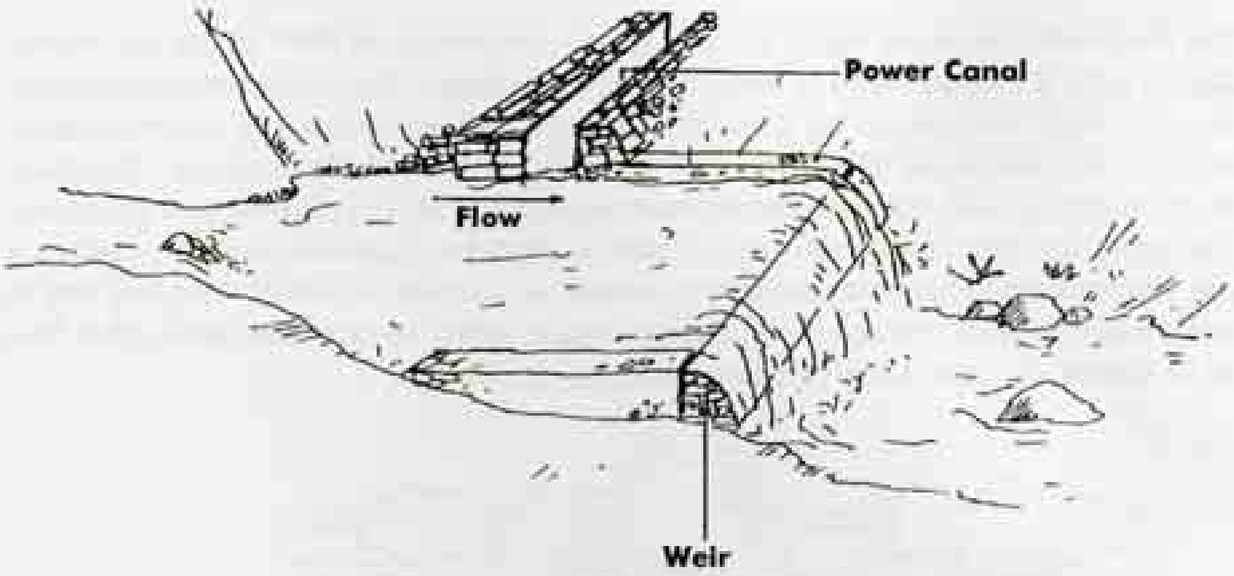


Figure 2.2: A Typical Stone Masonry Weir

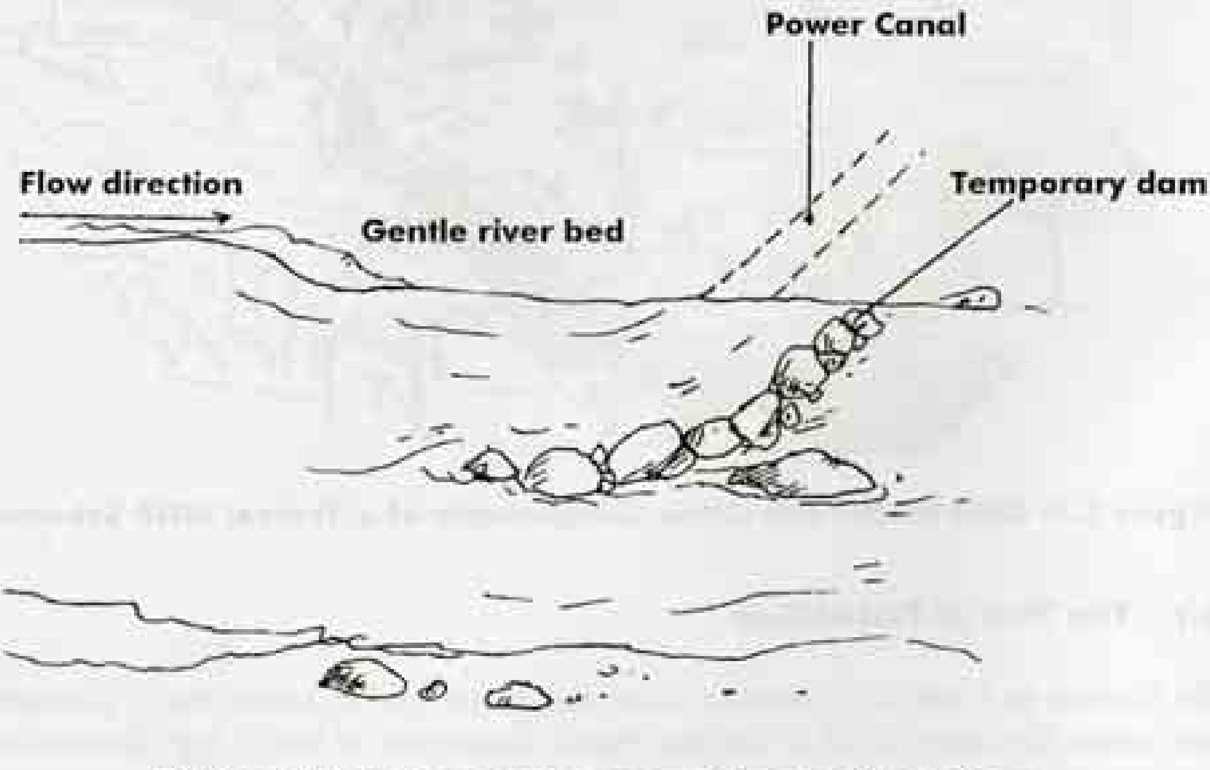


Figure 2.3: A Partial Temporary Dam to Divert Flow

Different types of construction material can be used to make a weir. The weir can be made of stone, in which case dressed stone is used on the wall face with ordinary stones inside; or a gabion or cement-stone masonry wall may have been constructed to make the weir stronger. Concrete weirs are rarely used for MHP plants. Partial dams are almost always constructed from mud mortar and stone, since they are temporary structures able to be washed away, removed partially or fully, or extended according to the requirements of the flow in the canal.

In general, damage to the weir or a partial dam is caused by floods or a high flow in the river which can break the structure or partially wash it away. Sometimes big boulders are carried or rolled by high flows, and these may hit the weir and damage even more permanent structures such as stone masonry walls which otherwise would not be affected by floods. The third source of problems is silt carried in the water, or caused by an upstream landslide. Silt deposits normally raise the level of the weir without breaking it.

The damage caused to a weir is likely to be in the form of partial or complete breakage, or raising of height due to deposited silt. A partial dam may be washed away completely since it is a temporary structure anyway. Sometimes the weir or temporary dam may leak and need to be plugged.

Before commencing any repairs, it is necessary to assess the damage through inspection and different checks. For example, a gabion weir should be inspected for damage to the side of the gabion, change in shape, or breaking of the wires. Some foreign material might also have collected around or above the weir, and this will need to be removed. Thus an inspection is necessary to assess the damage and to decide what repairs are needed. The repairs will depend upon the type of structure as well as the extent and type of damage.

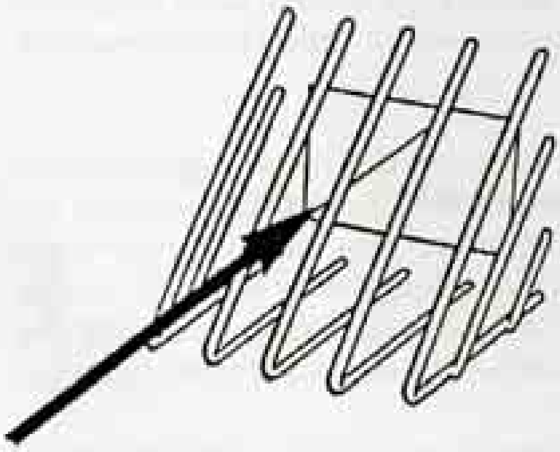
To repair a gabion weir, first remove any foreign material, such as silt, leaves, and sticks, from around the top and sides of the gabion, and then open the wire mesh at the top. Remove all the stone masonry that has bulged or eroded and start reconstruction using dressed stones on the outside and normal stones on the inside as if it was being constructed anew. The wire mesh can be repaired by adding and/or enmeshing similar wire to the original mesh and then closing it at the top by twisting the two wire-ends together and bending them down to the level of the surface.

To repair a dry stone or cement stone masonry weir, again remove all foreign material from around the sides and top of the weir. Then remove the damaged part of the structure in the masonry and start reconstruction using the same materials as used in the original structure.

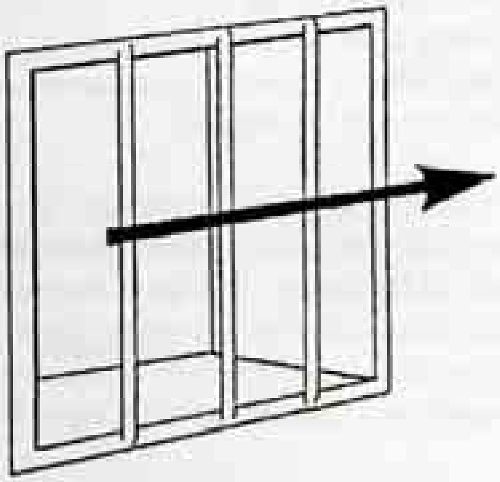
The repair of damage to mud mortar and stone masonry structures, especially partial dams, is simple. Remove the damaged portion and rebuild using the same materials as used in the original structure.

2.2 The Intake

The main function of the intake is to allow a rated flow into the power canal (headrace) and, as far as possible, to block entry of undesirable solid materials such as sticks or stones. For this purpose, either a coarse trashrack or cross-bars are provided at the intake mouth (Figure 2.4). There are three common types of intake in MHP schemes. The most common are simply an opening constructed in the side of the stream leading to the canal. The downstream end of the opening may be extended in the form of a partial dam, as described above. In the second type, a proper wall is constructed containing the intake mouth in the form of a rectangular window (Figure 2.4b). In the third type, a pipe is extended to the middle of the stream where the water is deepest and the pipe mouth remains submerged all the time. When the intake is just an opening in the wall, the sidewalls adjoining the intake area should be properly constructed from dry stone masonry or stone masonry and cement mortar.



a. A coarse trashrack for direct intake



b. Crossbars for a side intake mouth

Figure 2.4: A Coarse Trashrack and Crossbars for the Intake

The main sources of damage to the intake structure are high floods and flows; boulders, logs, or other heavy objects transported by the flow; and deposits of silt at the intake mouth that reduce the flow. Landslides may also either damage or block the structure. Silt and other solids may block the pipe mouth in a pipe intake.

The intake structure or adjoining wall can be damaged or broken; the intake mouth may become wider or smaller, or even blocked; and the trashrack or crossbars can be damaged, broken, or bent. Sometimes, the whole structure may also get washed away as a result of extreme conditions.

Assessment of the extent and type of damage to the intake wall and the mouth should be made through extensive inspection. The size and base level of the intake should be checked.

If the constructed walls of the intake structure are damaged, the damaged portion should first be demolished and then reconstructed using the same materials as used for the original structure, while ensuring that there is no gap between the wall and the actual earthen bank. Any such gap should be filled with soil and stones and compacted properly so that there is no chance of water seeping in. If silt has deposited at the intake mouth, it should be removed and the area cleaned and levelled, not just close to the mouth but extending further along the stream bed so that deposits are avoided in the future. If the crossbars or the trashrack bars are bent, they may be straightened. If they are broken they can be joined by welding, or by fastening steel wires around them. If the damage is extensive, the trashrack or one or more of the crossbars should be replaced.

2.3 The Power Canal

The power canal or headrace carries the design flow of water from the intake to the forebay. It may also incorporate one or more desilting basins and spillways (Figure 2.5). In most cases, open earthen canals are used; however, in some cases, parts of the canal may consist of a pipe or be lined with cement mortar. Sometimes, portions of the canal may have been raised above ground in the form of an aqueduct made of concrete to cross a gully or some other similar difficult area.

The usual sources of damage to the canal are excessive flow, depositing of silt, landslides, rainwater flowing down the hill, or sometimes animals or humans. The damage may appear in the form of leakage from the pipe or canal, or blockage as a result of silt or other foreign materials. The banks or the bed may be eroded, and this could eventually result in part of the canal falling down. Inspection of the power canal to assess the extent of damage should not just be confined to the canal or pipe, but should also cover the surrounding area. All signs of leakage, slip, or other type of degradation must be assessed. All of the affected area will need to be repaired in an appropriate way, depending upon the type and extent of damage, to avoid a serious breakdown in the future.

If there is any leakage from the canal, the water should be stopped at the intake and the damaged area inspected to determine whether a retaining wall underneath the damaged portion is needed; or whether it will be necessary to use a better masonry system such as cement-stone masonry for the wall. Usually, a portion of the bank beyond the damaged portion should be removed and then reconstructed from the same or better materials such as cement-stone or mud-stone masonry. If there is a very small crack in a stone masonry or concrete wall, it can be blocked with the help of bitumen. If a large amount of silt has been deposited on the bed of the canal, it should be removed in such a way that the bed is maintained at its original level. If a portion of the canal bank has col-

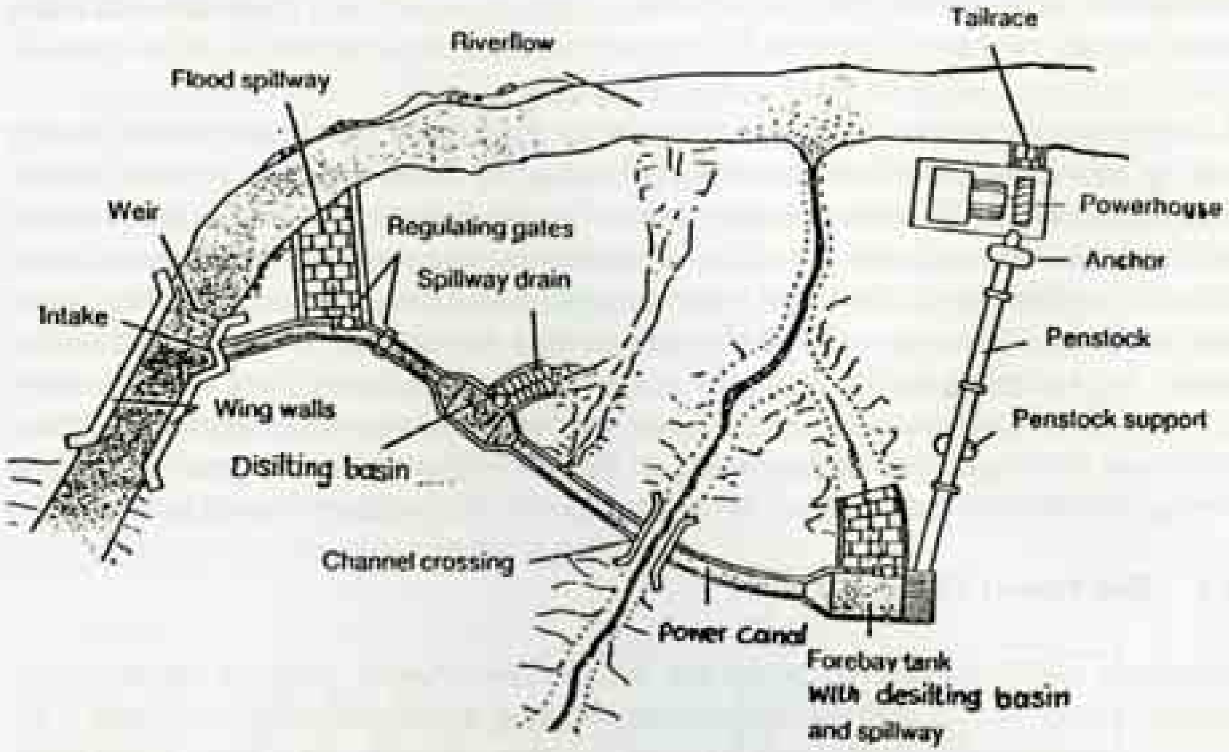


Figure 2.5: Main Components of a Micro-hydro Scheme Including Power Canal and Desilting Basins

lapsed, it will be necessary to dig deeper into the mountainside until a more stable soil or surface is reached. Then stone soling should be placed along the bottom in a horizontal direction, and a sloping stone or gabion wall built up the side to the level of the canal wall (Figure 2.6). The space between the mountainside and the wall should be filled with stone and earth in layers (~300 mm thick) and compacted well. If the canal has been damaged by a landslide from the slope above it, then a larger portion of the canal should be dug out, extending beyond the damaged area until a firm base is reached. Stone soling should be placed at the base and a canal wall built as described above. Sometimes, a landslide from the upper side of the canal may completely destroy the canal and the supporting area beneath. In this case, construction should be started from down below where there is firm ground using stone soling (about 3 metres below) as described above. A retaining wall should also be built above the canal to stabilise the mountain slope. If a portion of a cement-stone masonry canal has been damaged, or has slipped down as a result of a landslide on the upper side or erosion on the lower side, then more care needs to be taken in rebuilding the canal. Much thicker stone soling should be provided at the base to support more weight. Construction of the retaining wall and canal may then be carried out as described before.

If there is a passageway for flow of rainwater above the canal, then it should also be cleaned by removing stones or other debris to keep it functional. Otherwise, the flow may be blocked and may enter the canal.

If a pipe has been used for all or part of the headrace, it may get blocked with silt. For example, if a break-pressure tank has been damaged and that end of the pipe closed, then the silt already present in the water would deposit in the pipe. Silt deposits in the pipe can be removed by force flushing or by inserting a long wooden pole in the pipe to scrape the silt, but care must be taken to avoid damaging the pipe during this operation. If a proper slope had been calculated for the pipe at the time of the design, and the pipe had been properly installed, there should be no deposition of silt.

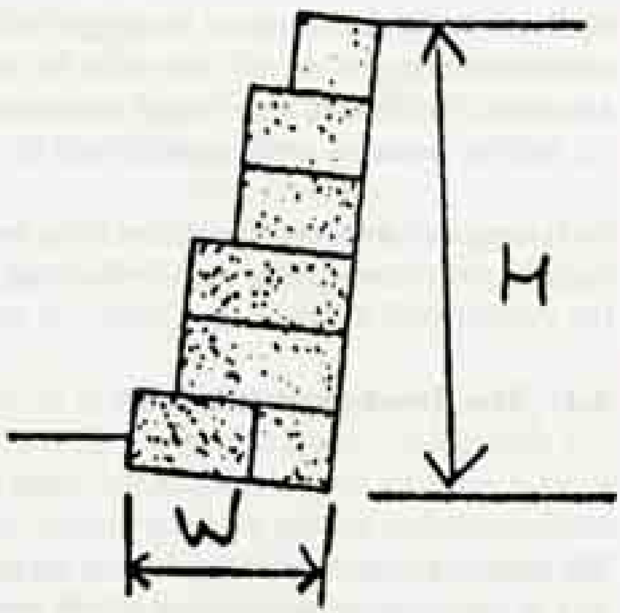


Figure 2.6: A Gabion or Masonry Retaining Wall

One unusual type of damage was reported in Nepal; a stone entered the HDPE pipe headrace and got stuck at the lip of a joint between two pipe lengths. It was very difficult to determine the location of the blockage. A simple technique was devised whereby a smooth heavy piece of steel was tied to a rope and allowed to slide into the pipe from the top until it reached the blocked location and stopped. The length of the rope was measured and in this way the point of the blockage was located. The pipe was cut at this point and the stone removed.

If a large crack has developed in an HDPE pipe, the best way to deal with it is to cut the cracked portion and insert and join an equivalent new piece. If the crack is small, the simple method of repair is to wrap a piece of rubber around the crack and use one or more screw clamps to keep the rubber in place to stop the leakage.

2.4 The Desilting Basin

The function of the desilting basin is to remove silt or heavier suspended particles carried by the flowing water. This is done by slowing down the speed of the water and making it calmer so that heavier particles settle on the bed. Desilting basins are usually constructed using cement-stone masonry with a properly plastered surface. The desilting basin is three to five times as wide as the canal, and the length is about 2.5 times the width.

The main sources of damage for desilting basins are landslides, floods or flows carrying excessive silt, and unstable ground. The most common types of damage are filling up of the basin with silt or debris; leakage, which means cracking of plaster or masonry; and sinking because of unstable ground underneath.

Molten bitumen can be used to plug small cracks in the plaster or repair leakage. Rich cement mortar (1:2 or 1:3) can also be used to close small cracks. If the damage is extensive, the affected area should be replastered. Before replastering, the damaged plaster and the masonry underneath should be removed by chiselling.

If silt deposits have remained in the basin for a long time and dried and hardened, it may be difficult to remove them just by flushing. In this case, the usual method is to dig out the deposit with a shovel.

2.5 The Break Pressure Tank

A break pressure tank is constructed when HDPE or other types of pipe are used for the headrace so that it is not necessary to use a very thick pipe to withstand higher pressure. The break pressure tank is provided at an appropriate location, water comes out of one pipe at atmospheric pressure and enters another. The small tank is very small, about one metre or so high, and is constructed in a similar way to the forebay using cement-stone or cement brick masonry. It is properly plastered both inside and out.

The sources and type of damage are similar to those for the forebay. The tank may subside, or be filled with debris or silt which needs to be cleared. Sometimes, the tank may develop cracks that have to be plugged. Since the inside area is small (less than $1 m^2$), getting inside and plugging leaks or removing debris may be difficult. Debris can usually be removed by shovelling.

2.6 The Forebay

The forebay is the last open link between the canal and the closed penstock pipe, and its function is to facilitate the flow from an open system into a closed one. At the same time, the trashrack removes any remaining floating debris from the flowing water. Sometimes, a desilting basin may be incorporated in the forebay so that any remaining silt is also removed at this stage. Usually, the forebay is constructed from cement-stone or cement-brick masonry and is properly plastered (Figure 2.5). Thus it is a fairly permanent structure and does not normally break or need serious maintenance.

Damage to the forebay may be caused by landslides or boulders falling from above, by floods, or by excessive rainwater. Instability of the ground on which it is constructed may also cause sinking and cracking. The damage may be in the form of cracks, resulting in leaks; or sinking, which may again cause cracking and leaking. The other possibility is excessive accumulation of silt or other material that cannot be removed by normal flushing. As always, it is necessary to inspect the whole area surrounding the damage, especially if the walls have cracked and there may be a possibility of further disintegration of the structure. If this has happened, then the situation is serious and the whole forebay structure should be dug up and reconstructed. If the cracks are small, say less then three mm wide, they can be plugged with molten bitumen or rich cement mortar. If there are larger cracks, then the damaged plaster and masonry underneath should be cut out or scraped and replastered with cement mortar. If the cracking is the result of sinking or landslip and the sinking is considerable, say 10 mm or more, then the best way is to dismantle the forebay structure, dig down through the unstable soil until firm ground or rock is reached, and then reconstruct the whole forebay. Stone soling should be provided at the base, and retaining walls constructed as described in section 2.3.

It should be possible to remove small amounts of silt deposits or debris by flushing two or three times. However, if the amount of debris is quite large, the result of a landslide, for example, then it has to be removed by shovelling.

Sometimes, a leak may develop around the neck of the penstock where it leaves the forebay. This is normally caused by movement of the penstock causing a leak at the interface between the steel pipe and the forebay masonry. Bitumen can be used to fill the crack, or a small recess can be formed by chiselling around the penstock mouth and a piece of rubber forced into the recess with the help of a screwdriver or chisel to make a force fit.

2.7 The Tailrace

The tailrace carries the water exiting from the turbine back to the river, and part of it is located inside the powerhouse. Usually the tailrace is relatively short and on ground where the likelihood of serious damage is minimal. Inside the powerhouse the tailrace is usually built of stone masonry and properly covered by a reinforced concrete or stone slab. Outside the powerhouse, it is an open channel, usually earthen. In rare cases, where the area outside the powerhouse is precious (irrigated cultivated land, for example), the tailrace may be constructed of cement-stone masonry to prevent any leakage to the surrounding area.

Damage to the tailrace can be caused by sinking of the ground or, if the slope of the tailrace is high, erosion and appear in the form of leakage or increased width or depth. In some cases, the tailrace may become filled by debris from a landslide, or from collapsed banks. In this case it can be re-dug by shovelling.

If the channel has become too deep, the ground should be filled to the proper level and compacted, and then covered by stone pitching with a layer of thin stone slabs on the top so that the surface becomes hard and resistant to erosion. Pitching should be provided on the whole inner surface, the bed as well as the sides. If done properly, stone pitching can also stop leakage.

Sometimes a hole is dug by a rodent in an earthen canal. In this case the hole must be located, the surrounding area dug out about 300 mm deep, and then refilled and compacted to plug the hole.

Chapter 3
The Penstock and Allied Structures

3.1 The Penstock Pipe

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

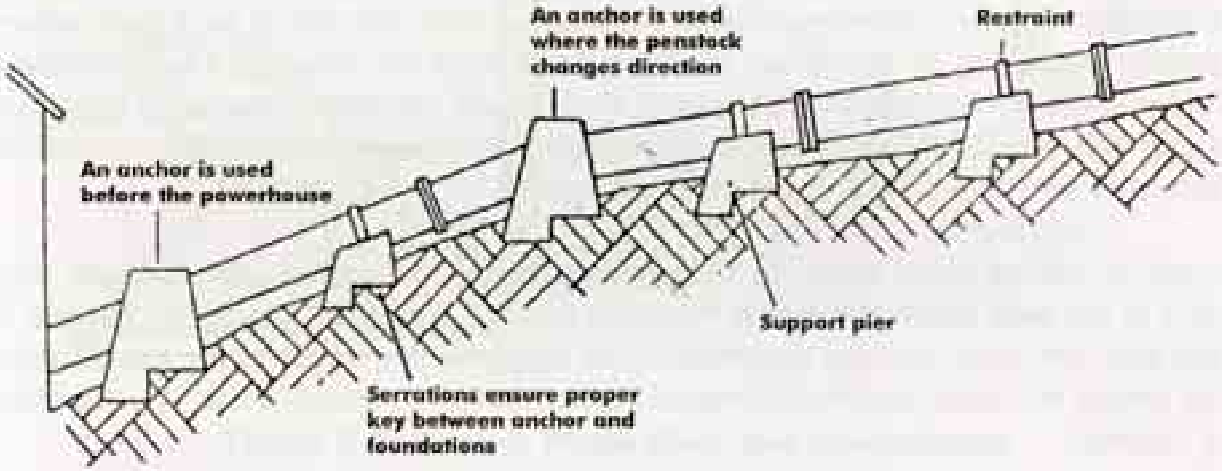


Figure 3.1: A Typical Penstock Installation with Support Structures

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

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

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

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

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

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

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

3.2 Support Structures for the Penstock

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

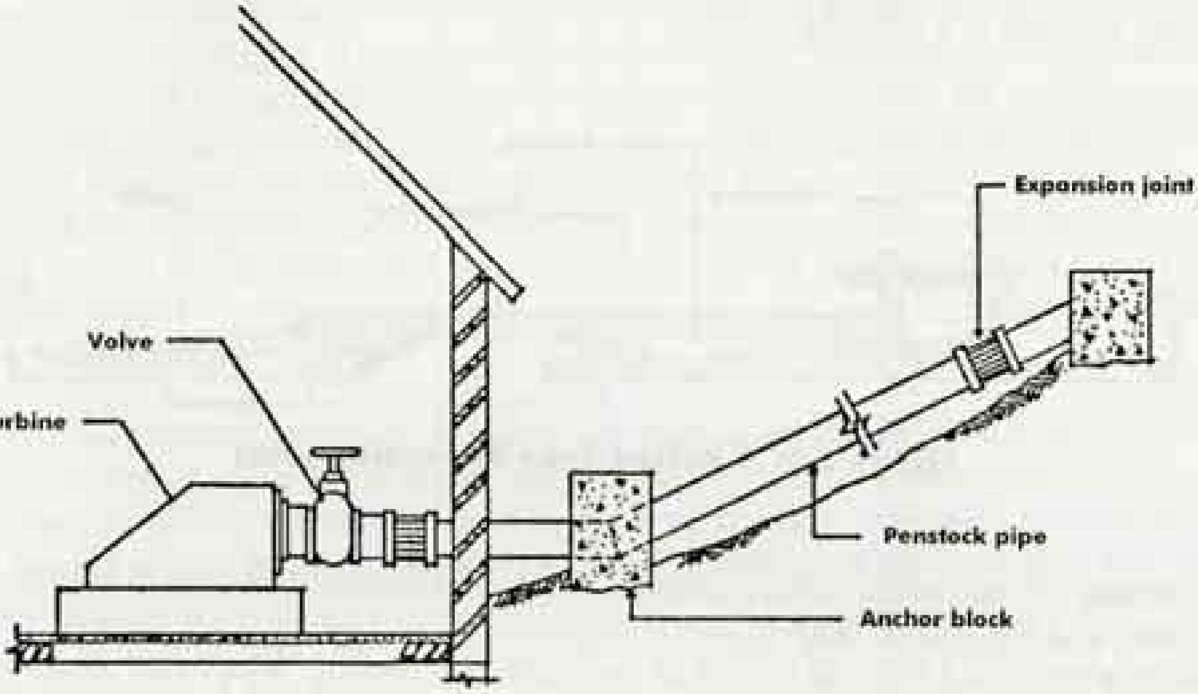


Figure 3.2: Anchor Block Near the Powerhouse

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

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

3.3 Expansion Joints

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

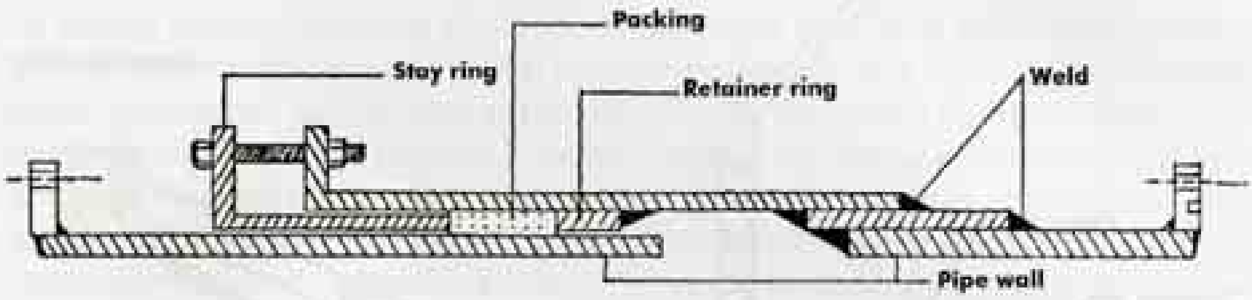


Figure 3.3: A Bolted Type Expansion Joint

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

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

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

If the expansion joint is leaking, but the pipe is not misaligned and the gap between the two ends of the pipe is correct, then extra turns of packing rope of the same size may be added. Sometimes, leakage can be stopped by just tightening the bolts of the stay ring to compress the packing further. If the packing is badly worn, it should be replaced with new packing after dismantling the joint and cleaning the surfaces. Usually, a jute rope with a square cross-section is used as packing material. If extra packing is to be added or replaced, the stay ring should be removed and the original packing taken out and new packing inserted after cleaning the surfaces. The number of turns of packing depends upon the pipe length that it needs to cover (usually between 20-30 mm). Reassembly of the joint is described below.

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

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

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

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

Chapter 4
Maintenance and Repair of Electro-mechanical Equipment

Most of the electro-mechanical equipment in an MHP scheme is located in the power-house. The equipment may include an expansion joint, a gate or butterfly valve, a manifold or adapter, the turbine, end-use equipment such as a generator or agro-processing units, and instrument and control systems. Extensive maintenance and repair of this equipment may become necessary as a result of normal wear or ageing, inappropriate operational practices, faulty design or installation, or an accident. Before commencing disassembly of any unit, always study the layout of the unit carefully. Do not remove any components of the unit that do not need to be removed because there is always a possibility of creating additional damage during disassembly or reassembly. If the parts of the units can be assembled in different positions, the mating surfaces should be marked before disassembling in order to ensure that the components are reassembled in their proper positions after the repairs have been carried out.

4.1 Valves

Valves are usually provided in an MHP plant to open or shut off the water supply completely. They should not be used to control the flow. The most common types of valves are gate or butterfly valves. Butterfly valves have mostly been used in Nepal in recent years, since they are easier to install and operate. Considerable force may be needed to operate gate valves. Figure 4.1 shows typical butterfly and gate valves.

The main sources of damage to valves are silt, rusting, lack of lubrication, using too much force to open and close them, and wear and tear. The damage may be in the form of bent or broken spindles, damaged threads, damaged seat, leakage from the valve joint or body, and difficulty in operating the valve. A small amount of water leaking from the penstock to the turbine may not be a serious problem. If the flow is large, however, then it should be stopped, otherwise the turbine will rotate.

Leakage from the stuffing box or gland can sometimes be reduced by tightening the bolts around the spindle. If the packing is badly worn, however, then it should be replaced. The bolts should be unscrewed and the handle removed. The surfaces should be cleaned with a wire brush and new rings of sealing packing should be cut to size to fit the groove around the spindle. The number of rings needed can be determined from the available length of the spindle. When cutting new rings of packing, the length should be such that

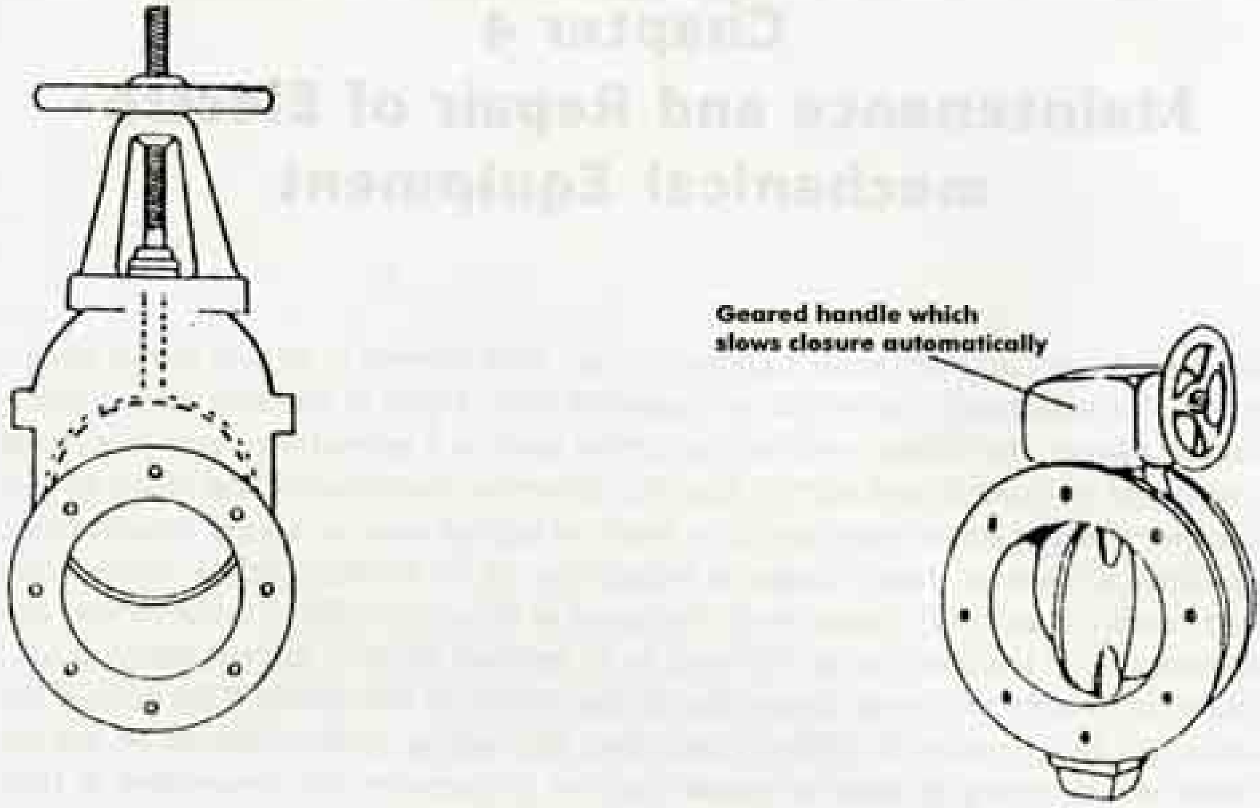


Figure 4.1: Typical Valves Used In MHP Plants

the gap between the ends of the rings when assembled is the minimum possible and there is no possibility of overlapping. Otherwise, the sealing will not be correct.

Gaskets are also provided at other joints in the valve, but most of them are not in contact with a moving part and damage is usually rare. If a joint with a gasket is leaking, then the bolts should be removed, the surfaces cleaned, and a new gasket of the same size and material installed.

If the valve does not close properly or leaks, some silt or rust may have deposited at the seat. In this case, the whole valve assembly should be removed and dismantled and the mating surfaces cleaned properly with a wire brush or emery paper if necessary.

Some valves, especially butterfly valves, may have a gearing system to transfer the motion at right angle and facilitate operation. This gearing system should be kept properly lubricated and oil replenished at the time of extensive maintenance or whenever the valve is disassembled for cleaning or repairs.

If the spindle of a valve is bent, it is usually difficult to repair and should be replaced. In general, many workshops are able to fabricate a spindle.

4.2 Turbines

Either crossflow or Pelton turbines are used in most MHP plants. Crossflow turbines are usually used for low heads, up to about 50m, whereas Pelton turbines are used for larger heads. Essentially, the turbines convert the potential and kinetic energy of the flowing water into mechanical power to be used for other purposes such as driving a generator or an agro-processing unit.

4.2.1 Crossflow Turbines

Figure 4.2 shows a typical section through a crossflow turbine. Damage can be caused to the turbine, especially to the runner, bearings and shaft, by improper installation or operation, silt or small stones in flowing water, and lack of timely routine maintenance or minor repairs leading to extensive damage to the part concerned as well as to other parts. For example, if a bearing is worn out and is not replaced, the subsequent damage may extend to the bearing housing, the shaft, and the seals. The causes and types of damage to crossflow turbines, and the appropriate repair processes, are outlined briefly in Table 4.1.

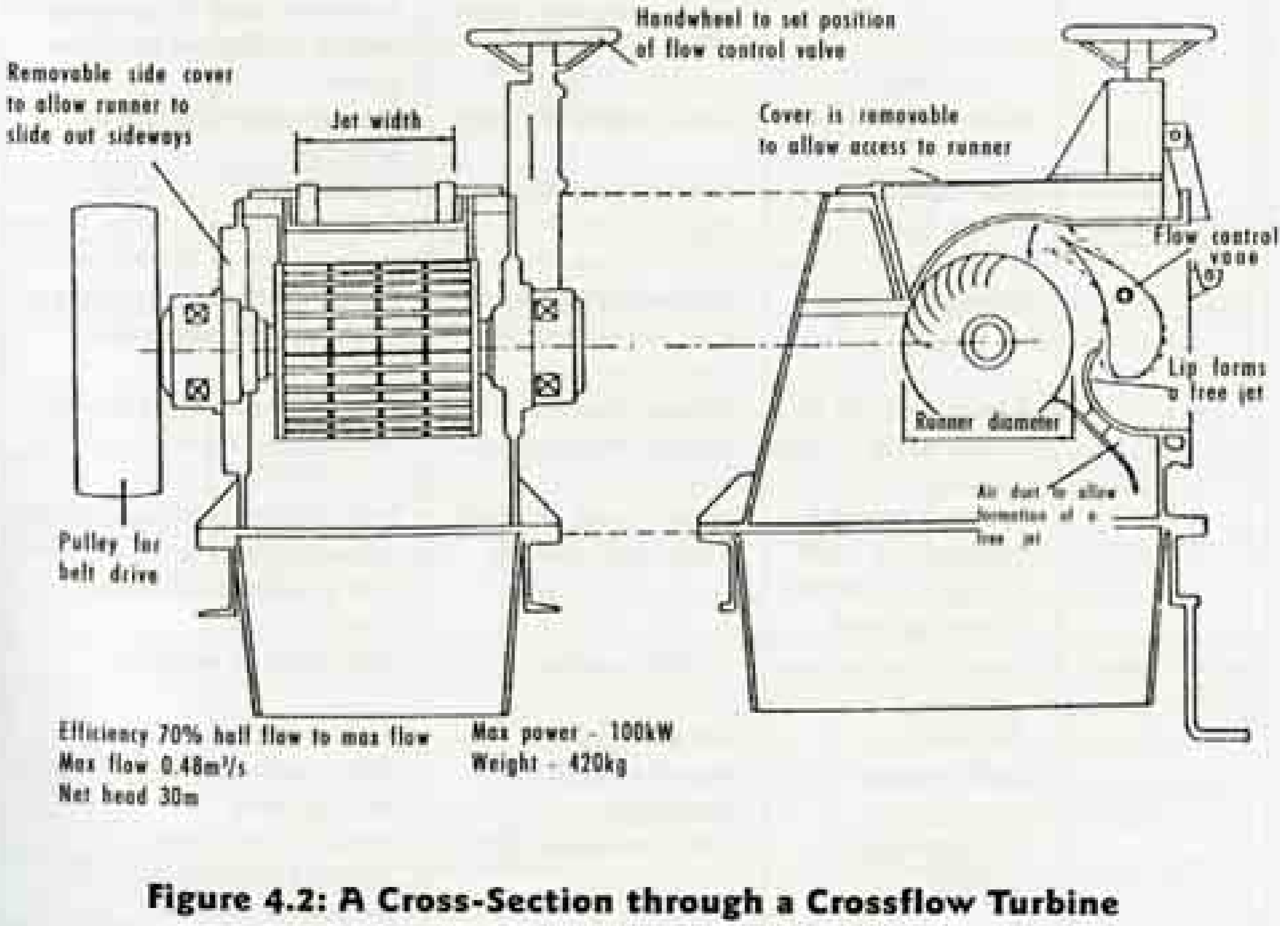


Figure 4.2: A Cross-Section through a Crossflow Turbine Showing the Main Components

Table 4.1: Types of Damage, Causes, and Appropriate Repairs for a Crossflow Turbine

Type of Damage	Cause	Identification / Assessment	Repairs
Vane assembly not functioning properly	- Bent spindle	- Rotate wheel/handle to check if it operates freely - Disassemble and check straightness	- Replace spindle
	- No lubrication	- Dismantle and check quality of grease	- Remove old grease - Clean with kerosene - Apply fresh grease - Assemble and check working
	- Vane jammed	- Remove turbine cover - Check for foreign material or rust	- Remove foreign material if any - Remove rust and clean surfaces
	- Bushes worn out	- Check bushes	- Replace bushes if damaged - Otherwise clean and assemble - Replace seals and gaskets
Runner not picking up speed	- Stones or other solids in casing	- Rotate runner and listen to noise - Open casing and inspect	- Remove covers/parts of casing and remove stones - Sometimes sides of casing also need to be removed to remove stones
	- Blades bent or broken	- Open casing and inspect	- Remove runner and take to workshop
	- Shaft bent	- Disassemble and inspect shaft	- Replace shaft *1
	- Damaged bearings	- Remove bearings from shaft and housing and check by rotating	- Replace bearings by new ones of same type and specifications
	- Runner touching the side of casing or seal housing	- Remove cover and check spacing, rotate runner as well	- Centre the runner and bearings and tighten, check nut and lock
	- Casing deformed or damaged as a result of impact or touching of rotating runner	- Inspect casing especially around seals and side	- Small amount of damage may be repaired by hammering and filling - Take to workshop if damage extensive
Turbine/runner vibrates	- Some blades damaged	- Inspect blades (as above)	- Take runner to workshop
	- Bent shaft	- Inspect as before	- Replace shaft
	- Shaft worn out	- Inspect shaft after removing it	- Take to workshop for welding and machining
	- Damaged/loose bearings	- Check bearings as before	- Replace by same type - Tighten bolts/nuts after positioning properly

*1 It is usually difficult to straighten a bent shaft.

Table 4.1 Cont.......

Type of Damage	Cause	Identification / Assessment	Repairs
	- Side plate or bearing housing bolts loose - Loose foundation bolts - Shaft broken	- Check nuts and bolts - Check vibration on base and bolts - Inspect shaft as before	- Tighten nuts/bolts - Replace damaged ones - As above - Redo concrete to fix foundation bolts properly - Take to workshop for welding and machining - Replace shaft
Leakage at sealing	- Sealing flange bolts loose - Packing worn out - Loose bolts on non-contact seal	- Inspect bolts of sealing flange - Dismantle packing flange and inspect - Dismantle runner - Check if the sealing bolts are loose	- Tighten bolts but not too tight - If leakage continues, replace packing - Replace packing by one of same size and material - Tighten the bolts after positioning
Leakage from control vane (valve)	- Packing worn out - Bush of vane shaft worn out	- Open side cover of vane shaft and inspect packing - Dismantle shaft and check bush by measuring diameter	- Replace packing by same size and material - Replace bush with new one of same size
Casing badly rusted	- Corrosion - Damaged paint	- Inspect affected area - As above	- Remove rust and repaint - Use putty/filler before painting
Bearings too hot	- No grease or old grease	- Open bearing cover and inspect grease	- Clean bearings - Apply fresh grease as necessary
	- Too much grease	- As above	- Check and reduce grease if necessary
	- Rollers or balls worn out	- Remove bearings, turn them, listen to the noise	- Replace bearings by new ones of the same size and quality
	- Worn out housings	- Open housings, check for wear	- Replace with new housing of same size
	- Misalignment of housing	- Open top cover of bearing housing and check if it fits properly without bolts	- Adjust the bearing block or insert shims to improve alignment if the housing is separate from the casing
		- Remove pulley, place a spirit level on the shaft axially and check whether the bubble is in the centre	- If the housing is bolted to the casing, loosen the bolts of bearing housing and raise/lower the housing to get proper alignment

Small crossflow turbines are generally assembled from the base upwards. To dis-assemble a small crossflow turbine proceed as follows.

- Disconnect couplings or remove belts from the runner shaft.
- Separate the whole turbine from the penstock and the draft tube (if installed).
- Remove the bearings from the runner shaft by unbolting from the casing and slackening the socket head screws locking the bearing sleeves to the runner shaft.
- After removing the side sealing plates, the runner can be taken out from the base of the casing.
- To remove the guide vane, remove the retaining bolt and washer from the end of the guide vane shaft and drive the shaft out with a hammer and a blunt drift.

Assembly is usually a reversed sequence of disassembly. To reassemble the turbine, proceed as follows.

- Replace the damaged gaskets or seals with new ones and replace any worn or damaged parts with equivalent new units. (It is better to replace all seals after any disassembly.)
- Position the guide vane in the casing and drive the shaft and key into position with a mallet or a light hammer. Fit the retaining bolt and washer to the end of the shaft and tighten.
- Place the runner in the casing and fix the sealing plates.
- Bolt bearing housings in position and centre the runner. If unsealed bearings are used, clean the bearings well with kerosene prior to assembly and half fill with a good quality bearing grease. Do not overfill.
- After centring the runner, tighten socket head screws to secure bearing sleeves to runner shaft.
- Check that the runner rotates freely and does not touch the housing.
- Replace and apply tension to belts or coupling. If V-belts are used, increase tension until each belt can be deflected about 15 mm for each metre of span when pressed with the full force of a finger at the mid point between the two pulleys. If a flat belt is used, follow the manufacturer's recommendations to obtain proper tension.

4.2.2 Pelton Turbines

Pelton turbines (Figure 4.3) are fast running machines that work under a much higher head than cross-flow turbines; thus they have to be precision made. The runner of a Pelton turbine consists of buckets cast from cast steel or bronze that are fixed to the runner disk by welding or bolting. One or more jets of water diverged from the penstock manifold hit the buckets. The flow in each jet is controlled separately using a spear valve and nozzles. Usually, automatic jet deflectors are also provided for each jet that can deflect the flow and stop the turbine in an emergency.

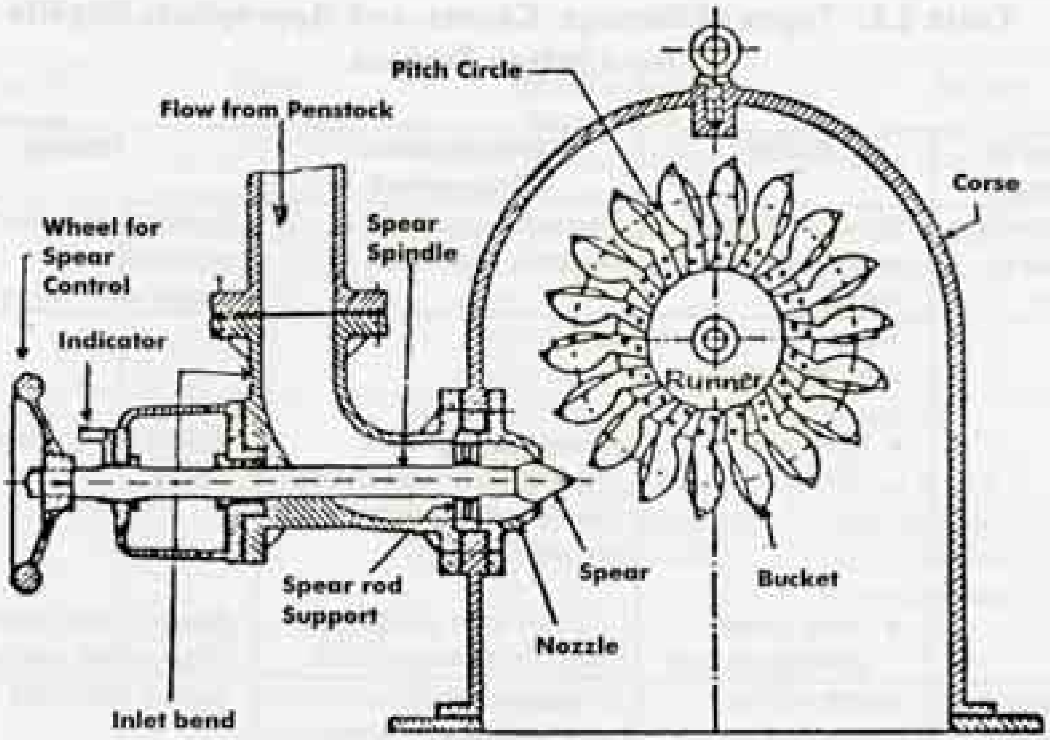


Figure 4.3: Cross-Sectional View of a Single Jet Pelton Turbine

The sources of damage to Pelton turbines are mostly similar to those for crossflow turbines. They include such things as a stone blocking the nozzle or hitting the buckets, inappropriate operation, inappropriate design, and low quality equipment or components. The types of damage that can occur to various parts or components of a Pelton turbine are listed in Table 4.2, together with suggestions and procedures for repairs. The procedures for dismantling and assembling these turbines are given below.

To disassemble a Pelton turbine with the runner directly mounted on the generator shaft proceed as follows.

- Remove the casing access cover.
- Remove the bolt or tapered sleeve holding the runner to the generator shaft. (Refer to section 4.2.3 for removal instructions for tapered sleeves.)
- Remove the runner from the shaft

Assembly is the reverse of the above procedure. Prior to assembly, clean all mating surfaces well, especially the shaft and runner mating surfaces. Replace all gaskets and any worn or damaged parts with equivalent new ones. Smear the shaft and runner mating surfaces with grease and reassemble.

Table 4.2: Types of Damage, Causes, and Appropriate Repairs for a Pelton Turbine

Type of Damage	Cause	Identification/ Assessment	Repairs
Inadequate flow from nozzle assembly	- Stone or other material stuck in nozzle	- Dismantle spear valve assembly and inspect	- Remove foreign object without damaging nozzle/spear surface
	- Spear valve not opening properly • Bent screw	- Dismantle spear valve assembly and inspect screw - Turn the screw to check bending	- Replace screw if damaged*[1]
	• Foreign object jamming the bush	- Remove spear spindle from bush and mating surfaces	- Remove foreign material - Clean surface and reassemble
Proper jet not forming	- Nozzle end tip damaged as a result of silt/erosion	- Dismantle nozzle tip, measure internal diameter, and check roughness	- Replace if damaged
Leakage from spear valve assembly	- Packing/seal worn out	- Dismantle spear valve sealing unit	- Replace packing/O-ring
	- Spear spindle damaged	- Remove the retaining nut, inspect spindle	- Weld spindle if pitted and re-machine
	- Retaining nut loose/damaged	- Check spindle for damage	- Replace retaining nut if damaged
Play in spear spindle	- Threads damaged	- Dismantle spindle and inspect threads on both surfaces	- Replace damaged parts (bush or spindle) - Re-machine spindle threads if damaged
Jet deflector not functioning properly	- Cover bent	- Dismantle and inspect for damage	- Straighten bent part
	- Deflector plate slipping	- As above	- Weld and re-machine
	- Plate/spindle worn out	- As above	- Weld and re-machine or replace

*[1] It is usually not possible to straighten a shaft properly. Therefore, replacement is the best solution.

Table 4.2 Cont.......

Type of Damage	Cause	Identification/ Assessment	Repairs
Magnet not holding	- Solenoid damaged/burnt out - No power supply (AC/DC)	- Check resistance/ continuity using multimeter - Check power supply both input and output of solenoid circuit - Check rectifiers and other components	- Rewind solenoid if damaged - Replace damaged components and restore power
Runner not rotating freely	- Shaft bent - Bearing damaged - Bearing not gripping shaft • taper sleeve/neck washer damaged - Bearing block slid - Bearing check nut loose/damaged	- Take out runner and inspect shaft for bending - Take out bearing, clean, rotate and listen to sound, inspect play (worn rollers) - Open check nut, take out washer and inspect - Remove block, check for damage (cracking, wear) - Open cover of bearing block and inspect check nut	- Replace shaft - Replace bearing - Clean, refit after properly aligning and insuring same clearance around shaft - Replace locking washer - Replace block if seriously damaged - Replace if damaged or tighten if loose
Runner/turbine vibrates	- Broken bucket - Runner unbalanced - Bearing damaged - Loose tapered sleeve - Shaft scoured/pitted - Foundation or bearing block bolts loose	- Take out runner and inspect - Remove casings cover, rotate runner slowly and let it stop normally. if it stops in the same position repeatedly or it rotates backwards then it is unbalanced - Inspect bearing - Remove bearing cover and inspect nut - Check tightness of nuts - Remove and inspect shaft - Check whether foundation bolts loose in concrete	- Replace bucket by one of same size - Get runner balanced - Get runner balanced at a proper workshop - Replace bearing if damaged - Clean and apply grease - Tighten check nut using spring washer - Replace check nut/sleeve if damaged - Get shaft welded and machined - Dig out and re-build the foundation

Table 4.2 Cont.......

Type of Damage	Cause	Identification/ Assessment	Repairs
	- Jet not properly centred	- Remove top covering and measure perpendicular distance between centre of nozzle and casing and centre of bucket and casing to see if the two are the same	- Move runner side ways to centralise the jet - Tighten nuts/bolts
Leakage from casing • At casing joints	- Loose bolts - Gaskets between casing flanges damaged - Casing flange deformed	- Inspect bolts - Remove and inspect gaskets - Remove and inspect casing/flange for deformation pitting/cracking	- Tighten as necessary - Replace if damaged - Repair deformation by hammering and filing - Fill holes/cracks with sealing epoxy putty
• At shaft entry point	- Sealing system damaged	- Remove turbine cover and inspect the sealing assembly for deformation and damage	- If deformation is small repair it by hammering and filing - Otherwise replace or send to workshop
	- Clearance between two discs too large	- Remove sealing component on the shaft - Remove cover and inspect clearance between the two sealing discs	- Adjust the clearance (about 2-3 mm)
	- Gasket between casing and sealing disc may be damaged	- Remove both sealing discs and inspect gasket	- Replace gasket if damaged - Tighten bolts

To disassemble a Pelton turbine with a belt or coupling drive proceed as follows.

- Remove the belts or coupling
- Remove the access cover in casing
- Unbolt sealing device discs from casing
- Remove bearings from runner shaft and casing. (If bearings are provided with tapered sleeves, refer to sections 4.2.3 and 4.2.4 below.)
- Remove runner and shaft from the casing.

To reassemble, proceed as follows.

- Clean runner shaft well and remove rust or other deposits from bearing mounting area with fine abrasive paper. Replace any worn or damaged components with equivalent new units.
- If unsealed bearings are used, wash in kerosene and half fill bearings with a good quality bearing grease. Do not overfill. Replace all gaskets and any worn or damaged parts with equivalent new units.
- Install runner and shaft in casing and position bearings on shaft.
- Lock bearing inner race to runner shaft. (If tapered mounting sleeve is used, refer to section 4.2.3 and 4.2.4 below for instructions).
- Bolt sealing device discs into place (Figure 4.4).
- Rotate runner and ensure that it is rotating freely and not touching any other component.
- Install access cover and belts or coupling. If V-belts are used, adjust tension as described above in section 4.2.1. If a flat belt is used, follow the manufacturer's recommendations for proper tension.

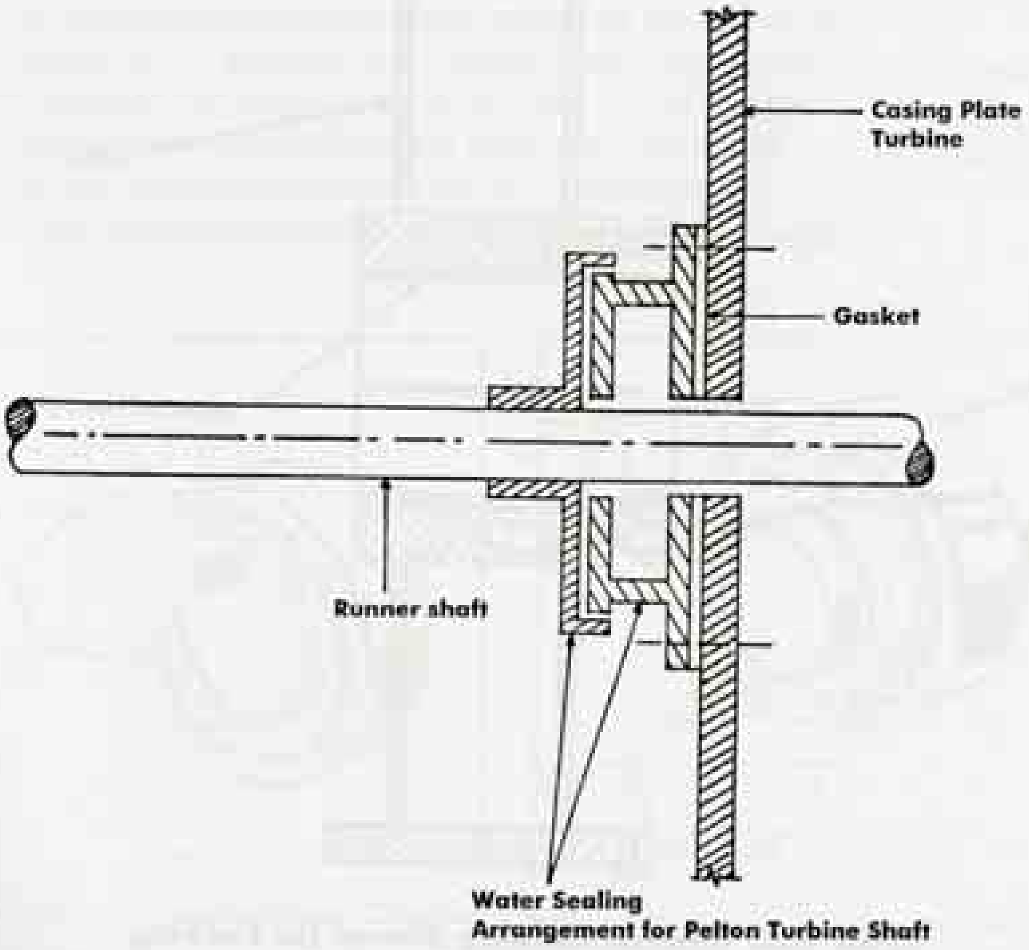


Figure 4.4: Non-Contact Seal for Pelton Turbine Casing

4.2.3 Tapered Locking Sleeves

The general layout of a tapered locking sleeve used for bearings or pulleys is shown in Figure 4.5. To remove the tapered locking sleeve, first remove the screws or bolts from the sleeve. Fit bolts to the jacking bolt holes provided on the hub in between the clamping bolt holes and torque evenly until the sleeve is removed. The bolts used for tightening the sleeves should not be used as jack bolts, and damaged or incorrectly sized bolts should not be used.

To re-assemble, proceed as follows. Clean all the mating surfaces well, apply a film of grease to the outside of the tapered sleeve, and re-fit. Re-fit bolts to clamping holes and tighten uniformly. The gap marked (x) in Figure 4.5 must be approximately five mm after the bolts are tightened.

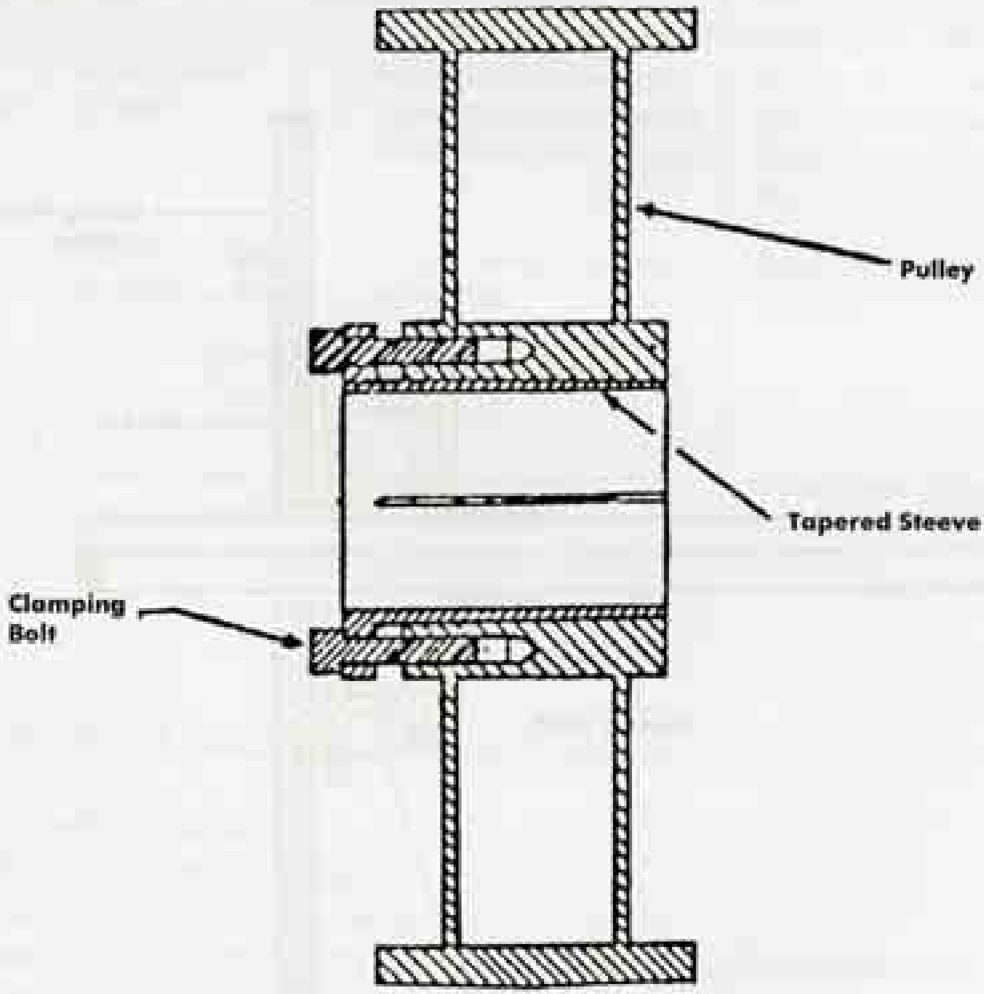


Figure 4.5: Tapered Locking Sleeve for Locking Pulleys and Runners to Shafts

4.2.4 Bearings Fitted with Tapered Adapter Sleeves

Large runners are sometimes fitted with tapered adapter sleeves to mount the bearings as these ensure a good grip between the bearings and the shaft. To remove these sleeves from the shaft, loosen the locking ring and tighten the check nut with a 'C' spanner or a blunt ended drift. The bearing can now be removed from the shaft.

Before re-assembly, clean all components well with clean kerosene. There are two techniques for re-tightening bearing sleeves, the reduction of clearance method, and the axial drive-up method, both described below. The reduction of clearance method is the better technique, but needs accurate feeler gauges. If these are not available the axial drive-up method should be used.

Reduction of Clearance Method

- Before fitting the bearing to the shaft, measure and note down the bearing clearance (between the rollers and the outer ring of the bearing) using accurate feeler gauges as shown in Figure 4.6. Rotate the bearing a few times to ensure that the rollers are sitting in their correct positions before measuring the clearance.
- Apply a thin film of grease to the outside of the adapter sleeve. Fit the bearing and adapter sleeve to the shaft and locate it in the correct position.
- Gradually tighten the locking ring and check the clearance as shown in Figure 4.6 until the clearance reduction shown in Table 4.3 is achieved.
- Tighten the withdrawal ring and secure the rings with tab washers.

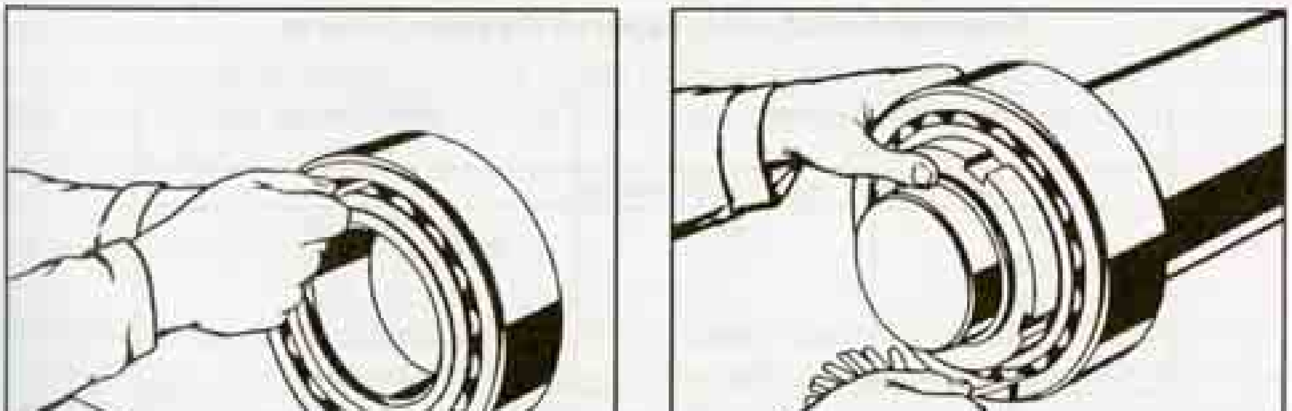


Figure 4.6: Checking Clearance of a Spherical Roller Bearing with Adapter Sleeves

Table 4.3: Reduction in Clearance for Spherical Roller Bearings Mounted with Tapered Adapter Sleeves

Shaft diameter (mm)		Reduction in radial clearance (mm)		Minimum permissible clearance after mounting (mm)
more than	up to and including	min	max	
30	40	0.020	0.025	0.015
40	50	0.025	0.030	0.020
50	65	0.030	0.040	0.025
65	80	0.040	0.050	0.025
80	100	0.045	0.060	0.035

Axial Drive-up Method

- Apply a thin film of grease to the outside of the adapter sleeve and fit the bearing and adapter sleeve to the shaft.
- Tighten the locking ring with a spanner or blunt-ended drift until it is just firm.
- Measure and note the distance from the bearing inner race to the end of the adapter sleeve with a vernier calliper.
- Tighten the locking ring until the measurement made in step 3 is reduced by the axial drive-up amount shown in Table 4.4.
- Tighten the withdrawal ring and secure the rings with tab washers.

Table 4.4: Axial Drive-Up Amount for Spherical Roller Bearings Fitted with Tapered Adapter Sleeves

Bearing bore diameter (mm)		Axial drive-up (mm)
more than	up to and including	
30	40	0.35 - 0.40
40	50	0.40 - 0.45
50	65	0.45 - 0.60
65	80	0.60 - 0.75
80	100	0.7 - 0.9

4.2.5 Checking Bearing Damage

Bearings can be checked roughly for performance by feeling the cover of the housing for unusual temperature rise, noise, or vibrations. Noise/vibrations can be detected with the hand or with an object such as a screwdriver that can amplify the sound, as shown in

Figure 4.7. The operator should constantly monitor the condition of important bearings in this way so that he/she knows the correct sound for each bearing and can quickly notice changes in the noise or vibration level. Bearings should also be removed from the housing occasionally and rotated while holding close to the ear to listen to the noise. Any sharp crackling indicates damage to the recess or the rollers.

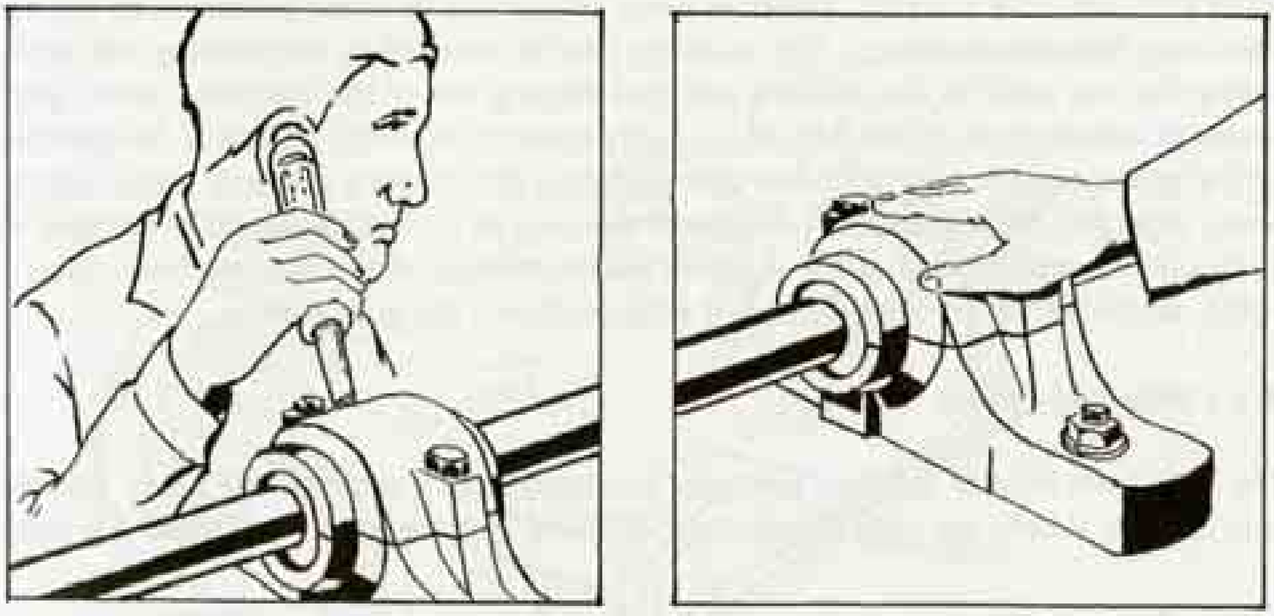


Figure 4.7: Simple Techniques for Sensing Bearing Noise and Condition

4.3 Power Drive Systems for MHP Plants

Mechanical power may be transmitted from the turbine shaft to the driven shaft of a generator or some other machine either by direct coupling or by belt and pulley systems. Direct couplings are usually used for Pelton turbines when the speed of the generator and the turbine is the same. In the case of Peltric sets, the runner is mounted directly on the generator shaft.

4.3.1 Couplings for Direct Drives

Rigid couplings can be used for direct drive systems when the speeds of the two shafts are the same. However, since there is almost always some misalignment between the two shafts, flexible type couplings are mostly used for MHP plants since these can withstand some level of misalignment and vibration. There are many different types of flexible couplings available in the market with different trade names. The main component of such couplings is usually a rubber-based joint that absorbs vibrations. Damage to the couplings, especially to the rubber components, may be caused by excessive misalignment of the shaft and resulting vibrations, loose bolts in the coupling, water, and lubricants. The damage can show in the form of deterioration of rubber and/or slipping. The damage should be inspected and assessed by watching the coupling while it is rotating for slipping, noise, and other such malfunctions; and by stopping the turbine and inspecting the rubber component thoroughly.

Usually it is very difficult to repair flexible couplings and they should be replaced when the damage becomes extensive. Rubber can deteriorate more quickly in the presence of lubricants, oils, and solvents. Therefore every effort must be made to keep such chemicals away from the couplings. The couplings can be removed by dismantling and separating the two parts of the coupling and then moving one of the machines, either generator or turbine, from its position. It is usually easier to move the generator. Reassembly and alignment of the two machines after replacing the coupling are fairly skilled operations, especially the alignment. A skilled and experienced technician should be engaged to carry out the replacement of the coupling and reassembly of the two machines. Alignment can be performed using a straight edge as shown in Figure 4.8.

4.3.2 Belts and Pulleys

The belts used in MHP schemes generally belong to one of two different types. Usually one or more V-belts are used for plants of 20kW or less (Figure 4.9); whereas flat belts

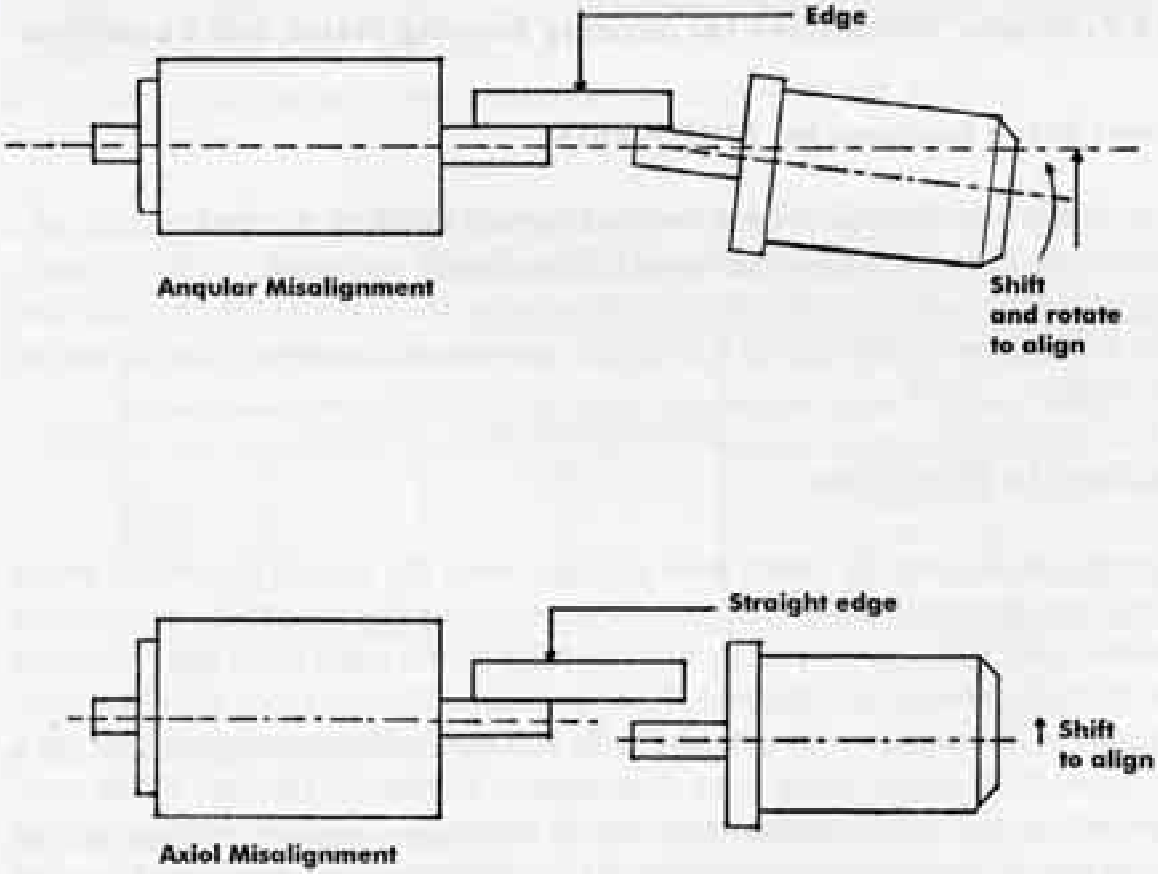


Figure 4.8: Aligning Two Directly Coupled Shafts Using A Straight Edge

are mostly used for larger plants. Belts are fitted over the pulleys provided on both the shafts. If a flat belt is used, the surface of the pulley will be almost flat with a small rounded 'crown'. If a V-belt is used, the appropriate number of grooves will be provided on the outer surface of the pulleys which are usually fixed to the shafts with the help of keys or in some cases by tapered sleeves.

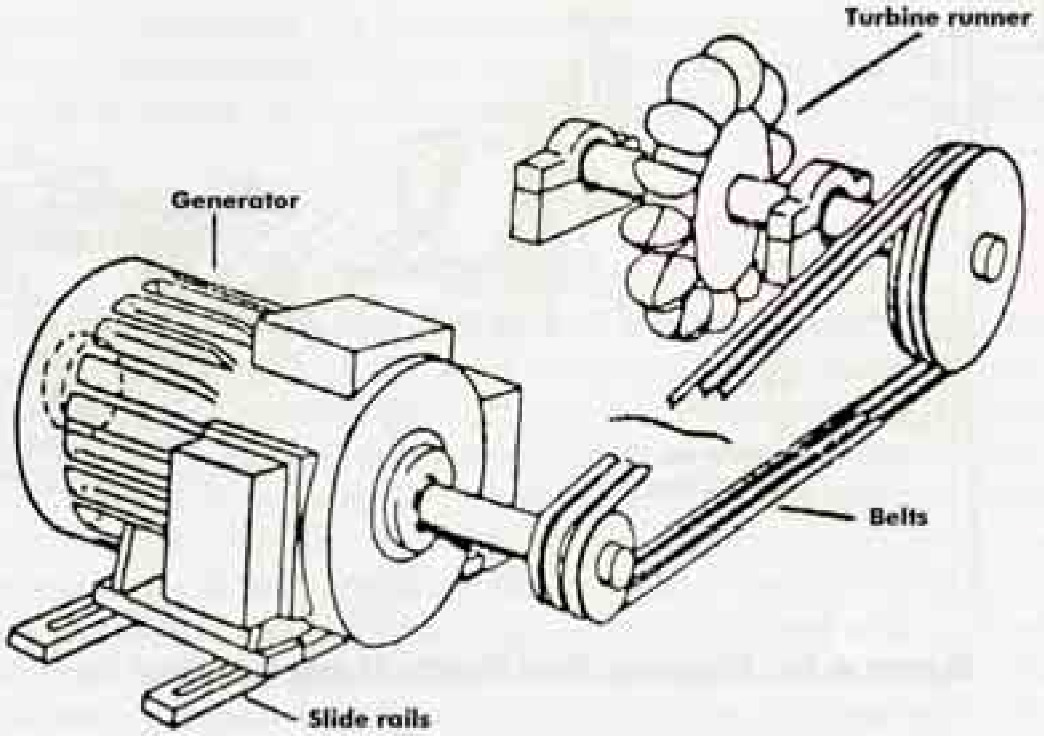


Figure 4.9: Sketch of a V-Belt Drive System

Damage to the pulleys and the shafts may be caused by improper installation — including misalignment between the two shafts or pulleys, improper handling during assembly and removal of the pulleys or belts, rusting, and loose belts or loose keys. Damage to the pulleys may be in the form of a broken or bent arm leading to further misalignment, which may in turn result in belts being thrown off, or pulleys becoming loose or slipping on the shaft and causing damage to tapered sleeves or even scouring the shaft.

If the arms are made of mild steel, damage can be repaired in a workshop by straightening or even welding. If the arms are made of cast iron, then they cannot be repaired and should be replaced. If the diameter of the hole that fits on the shaft has become too large or gone out of shape, then the surface of the hole should be machined and a bush can be pressed into it in a workshop to make it fit the shaft diameter. If tapered sleeves are damaged as a result of misalignment or slipping of the pulleys, they should be replaced.

Damage to the pulleys may also be caused by the two shafts not being parallel, i.e., having angular misalignment. In such cases, a skilled and expert technician should be hired to realign the two shafts properly. This can be done using a string as shown in Figure 4.10.

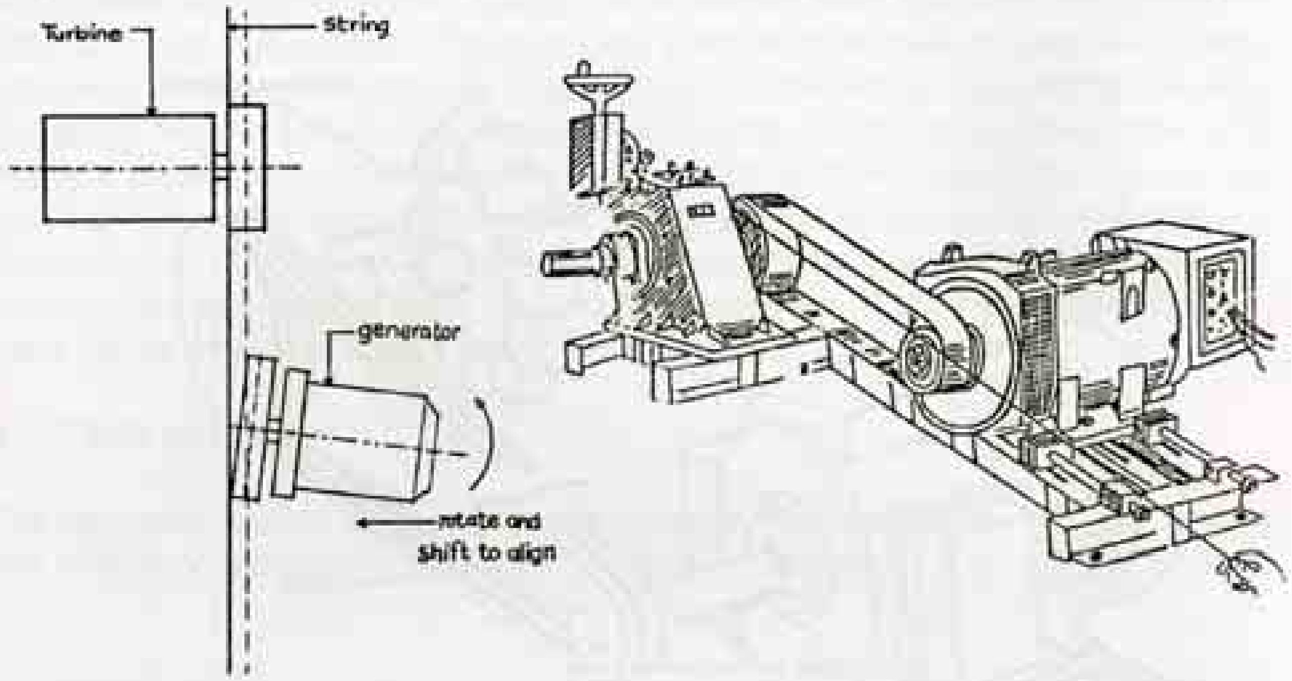


Figure 4.10: Aligning Two Shafts Using a String

Damage can be caused to the belts by, amongst others, misalignment, mishandling, the presence of grease or another substance on the surfaces, a bad joint in a flat belt, improper tension, and a rough surface on the pulley. The damage can appear in the form of belts becoming longer and therefore slipping, wearing out, or cracking. Slightly damaged V-belts can be left in position until they are damaged badly. This is allowable since more than one belt is usually used. Once they are damaged extensively they must be replaced, they cannot be mended. It is not a good idea to mix old V-belts with new V-belts since the new V-belts may be shorter as the belts stretch through use. It is recommended that all the belts should be changed at the same time. Old belts may, however, be stored and re-used to replace single extensively damaged belts once the new belts have stretched.

Flat belts can be joined using thermal and chemical equipment, but this cannot be done at the site. Thus if a part of a flat belt, especially a nylon type flat belt, gets damaged; it can be taken to a workshop where the damaged portion can be removed and another piece joined to it using special equipment. Flat belts used for MHP plants, especially for generation of electricity, should not be joined with bolts. Solvents and lubricants can also damage the belts and care should always be taken to keep such chemicals away from the belts. If solvents or lubricants do come into contact with a belt, they should be wiped off as quickly as possible and the belts washed with soap and water.

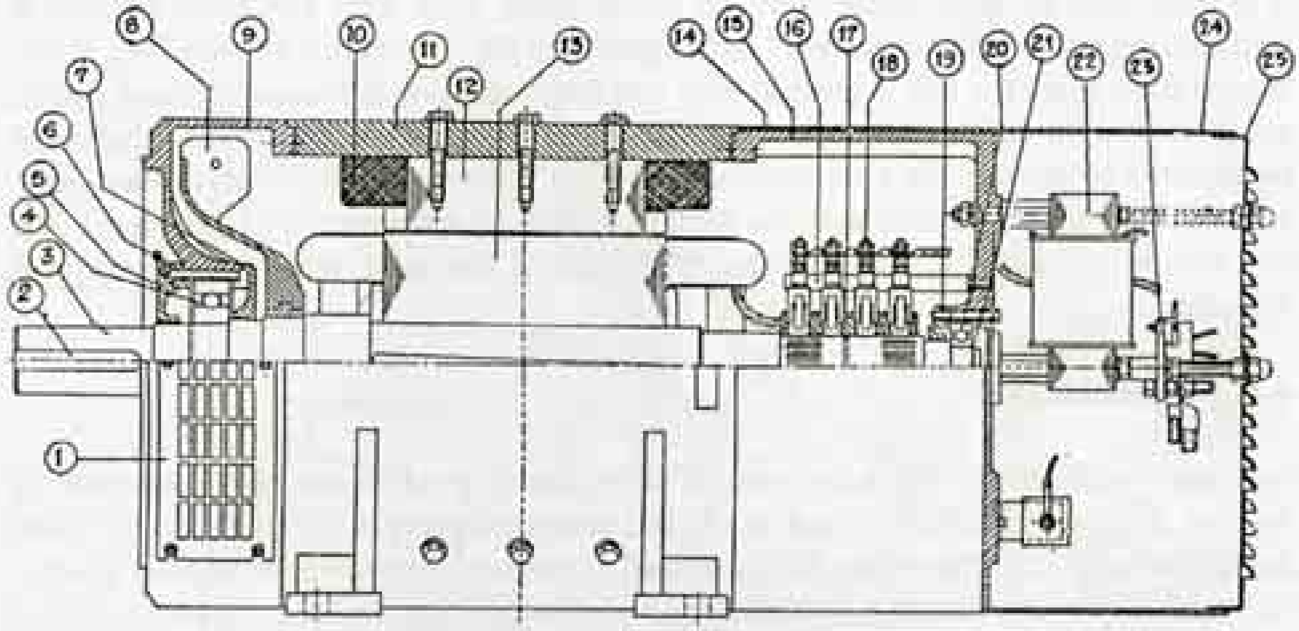
It is important to apply proper tension to the belts, both from the point of view of transmitting power efficiently and of prolonging their life. The correct tension for a V-belt is such that, when the belt is pressed with one finger applying full force, it should deflect about 15 mm for each metre of the span. The tension on both V-belts and flat belts can be adjusted by moving the two machines nearer or further away from each other. However, the two machine shafts will also need to be aligned if the machines are moved, and this should be carried out by a skilled technician at the same time as the tension is adjusted.

4.4 Generators

Two main types of generators are used for MHP plants: synchronous generators with or without brushes (Figures 4.11 and 4.13) and induction generators (Figure 4.14). These days, electronic load controllers (ELC) are used in conjunction with synchronous generators. ELC sense any variation in frequency and divert excess available power to ballast heaters as required. In this way, the load on the generator and turbine is maintained at a constant maximum all the time and both the voltage and frequency are constant. Induction generators are actually reversed induction motors. They are robust in construction and available cheaply and in a wide range of sizes. Even very small sizes of induction generators are available freely. Induction generator controllers (IGC) have also been designed recently. IGC sense variation in the output voltage and divert any excess power to ballast heaters, thus keeping the load, voltage, and frequency constant.

Damage may be caused to the generators by both mechanical and electrical mishaps. If the shaft is vibrating too much this will cause mechanical damage to the generator. If an excessive load has been connected to the generator, the windings may heat up causing a short circuit or the rectifiers or diodes may burn out. A low turbine speed can also damage the generator as it will cause the frequency to drop and the windings to heat up.

The common problems associated with brush type and brushless synchronous generators and induction generators are listed below in Tables 4.5, 4.6, and 4.7, together with their causes, methods of identification, and suggested methods of repair.



Parts List

1. Ventilation grid D.E
2. Extension key
3. Shaft
4. Ball bearing D.E
5. External bearing cap D.E
6. Conical head grease nipple
7. Internal bearing cap D.E
8. Fan
9. D.E shield
10. Field shell
11. Rolled shell
12. Pole brick assembly
13. Rotor assembly Circular band N.D.E
14. Circular band N.D.E
15. N.D.E. shield
16. Brush holder spindle
17. Slipring assembly
18. Brush holder assembly
19. Inside bearing cap N.D.E.
20. Ball Bearing N.D.E.
21. Circlip
22. Mx. unit assembly
23. Terminal board
24. Circular band mx.
25. Ventilator

Figure 4.11: Cross-Sectional View of a Synchronous Brush Type Generator

Table 4.5: Common Problems of Brush Type Synchronous Generators and Suggested Methods of Repair

Problem	Cause	Identification/Assessment	Repairs
No voltage output from generator	- Loss of residual magnetism	- Disconnect field wires and run the generator. Check the residual voltage across the generator output terminals. It should be approximately 5% of the rated voltage and be balanced between each pair of lines.	- If the residual voltage is less than 5% of the rated voltage, the generator field should be 'flashed' by connecting a 12 volt battery across terminals F1 and F2 for about 5 seconds making sure that F1 is positive and F2 is negative
	- Wrong field connections	- Check to ensure that the positive terminal of the rectifier is connected to F1 and the negative terminal to F2	- Switch connections if necessary
	- Open circuit in excitation unit	- Check continuity of the compounding transformer windings - Check connection between the compounding transformer and rectifier	- Correct as necessary
	- Faulty rectifier	- Flash generator field and check the output voltage at the terminals while generator is rotating. If output voltage is less than 5%, stop the unit and check the rectifiers with a multimeter.	- Replace rectifier if faulty
	- Carbon brushes may not be making good contact with slip rings	- Check contact between carbon brushes and slip rings	- Replace carbon brushes if worn
	- Short circuit or open circuit in armature winding	- Measure armature resistance	- Rewind if damaged
Low or high voltage from the generator on no load	- Low or high speed	- Check the speed	- Adjust speed by regulating flow
	- Incorrect connections between compounding transformer tappings and rectifier	- Check connections	- Correct connections if necessary

Table 4.5 Cont.......

Problem	Cause	Identification/Assessment	Repairs
	- Internal short in one of the field coils	- Measure resistance of each coil	- Rewind or change coil if necessary
	- Compounding transformer air gap too narrow/wide	- Check gap	- Adjust air gap
	- Compounding transformer may be defective	- Check output voltage of each winding	- Replace defective parts
Output voltage fluctuating	- Unbalanced currents in compounding transformer windings	- Check connections between compounding transformer tappings and rectifier tappings, they should be the same.	- If balance is slightly out, up to about 5% can be compensated for by adjusting the air gap within the compounding transformer
		- Check air gap between the two cores compared to specifications	- Increase air gap to increase generator voltage output
	- Load current is unequal between phases and not according to the generator rating	- Check load current on each phase	- Rearrange load between phases to balance
	- Generator overloaded	- Check the load current	- Reduce load if higher than rated load on each phase
	- D-windings are reversed	- If the voltage falls excessively when the load is applied, check D-windings for wrong polarity. After reconnection, check the voltage at the slip rings and output terminals.	- Correct D-winding connection. The slip ring voltage should be a few per cent lower than the voltage at the output terminals (Figure 4.12).
Overheating of generator or some parts	- Overloading of generator	- Check the load and compare to rated capacity	- Reduce load if overloaded
	- Insufficient ventilation	- Check screens and fan	- Clean generator and generator air inlet screens. Remove items that may be blocking the flow of cooling air to the generator while running - Provide additional ventilation to the powerhouse if necessary
	- Internal short circuits	- Measure resistance	- Rewind if there is an internal short circuit
	- Bearings worn out, damaged, or incorrectly installed	- Check bearings	- Refit or replace with new unit if necessary

Table 4.5 Cont.......

Problem	Cause	Identification/Assessment	Repairs
	- Too much or not enough grease in bearings	- Check grease	- Remove old grease and add fresh grease, half filling the bearings
Vibration of generator	- Bearings worn out	- Check bearing sound while rotating and after removal	- Replace with new bearings of same size and type
	- Bearing loose in housing	- Check whether bearing is loose in housing	- Remove the bearing by dismantling the side covers
		- Replace bearings in housing and check play	- Replace housing if too much play
	- Loose foundation bolts	- Check all foundation bolts	- Tighten if necessary - Reconcrete foundation bolts if foundation damaged
	- Pulley or rewound generator rotor out of balance	- Remove belts and rotate pulley. If it stops in the same position each time either the pulley or the generator rotor is out of balance. Remove the pulley and try the same test. If the generator rotor stops in a different position each time, the pulley is out of balance	- Return the pulley to the manufacturer for rebalancing
		- If the generator rotor stops in the same position each time the rotor is out of balance	- Return generator to the manufacturer for rebalancing

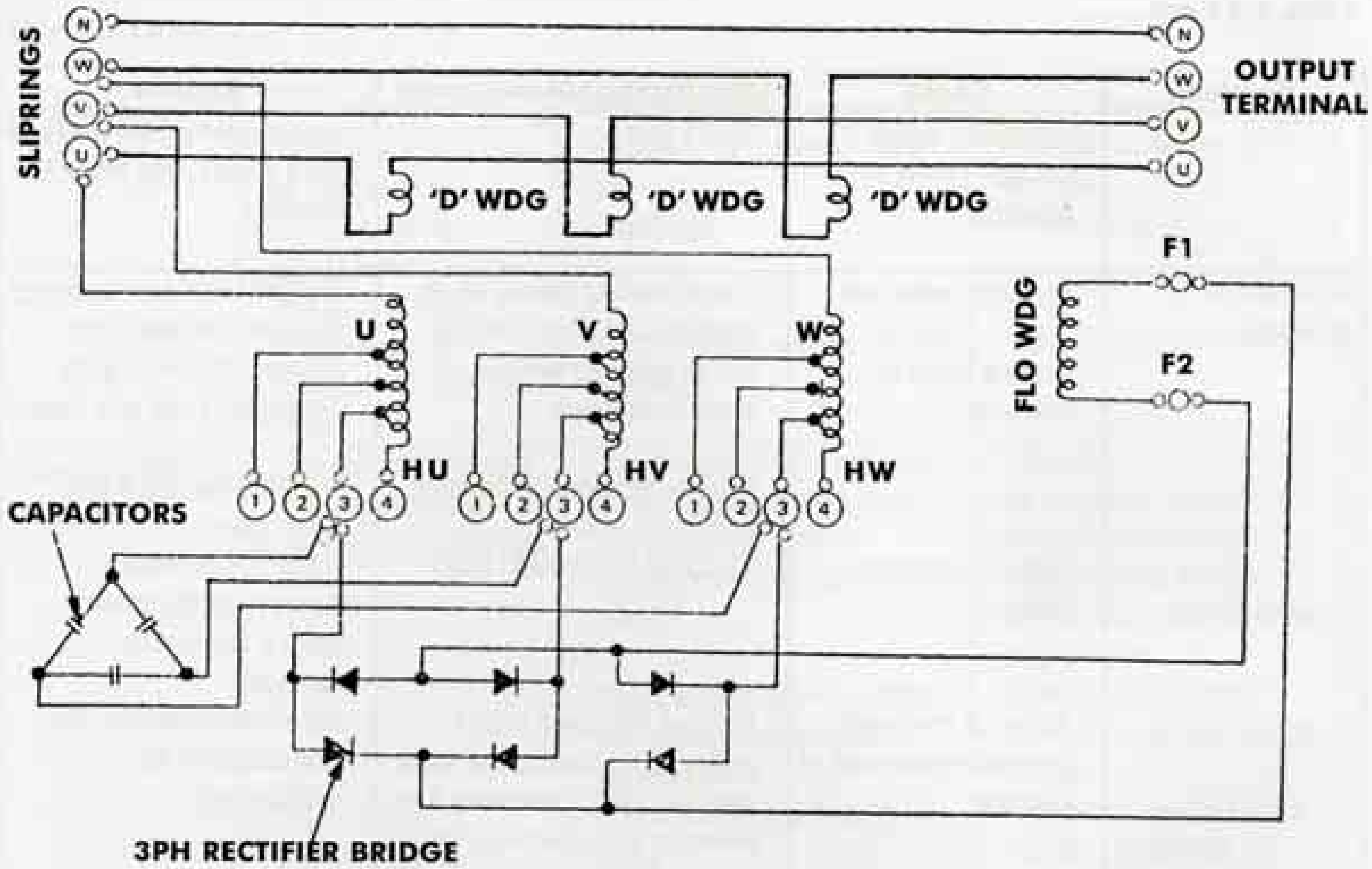


Figure 4.12: Wiring Diagram for a Synchronous Generator Showing D-Windings

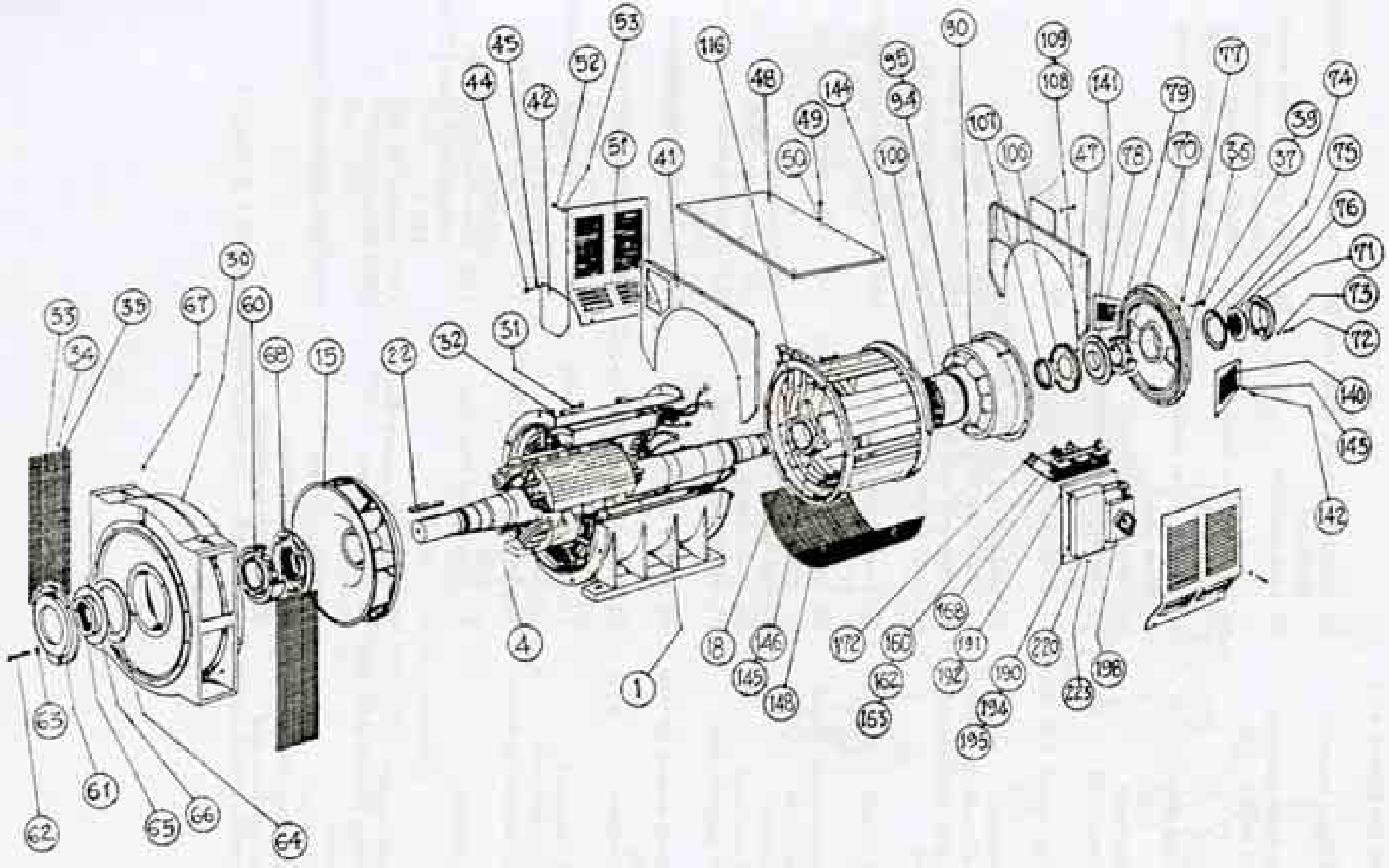
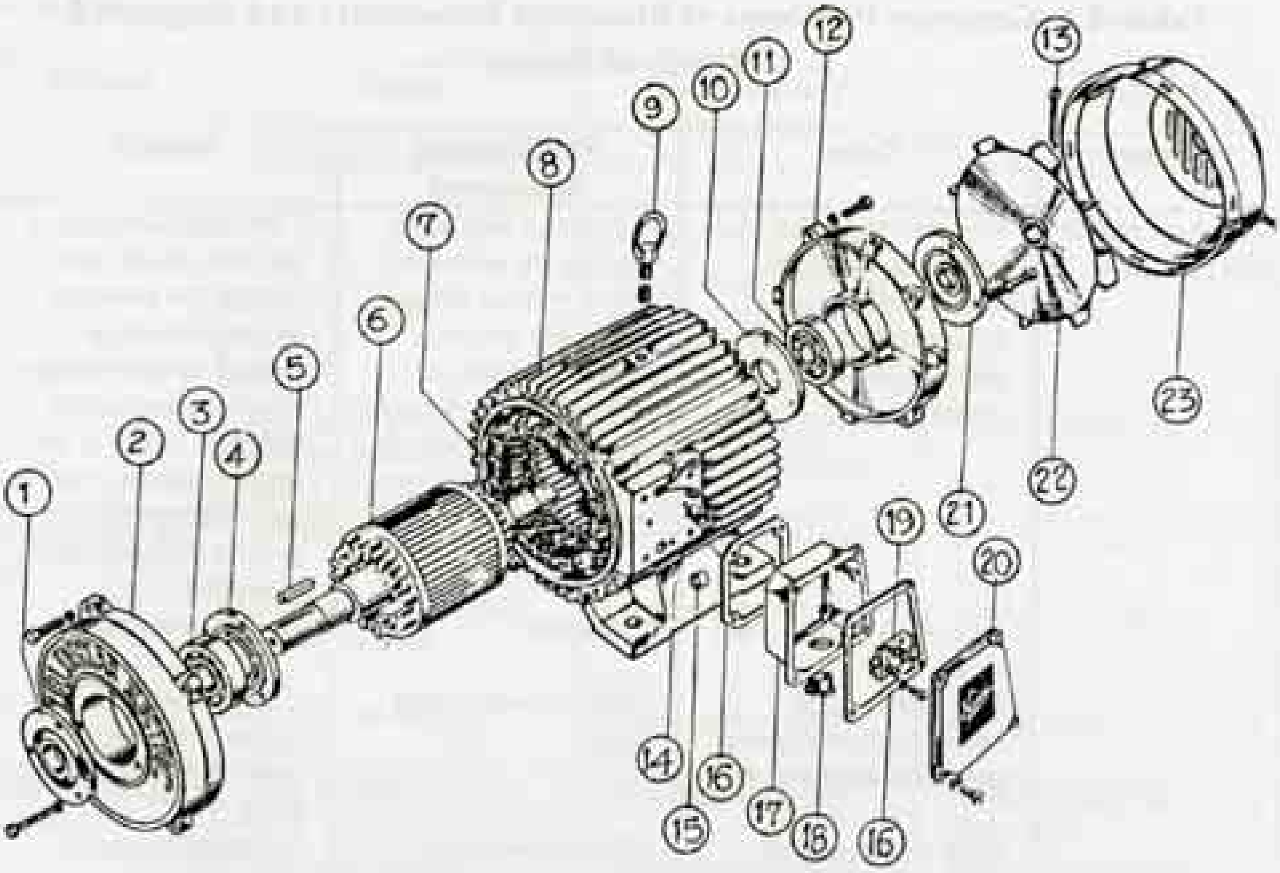


Figure 4.13: Exploded View of a Brushless Synchronous Generator

List of Parts for Figure 4.13

1. Would stator assembly
4. Wound roter assembly without exciter
15. Fan
18. Balancing disc
22. Key, shaft end
30. Drive endshield
31. Securing screws, D.E. shield
32. Lock-washers
33. Grid, air outlet protection
34. Rivet, grid attachement
35. Washer
36. N.D.E. shield
37. Attaching screws, gland support plate
39. Lock-washer
41. Hood, rear part
42. Gland support plate
43. Attaching screws, air inlet louvers
44. Lock-washer
47. Hood, rear part
48. Hood, upper part
49. Hood, connecting screws
50. Lock washers
51. Air inlet louvers
52. Attaching screws, outer cap, drive end
53. Lock-washers
54. Ball bearing, drive end
55. Outer cap drive end
56. Attaching screws, outer cap, drive end
57. Lock washers
58. Grease valve, fixed part, drive end
59. Grease valve, mobile part, drive end
60. Set screw, drive end
61. Bearing grease nipple, drive end
62. Inner cap, drive end
63. Ball bearing, N.D.E. cap
64. Outer cap N.D.E.
65. Fastening screws, N.D.E.
66. Lock washer
67. Grease valve, fixed part, N.D.E.
68. Grease valve, moving part, ND.E.
69. Set screws, ND.E.
70. Inner cap, N.D.E.
71. Spring, for pre-load
72. Exciter frame
73. Coils, exciter field
74. Split, for retaining coils
75. Exciter armature
76. Rotating diodes supporting disc
77. Supporting ring, disc
78. Fastening screws disc
79. Lock-washers
80. Diodes, direct
81. Diodes, inverse
82. Protecting resistor
83. Connection bars, assembly
84. Right diode access louver (viewed from shaft end)
85. Left diode access louver (viewed from shaft end)
86. Fastening screws, louver
87. Lock-washers
88. Frame extension
89. Securing screws, frame extension
90. Lock-washers
148. .... louver
160. Compounding plate
162. Securing screws, compounding plate
163. Compounding transformer
164. Lock-washer
165. Insulator
166. Regulation plate
167. Securing screws, (190) on (160)
168. Self-locing nut (Nytstop)
194. Securing screw, regulation plate
195. Self-locking nut (Nytstop)
196. Gromments
197. Three-phase, rectifier bridge
198. Auto-transformer (for voltage other than 220 or 380 V)
199. Rectifier bridge
200. Guard-cover
223. Self-locking nut (Nytstop)



List of Parts

1. Outside bearing cap, Drive End (DE)
2. End shield, DE
3. Bearing, DE
4. Inside bearing cap, DE
5. Shaft key
6. Rotor with shaft
7. Winding
8. Body
9. Eye bolt
10. Inside bearing cap, Non Drive End (NDE)
11. End shield, NDE
12. End Shield, NDE
13. Split pin
14. Bush
15. Earthing bolt
16. Gasket
17. Terminal box
18. Gland
19. Terminal box assembly
20. Terminal box cover
21. Outside bearing cap, NDE
22. External fan
23. Fan cover

Figure 4.14: Exploded View of a Small Induction Generator

Table 4.6: Common Problems of Brushless Generators and Suggested Methods of Repair

Problem	Cause	Identification/ Assessment	Repairs
No voltage output from generator	- Residual magnetism could be lost as a result of a heavy short, during transportation, or if standing idle for a long period	- Disconnect field wires and run the generator. Check residual voltage across the generator output terminals, it should be approximately 5% of the rated voltage and balanced between each pair of lines	- If the residual voltage is less than 5% of rated voltage, the generator field coil should be 'flashed' by connecting a 12 volt battery across terminals F1 and F2 for about 5 seconds, making sure that terminal F1 is positive and terminal F2 is negative
	- Fuse on (AVR) may have blown	- Check fuse	- Replace if necessary
	- Field wires may be connected to the wrong polarity of excitor or AVR	- Check polarity of field wires	- If they are wrongly connected change polarity, (+) to (+), (-) to (-)
	- Loose connection of excitor or field wires	- Check connections	- Tighten as necessary
	- Rectifier or diodes may be faulty	- Check continuity of diodes (rectifier) with multimeter	- Replace if necessary
	- Internal short in windings	- Test winding resistance with multimeter and test insulation with a meggar	- Send to workshop for rewinding if damaged
	- AVR may be defective	- Check residual voltage at field terminals with AVR disconnected as described above. If generator excites, AVR is defective.	- Arrange for AVR to be repaired
Generator output voltage too low at no load	- Voltage settings are too low on AVR	- Check settings and voltage	- Adjust voltage by turning potentiometer on AVR
	- AVR sensing wires connected to wrong terminals	- Check connections to AVR against generator wiring diagram	- Correct if necessary
Generator output voltage too high at no load	- Turbine speed may be high	- Measure speed	- Bring to correct (rated) speed by adjusting flow
	- Voltage settings (preset) on AVR may be high	- Check voltage settings	- Adjust voltage by turning potentiometer (electronic AVR) provided on AVR

Table 4.6 Cont.......

Problem	Cause	Identification/ Assessment	Repairs
	- AVR may be defective	- Run the generator with AVR at rated speed on no load and try to decrease voltage by adjusting AVR potentiometer. If voltage cannot be adjusted, then AVR is defective	- Get AVR repaired or replaced
	- AVR sensing wires (input voltage) connected to wrong terminals	- Check connections to AVR against generator wiring diagram	- Correct if necessary
Voltage drops with load	- Belt slipping	- Check tension of belts	- Increase tension to proper level
	- Electronic AVR setting may be incorrect	- Reset AVR settings	- Check field voltage on AVR if low
	- Unbalanced load on phases	- Check loads on each phase	- Balance loads
Generator voltage oscillates	- Belts slipping	- Check tension of belts	- Increase tension to proper level
	- Very long, flat belt	- Check shaft distances	- Reposition generator to enable the use of a shorter belt
	- Faulty AVR/ELC	- Check stability of AVR/ELC	- Adjust stability of AVR/electronic governor by adjusting the potentiometer
	- Loose connection to AVR	- Check all electrical connections	- Tighten if necessary
	- Faulty bearings	- Check bearings	- Replace if necessary
	- Oval pulley	- Check the rim of the pulley	- Replace if damaged
Overheating of generator and excessive noise	- Generator overloaded	- Check load	- Reduce if necessary
	- Faulty bearings	- Check bearings	- Relubricate or replace if necessary - Unsealed bearings should be half filled with a good quality bearing grease
	- Insufficient ventilation	- Check vents and screens	- Clean generator and generator air inlet screens. Remove items which may be blocking flow of cooling air to generator while running

Table 4.6 Cont.......

Problem	Cause	Identification/ Assessment	Repairs
		- Check ventilation of powerhouse	- Provide additional ventilation if necessary
Vibration of generator	- Bearings worn out	- Check bearings as described before	- Replace with new bearings of same size and type
	- Bearing loose in housing	- Check whether bearing is loose in housing by checking play	- Replace housing if damaged
	- Loose foundation bolts	- Check all foundation bolts	- Tighten as necessary - Reconcrete foundation bolts if foundation damaged
	- Pulley or rewound generator rotor out of balance	- Remove belts and rotate pulley. If it stops in the same position each time either the pulley or the generator rotor is out of balance. Remove the pulley and try the same test. If the generator rotor stops in a different position each time, the pulley is out of balance	- Return pulley to the supplier for rebalancing
		- If the generator rotor stops in the same position each time the rotor is out of balance	- Return rotor to the supplier or a good workshop for balancing

Table 4.7: Common Problems of Induction Generators and Suggested Methods of Repair

Problem	Cause	Identification/Assessment	Repairs
Generator does not excite	- Low rpm (speed)	- Check speed of turbine. Induction generators excite at higher rpm than synchronous generators	- Increase speed by increasing flow
	- Insufficient capacitance	- Check capacitor connections - Check size of capacitors - Check type of capacitor and connection configuration, e.g., Delta, star or C-2C connection	- Tighten if loose - Replace with units of the correct size if necessary - Redo connections
	- Lost residual magnetism	- Disconnect capacitor and run generator. - Measure residual voltage between terminals, it should be approximately 5% of the rated voltage	- If residual voltage is less than 5 per cent of rated value, flash output terminals by connecting a 12V battery across the terminals for a few seconds
	- Miniature circuit breaker (MCB) between excitation circuits may be switched off	- Check wires and MCB	- If MCB is switched off then switch on
	- Load may be switched on	- Check load connection switch. Induction generators will not excite under load	- Switch off load
High voltage from generator	- Generator run under no-load conditions without IGC	- If there is no IGC connected and generator speed is excessive, high voltage can occur	- Reduce turbine speed with flow regulating valve
	- Generator output higher than ballast capacity	- Check ballast capacity	- Provide additional ballast if necessary
Low voltage	- Too much reactive/inductive load	- Check power factor or actual loads	- Reduce inductive load (e.g., tube lights and motors)
Voltage fluctuation	- Loose connection in ballast/IGC	- Check if ballast heater does not get hot. If so, check function of IGC and ballast heaters	- Repair or replace as necessary
	- Faulty IGC or ballast heaters	- Check connections and tighten if necessary	- As above
	- Fuse may be blown in IGC (if used)	- Check fuse	- Replace if necessary

Table 4.7 Cont.......

Problem	Cause	Identification/Assessment	Repairs
	- Belt slipping	- Check belt tension	- Adjust if necessary
	- Worn out bearings	- Check bearings	- Replace if necessary
Overheating of generator	- Overload	- Check the users' load	- Reduce if necessary
	- Faulty bearings or lubrication problem	- Check bearings and grease	- Grease bearings - Replace bearings if necessary
	- Low frequency/speed	- Check rpm	- Run generator at correct speed

4.5 Controls and Instrument Panel

The controls and instruments installed in an MHP scheme will to some extent depend on the size of the plant and the type of generator used. For example, very small units may only use MCB, voltmeters, ammeters, and a few safety devices; whereas larger units may use a variety of devices to control the variation and quality of output voltage and frequency and isolate the output if a high or low frequency or voltage situation arises.

Generally, an AVR or some voltage regulation system must be provided for a synchronous generator, since many MHP plants installed in the HKH region have no ELC or IGC; and speed/voltage regulation is carried out manually. Nowadays, ELCs are normally installed for synchronous generators and IGCs for induction generators, in order to keep the load and thus the speed and voltage constant. Figure 4.15 shows a typical instrument panel for a small MHP plant with a load control system.

4.5.1 Instruments for Schemes without a Load Controller

For units not equipped with an ELC or IGC, the control and instrument panel usually contains the following.

- Miniature circuit breaker (MCB) for over-current protection
- Current transformer (for current measurement)
- Ammeter
- Voltmeters
- Push buttons for connecting excitation system
- Connectors
- Indicator lamps (for individual phase output)
- Over-voltage trip (safety protection system)

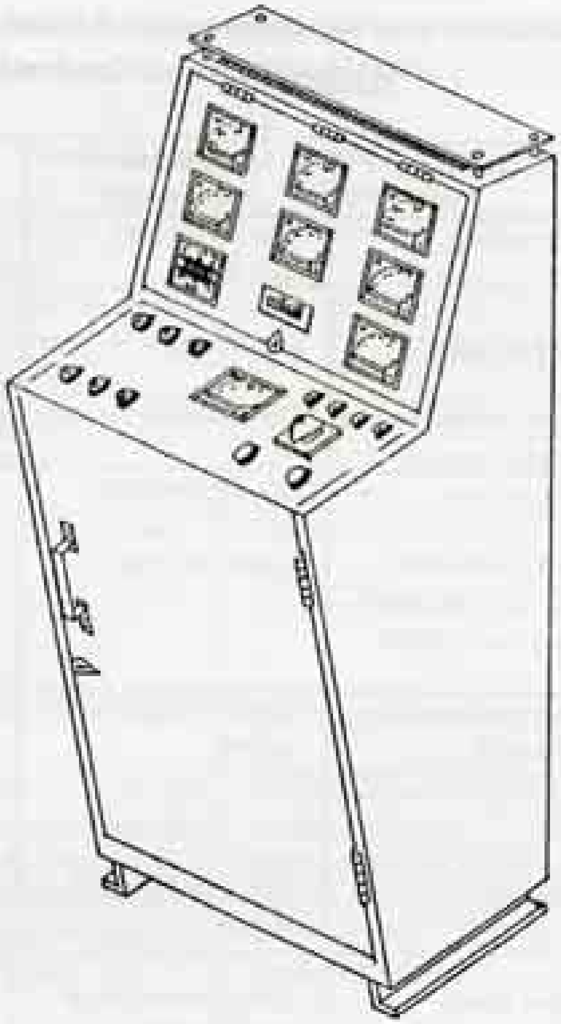


Figure 4.15: A Typical Instrument and Control Panel Including a Load Controller

Table 4.8 lists some of the common problems associated with control panels for plants that do not have a load controller installed, together with recommended solutions.

4.5.2 Instruments for Schemes with Load Controllers

For units equipped with an ELC or IGC, the control and instrument panel usually contains the following.

- Miniature circuit breaker (MCB) or miniature coil circuit breaker (MCCB)
- Thyristor (ELC electronic switch)
- Induction gate bipolar transistor IGBT(IGC electronic switch)
- Heat sink (for mounting of thyristor or IGBT switch)
- Heat sink (for mounting of thyristor or IGBT)
- Current transformer (for measuring current)

Table 4.8: Common Problems and Recommended Actions for Control Panels Without a Load Controller

Problem	Cause	Identification/ Assessment	Repairs
Voltage collapses after releasing push button	- Relay not holding - Relay may be faulty - Under/over-voltage setting not correct	- Check relay hold connection - Check relay - Check voltage setting	- Tighten connections if loose - Replace if necessary - Adjust voltage as necessary
Sparking/overheatin g of connector	- Loose connection - Undersize conductors (incorrect size may have been used during repair work)	- Check connections - Check wire size	- Tighten loose connections - Replace with appropriate size
High/low output voltage	- Over/under-voltage trip malfunctioning - Load variation - Fuses have blown	- Check settings of trip system - Check load through meters - Check continuity of fuse by meter	- Reset the settings - Test again - Replace any faulty component - Reduce load if higher on a given phase - Replace if necessary

- Ammeter (for measuring current)
- Voltmeter (for measuring output voltage)
- Frequency meter
- kW meter
- Ballast voltmeter (for ballast load indication)
- ELC or IGC main board
- Ballast fuse (to protect ELC, IGC, and ballast heaters)
- Push button (voltage/frequency over-ride for startup)
- Ballast heater (dummy output load for generator control)
- Ballast tank (housing for ballast heaters and water)
- Connector (for power output)
- Indicator lamps (for individual phase output indication)

Table 4.9 lists some of the common problems encountered with systems that have a load controller installed, and recommended solutions.

Table 4.9: Common Problems and Recommended Repairs for Control Panels Equipped with a Load Controller (ELC Or IGC)

Problem	Cause	Identification/ Assessment	Repairs
High output voltage and frequency but zero ballast voltage	- Thyristor open-circuited (damaged)	- Check thyristor	- Replace if damaged
	- Ballast fuse blown (no connection to ballast)	- Check fuse	- Replace with equivalent fuse if necessary
	- Defective ballast heater	- Inspect heaters	- Replace if necessary
	- MCB in off position	- Check MCB	- Switch on MCB
	- No supply to ELC	- Check 220V AC supply to transformer	- Restore supply
	- Defective transformer	- Check that transformer output is 18-01-18V	- If not send for repairs
Generator and ballast voltage rise together	- Belt slipping	- Check belt tension	- Tighten if necessary
	- Generator overloaded	- Check consumers' load	- Replace belt(s) - Reduce if necessary
	- Thyristor short-circuited so that ballast load and consumer load are on the generator, causing generator overload	- Check thyristors. If ballast voltage rises with generator voltage during startup, thyristor has short-circuited	- Replace if necessary
Speed fluctuation (hunting)	- Belt slipping	- Check belt tension	- Tighten if necessary - Replace belt(s)
	- ELC stability requires adjustment	- Turn 'STAB POT' slowly to check ELC stability	- Set proper stability
	- Incorrect function of AVR (new AVR only)		- Take AVR to expert/technician for testing and repairs
Ballast readings unequal when consumer load is not switched ON	- Defective meter	- Check meter	- Replace if necessary
	- Ballast fuse may be blown	- Check ballast fuses	- Replace if necessary
	- Loose ballast heater connection or faulty ballast heater	- Check connections and ballast heaters	- Replace as necessary
MCB or trip tripping	- Load too high	- Check load	- Reduce load to within rated limits
	- Current limiting or tripping device, e.g., MCB or over voltage trip (OVT) may be defective	- Check these devices	- Repair or replace as necessary

Table 4.9 Cont.......

Problem	Cause	Identification/ Assessment	Repairs
	- Incorrect voltage or frequency - Defective MCB	- Check voltage and frequency meters - Check	- Adjust potentiometer to correct voltage frequency - Repair or replace as necessary
Connector or wire burnt or sparking	- Loose connection - Short between connector terminals - Ventilation to ELC may be blocked - Fans not working (if provided in ELC)	- Check connections - Check for shorts - Check ventilation holes and screens - Check function of fan	- Tighten connections, change connector if damaged - Connections should be tightened periodically - Ensure air circulation during operation. Clean filters and air inlets and remove any obstacles to circulation - Repair/replace if required
Electric shock from ELC/ballast	- Current leakage	- Check voltage on metal casing and earth connection, live wire may be touching casing	- Check all live wires including heating elements and housings. Repair/replace as necessary
Indicators do not light	- Bulb blown - No supply to indicator bulb - Short circuit	- Check bulb - Check supply wires - If MCB/fuse/trip blows immediately after switch-on, there may be a short circuit between phases or between phase and neutral	- Replace if necessary - Repair connections to restore supply - Locate short and rewire as necessary
High/low output voltage	- Over/under-voltage trip malfunctioning - Load varying - Fuses blown	- Check setting of trip system - Check load through meters - Check fuses with multimeter	- Reset settings - Test again - Locate and replace any faulty component - Reduce load if high - Replace if damaged

4.5.3 Protection

Over-Voltage Trip (OVT) Board (or Safety Protection Board)

The over-voltage trip board protects consumers from high voltage by isolating the generator excitation in the event of high voltage output. It also protects the generator rectifier and field coil, which may otherwise burn out if the output voltage goes high.

Over speed/over-voltage may take place if:

- the load varies,
- the output fuses blow,
- there is no load controller,
- there is a sudden increase in water flow to the turbine, or
- the load controller or AVR do not work properly.

For any of these conditions first locate the cause and rectify before attempting to reconnect the load to the generator.

Earthing

All earth connections should be checked at least once a year. If possible, the resistance to earth should be measured, and the condition of all earthing conductors and plates closely inspected for corrosion and discontinuities.

Chapter 5
Maintenance and Repair of Transmission Lines

Transmission lines can be for high or low tension, whereas distribution lines are normally for 220V. The main components associated with transmission lines are transformers, lightning arresters, and the actual transmission lines themselves with their conductor wires, insulators, and supporting poles. The most common problems encountered with transmission lines are breaking of conductors, and breaking, loosening, or falling of poles.

5.1 Transformers

Many MHP installations do not have any transformers installed because the distance over which electricity is to be distributed is not long enough to warrant the additional cost and complexity of stepping the voltage up and down. When transformers are installed, they tend to be very reliable and to work well for many years without much attention. Nevertheless they can fail, mainly as a result of mishandling, and some routine maintenance and checks for security are necessary.

The transformer should be checked for cleanliness at least once a year. Excessive deposits of oil or dust on the insulators can cause a short circuit and damage to the insulators. Any damaged insulators should be replaced as soon as possible, including distribution switch gear insulators. The fence around the transformer should also be checked and maintained for security. Gaps in the fence could result in trespassers receiving an electric shock, leading to serious injury or even death.

Silica gel in the transparent container on the side of the transformer (to absorb moisture from the air cavity above the oil in the transformer) should be checked at least twice a year and replaced if it has turned pink. The oil level in the transformer should also be checked at least annually and new oil added as necessary.

Serious damage to a transformer can result from burned or short-circuited windings. The windings can be redone in a properly equipped workshop. A skilled person should check the continuity of the windings and the presence of any short circuit using a multimeter and a meggar. If the transformer is damaged, the whole assembly should be taken to a proper workshop for repairs and subsequent testing.

5.2 Transmission Lines

Usually, aluminum conductor steel reinforced (ACSR) wires/cables are used for transmission and distribution lines. Armoured cables are used for underground transmission lines and may also be used for overhead transmission lines if these are located in a densely populated area or one with snowfall.

Damage can be caused to the transmission cables and poles by high winds, landslides, over-tightening, and breaking or sinking of poles. Sometimes, rain or lightning can also damage the cables, as can people or animals who may unwittingly shake the poles and loosen them. The cables may break or sag, and the space between two conductors may become less or they may even touch. Poles may become loose, fall down, sink or break.

5.2.1 Broken wires

If a conductor wire is broken, it is usually necessary to add an extra piece of wire for overlapping and joining. In order to make a proper joint, all the strands at the end of each conductor wire must be opened to a length of about 300 mm and each strand twisted together with another strand from the opposite wire and then wrapped around the joint (Figure 5.1). In this way, all the strands should be twisted and wrapped to form a smooth tight and unbreakable joint. Clearly, it would be difficult to join two pieces of wire in space so as to give the exact length needed to ensure that the wire does not sag. Thus it is better to join with the broken wire a length of wire that is long enough to reach the next pole, and to tie this to the insulator on the pole. Excessive length, if any, should then be cut off. The other broken end of the wire should be trimmed and tied to another insulator on the same pole, and a jumper installed to connect the two wires (Figure 5.2).

5.2.2 Unequally sagging wires

Unequal sag of wires between two poles can be adjusted to some extent by tying the wires to an insulated stick, say a wooden piece; in vertical position (Figure 5.3). The wires should be tied to this stick in such a way that the distance between any two wires is not the same but instead a maximum for the wire that is sagging most. In this way, the chances of the wires touching at some other place will be reduced. Even so, it is better to disassemble the line and re-install all the wires and set the sag properly.

5.2.3 Leaning poles

Leaning poles can be straightened easily by pulling the wires in opposite directions. If the portion in the ground is not damaged or broken, then the same poles can be re-erected and earth and stones compacted well around the pole base so that they stay in position. If necessary, stay wires can be attached to the poles to keep them in position. If a pole is

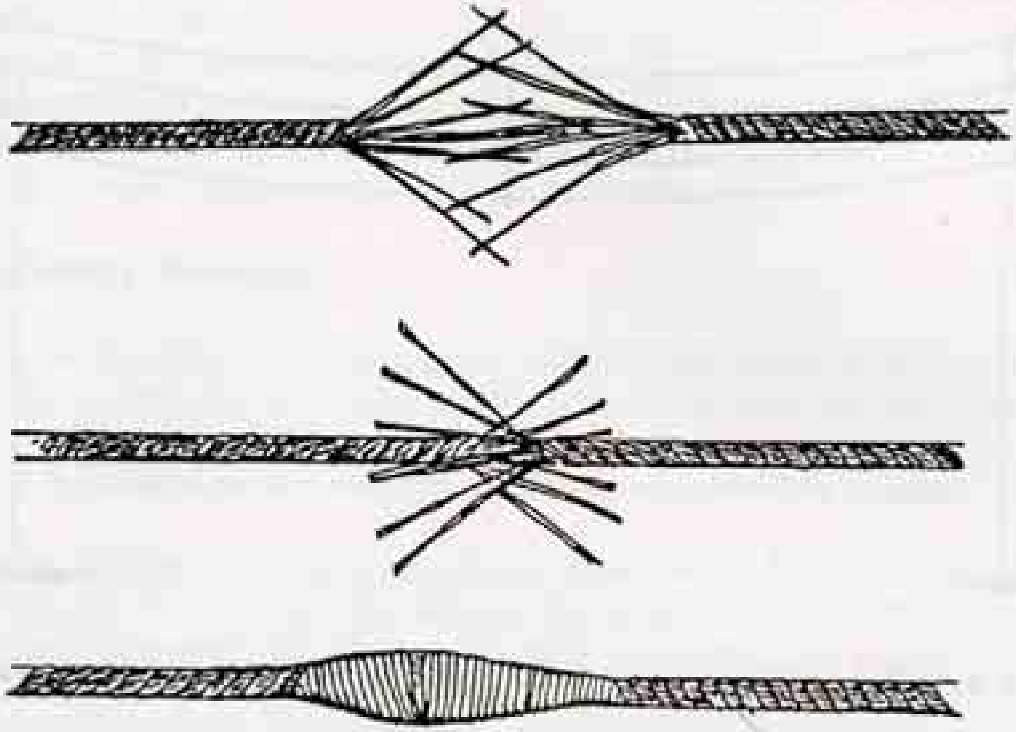


Figure 5.1: Joining Two Cable Ends

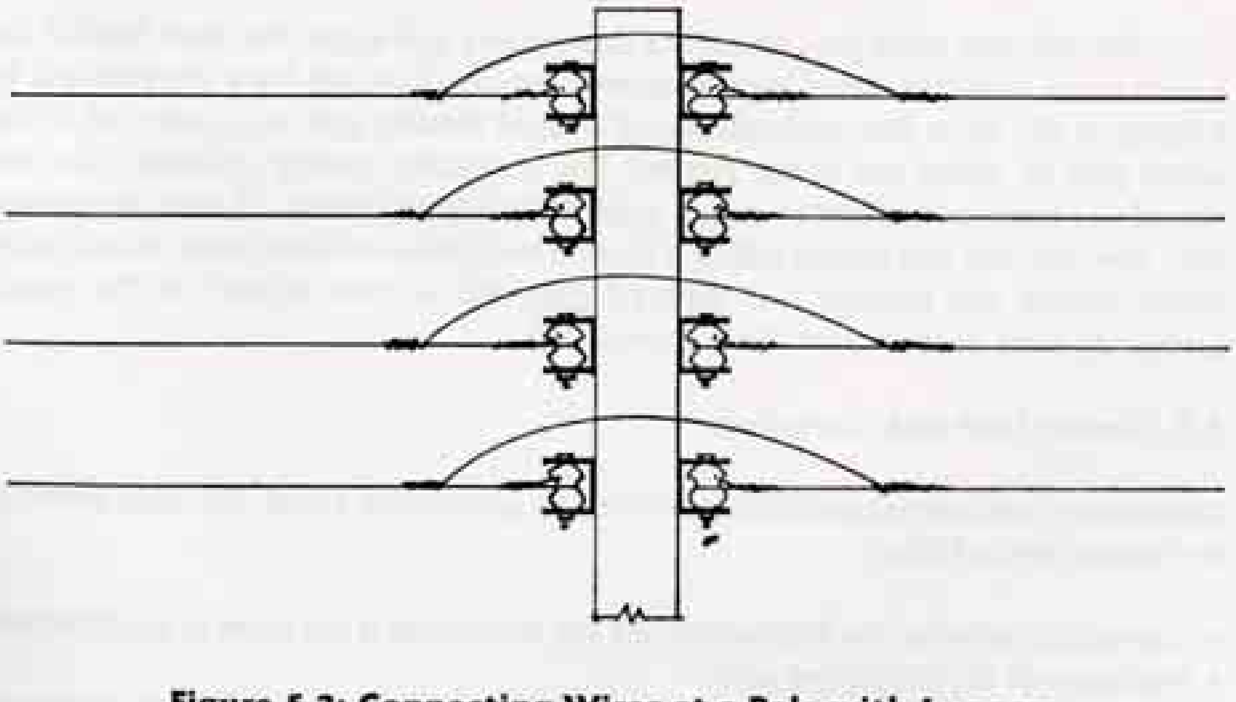


Figure 5.2: Connecting Wires at a Pole with Jumpers

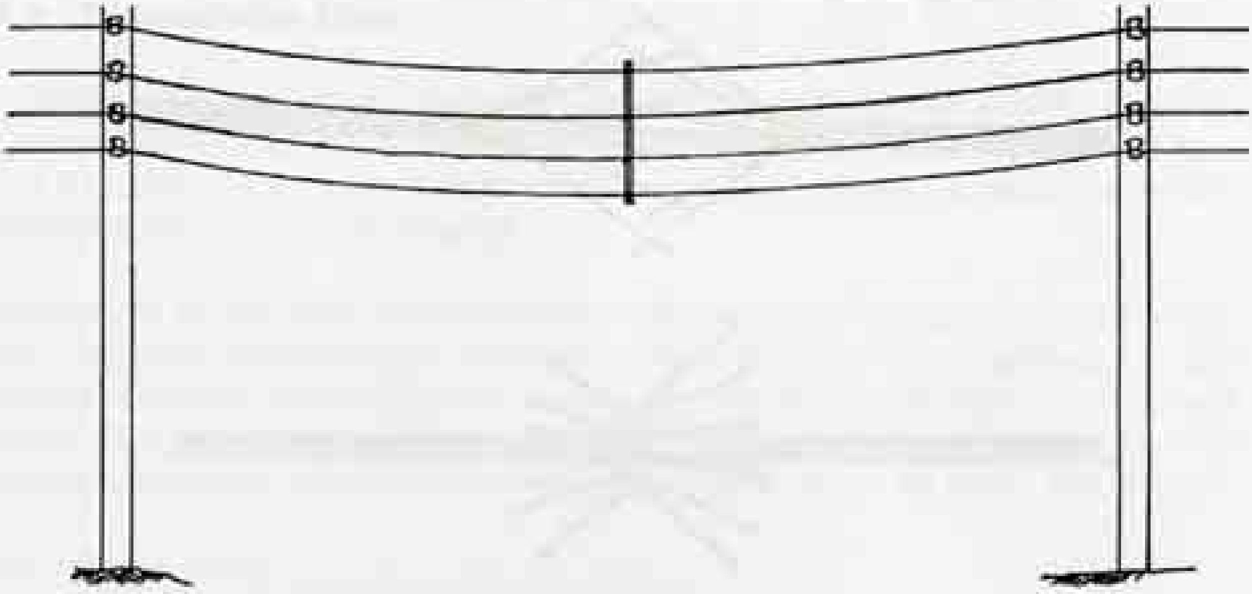


Figure 5.3: Tying Wires to an Insulated Stick to Control Unequal Sag

broken or otherwise damaged, cracked for example, then it is good practice to replace it. If the insulators on the poles are damaged or broken, they must be replaced.

5.2.4 Dislodged Poles and Wires

If the transmission wires pass through a sloping area and a pole has been fixed at the lowest point, then the wires may sometimes get disconnected from the pole and be hanging in the air, or the upper portion of a round metallic pole may come out or the whole pole be pulled out of the ground. This is actually a design problem, the pole should not have been placed in such a position during installation. If such damage occurs, then the best way to deal with it is to erect two poles, instead of one, on both sides of the original pole location, but slightly higher, and fix them properly in the ground using stay wires or foundation bolts if necessary.

5.2.5 Service Lines and Connection

Service lines and connections should be checked about once a year. The main points to be checked are as follow.

- Connection between the distribution line and service line is not loose or unauthorised.
- Insulation of the service line is ok.
- Any meters or current limiting devices installed in the houses are properly connected and not bypassed.

- The meters are calibrated.
- Faulty devices are replaced regularly.
- Distribution boxes containing connector switches or fuses are also provided where the distribution lines branch to go into different streets.
- These switches/fuses are checked and replaced if faulty.

5.3 Lightning Arresters

Lightning arrester units can be damaged if a high voltage passes through them many times. If this happens, the MCB may trip in the powerhouse, fuses may get blown, or the earth wire may show some voltage. In such a case, remove the arrester unit and check its continuity. A damaged arrester will show continuity and should be replaced.

The earthing resistance of a lightning arrester should be checked to ensure that it is within limits, i.e., less than five ohm between the earth plate and another point on the ground about five metres away. At the same time, the connections between the buried plate and the wires connected to it should be checked and, if found loose, rusted, or damaged, be disconnected, the surfaces cleaned with emery paper, and rejoined by soldering or using bolts.

Chapter 6
General Suggestions about Repairs

MHP plants are usually located in remote mountainous areas where transportation of damaged equipment to a good workshop or a manufacturer can be difficult and may cause delays. Therefore, arrangements should be made to try to carry out as many repairs locally as possible. It is advisable to identify and develop a good relationship with a local or nearby workshop, another plant owner with more expertise, or a good technician. The expert you will try to call for help may be invited to visit the plant before it breaks down so he* can familiarise himself with the machinery before it breaks down. The aim is that, when a problem arises, this person can be called upon to help assess the damage, identify causes, and help with some repairs. His experience may also be helpful for disassembling any parts of the plant that have to be transported to a proper workshop. In Nepal, many owners of MHP plants have developed expertise in repairing their own plants through trial and error over a long period of time. If possible, such persons may be engaged in the repair of other plants. It is necessary, however, to assess the capability of such people in advance through interaction and discussions as an unqualified or inexperienced technician may do considerable damage to the equipment and/or provide wrong advice.

6.1 Maintenance Check List and Schedule

Good and timely preventative maintenance will almost always help to reduce the number of breakdowns and increase the life and productivity of the equipment. Table 6.1 shows a check list and schedule for routine maintenance. Routine maintenance is also discussed in the manual on operation and management. It is helpful if the owner and operators receive good training and visit other plants that are being managed, operated, and maintained properly. In this way, they can learn good operational and management techniques.

In many cases, plants maintained and repaired by the owners and operators themselves are more successful economically and in their operation than those for which technicians for repairs have to come from other far away places. As far as possible, the major maintenance and repair work should be carried out at the site with the help of expert technicians when necessary, since this will save both time and money, including transportation costs. However, there are many components and types of damage that cannot be repaired at the site and have to be transported to a proper workshop facility.

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

Table 6.1: Summary of Preventative Maintenance Checks (Maintenance Must be Carried out Immediately if any Significant Damage is Discovered)

Item	Daily	Weekly	Monthly	Quarterly	Half yearly	Yearly
Weir/Dam						
Dam for debris			x			
Dam wall for cracks					x	
Dam silting up						x
Intake Mouth						
Free of debris	x					
Flow into intake not too slow or fast	x					
Sluice gate setting correct	x					
Water level at intake is sufficient	x					
Trash rack in good condition		x				
All concrete surfaces free of cracks					x	
No change in stream course causing change in flow						x
Power Canal/Headrace						
Foreign objects in channel	x					
Correct flow level in channel	x					
Leakage from channel	x					
Water diverted for irrigation, etc		x				
Footpath in good condition		x				
No leaks in pipe type headrace			x			
Flushing of pipe			x			
All channel surfaces sound and free of cracks				x		
Surface runoff drains not blocked				x		
Erosion under/around channel			x			
Danger of falling rocks damaging pipes					x	
Headrace not threatened by landslides					x	
Desilting Basin and Forebay						
Correct flow through desilting basin	x					
Forebay trash rack clear of debris	x					
Leakage	x					
Level of silt not above maximum		x				
Cracks in concrete surfaces				x		
Not threatened by landslides				x		
Penstock						
Leakage		x				
Expansion joints leaking/condition		x				
Anchor block movement/subsidence		x				

Table 6.1 Cont.......

Item	Daily	Weekly	Monthly	Quarterly	Half yearly	Yearly
Corrosion			x			
Anchor block cracking			x			
Erosion around anchor blocks			x			
Saddle support cracking			x			
Erosion around saddle supports			x			
Susceptibility to damage from falling objects				x		
Check bolts on all flanged joints				x		
Check retaining bolts on all saddle supports				x		
Check all weld joints for soundness					x	
Paint						x
Penstock route not threatened by landslides					x	
Powerhouse						
Any leaking valves	x					
Powerhouse clean	x					
Turbine bearings for vibration	x					
Turbine speed satisfactory	x					
No unusual noise from turbine	x					
Check coupling for vibration	x					
Generator output voltage satisfactory	x					
Check generator bearings for vibration	x					
Generator bearings not overheating	x					
Generator ventilation unobstructed	x					
Generator not overheating	x					
Generator environment clean and tidy	x					
Load controller functioning correctly	x					
All meters working satisfactorily	x					
Output frequency within limits	x					
Load on system within limits	x					
Phases balanced	x					
No blown fuses	x					
No overheating connectors or conductors	x					
Water flow to and out of ballast heater tank ok	x					
Any valve with operating difficulties	x					
Drive belt tension ok	x					
Drive belt condition ok	x					
Turbine/generator coupling wear ok			x			

Table 6.1 Cont.......

Item	Daily	Weekly	Monthly	Quarterly	Half yearly	Yearly
Inspect runner for damage				x		
Inspect runner for damage				x		
Coupling rubber and bolts ok			x			
Tightness of pulleys on shafts ok		x				
Inspect turbine shaft for straightness				x		
Inspect and grease turbine bearings				x		
Inspect turbine bearing seals			x			
Inspect and grease generator bearings				x		
Inspect generator bearing seals					x	
Check all casing and runner bolts for looseness				x		
Inspect tapered locking sleeves for bearings			x			
Inspect tapered adapter sleeves on shafts			x			
Check bolts on coupling to shaft sleeve					x	
Earthing satisfactory						x
Powerhouse not threatened by landslides						x
Tailrace						
Leaks from tailrace	x					
Foreign objects in channel	x					
All tailrace surfaces sound and free of cracks				x		
Check for erosion under/around tailrace					x	
Danger of falling rocks damaging tailrace					x	
Transmission & Distribution						
Insulators not damaged		x				
Overhead conductor tension ok			x			
Overhead conductor spacing ok			x			
Fencing around high voltage transformer ok			x			
Distribution switches, fuses, etc. ok				x		
No trees/bushes encroaching on conductors				x		
Poles in good condition				x		
Pole stay wire tension satisfactory				x		
Lightning arresters in good condition					x	
All earth plates and connections in good condition					x	

Table 6.1 Cont.......

Item	Daily	Weekly	Monthly	Quarterly	Half yearly	Yearly
No loose connections or hot joints					x	
Transformer casing clean					x	
Transformer silica gel ok					x	
Transformer switch gear clean					x	
Transmission line not threatened by landslides						x
Transformer oil level satisfactory						x
Transformer insulators clean and intact						x
20% of meters and cut outs checked and calibrated						x
Customer connections sound						x
Illegal connections checked wherever possible						x
General						
Spare parts available				x		
Tools in correct place and in good condition		x				
Meeting with consumers					x	

When components have to be replaced, the replacements should be of the same size and rating as the original and manufactured by a genuine factory. Less expensive or non-genuine components may not only break down more quickly, they may also cause damage to other more expensive parts.

It is always good practice to keep in stock some smaller items and items that need to be replaced more frequently such as bearings, belts, rectifiers, important panel meters, fuse wires/fuses, an MCB, bushes for the generator, nuts and bolts, packing and seals, conductors and cables, and insulators and lightning arresters. Adequate quantities of normal consumables, such as grease and kerosene, should also be kept in stock so that delays are avoided in procuring them when they are needed. A more comprehensive list of items to keep in stock is provided in the manual on management and operation.

Sometimes, equipment of various sizes needs to be transported to a workshop usually by porters. In such cases, care should be exercised when starting and stopping the journey and during transportation so that the items are not dropped, damaged, or lost. They should also be packed properly and covered to prevent damage by rain or other elements. Some ideas on ways of packing and transporting equipment are provided in the manual on installation

Proper tools should be used for a given job; for example, pliers should not be used as a spanner or a hammer. Such practices can damage the tools and may cause serious damage to the equipment that is being repaired.

6.2 Suggested List of Tools to be Stocked at an MHP Plant

The following is a list of the tools that should be kept in stock to enable maintenance of an MHP scheme.

Electrical
- Combination pliers
- Needle nose pliers
- Wire cutter
- Flat head screwdriver set
- Phillips head screwdriver set
- Soldering iron and solder
- Line tester and/or multimeter
- Safety belt
- Knife
- Wire puller (for large electrification plants)

Mechanical
- Hammer
- Hacksaw
- File set (flat, half round)
- Open and ring spanner sets
- Slide wrench (200 mm or 300 mm)
- Pipe wrench (600 mm)
- Steel rule
- Grease gun
- Metric Allen key set
- Vice grip pliers
- Bench vice
- Bearing puller
- Measuring tape
- Blow lamp
- Paint brush
- Oil can
- Spirit level
- Wire brush
- Emery paper

Civil
- Pick
- Spade

- Shovel
- Crow bar (lever)
- Trash rack cleaner
- Other tools related to civil works

Note: A torch or portable lamp is essential for working in the dark, both in the power-house and outside.

6.3 Maintenance of Tools

Good quality and reliable tools are essential in order to keep an MHP plant well maintained. The following rules will help keep tools in a good useable condition.

- Clean tools after use and return to storage area
- Apply lubrication if necessary
- Keep a record of tools
- Do not throw tools, handle with care
- Use tools as they are meant to be used
- Check condition of tools and do not use damaged tools
- Purchase new tools or repair old ones if tools are damaged
- Store hand tools on a board or in a cupboard
- Store measuring instruments (multimeter, vernier, etc) in a cupboard or a drawer to protect them from dust and impact

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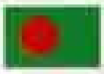
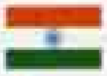
Participating Countries of the Hindu Kush-Himalayan Region

 Afghanistan

 Bangladesh

 Bhutan

 China

 India

 Myanmar

 Nepal

 Pakistan

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