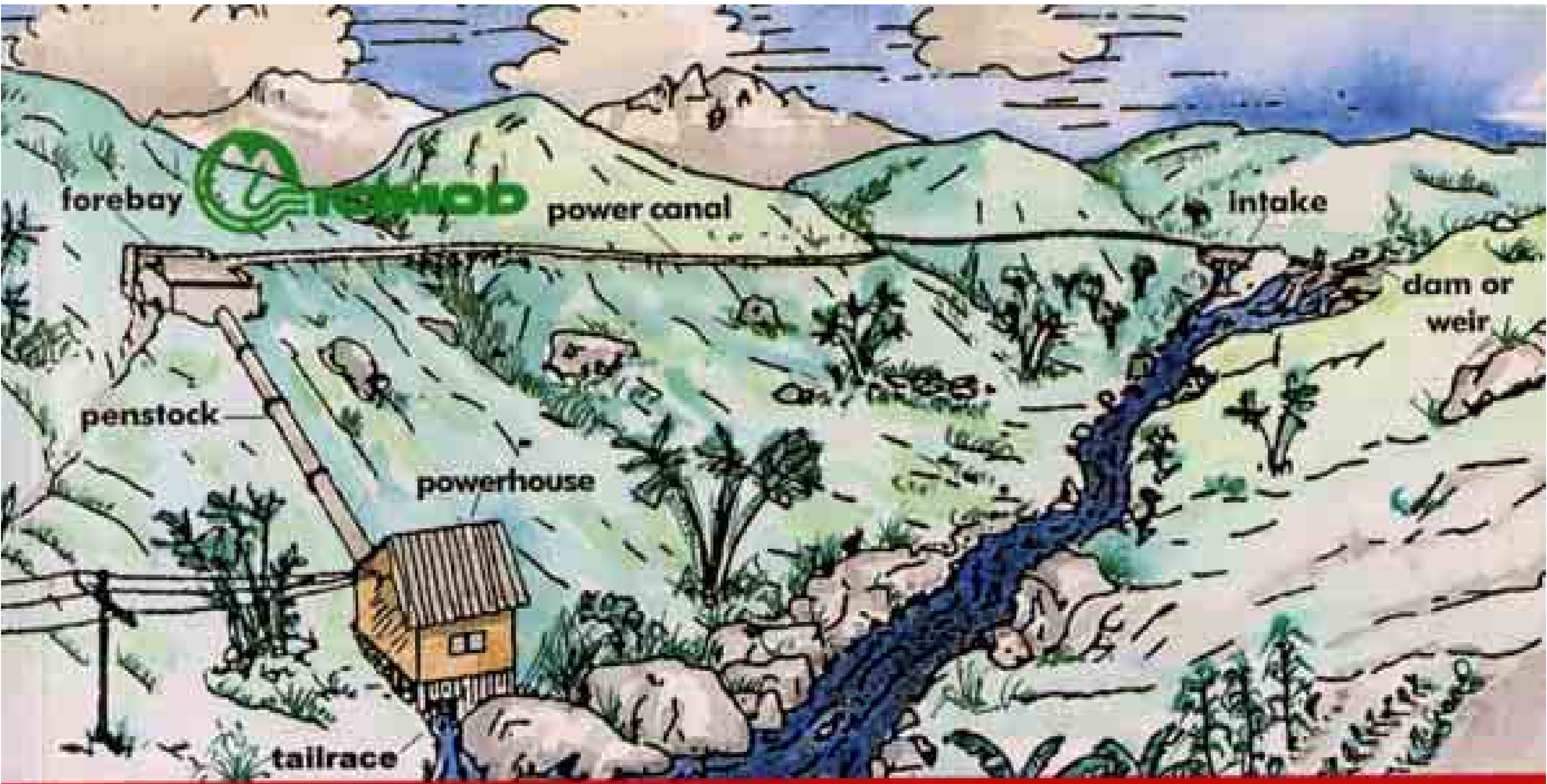
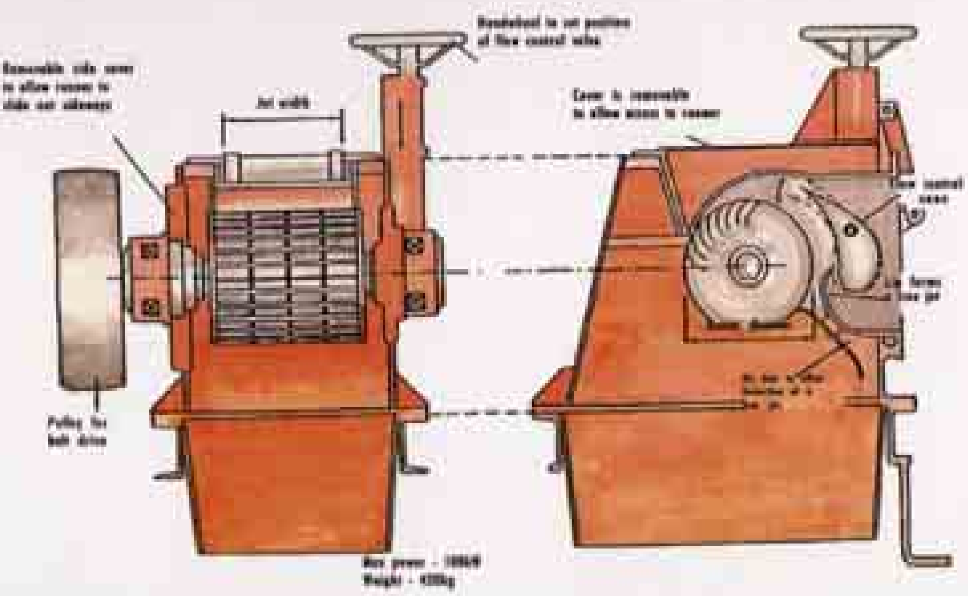



# Operation and Management Manual for Private Micro-hydropower Plants



International Centre for Integrated Mountain Development
Kathmandu, Nepal
1999

# Operation and Management Manual for Private Micro-hydropower Plants

Prepared by

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International Centre for Integrated Mountain Development (ICIMOD)
Kathmandu, Nepal
1998

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# Preface

This manual on the management and operation of private or community owned/managed mini- and micro-hydropower (MMHP) plants (especially micro-hydropower) is intended to provide assistance to managers and operators faced with the problem of running such systems in isolated areas. The managers and operators of MHP plants have often not had the benefit of extended education, may have little experience of working with machinery, and have often had very few opportunities to participate in relevant, high quality, training programmes.

The preparation of the manual was visualised, initiated, and sponsored by ICIMOD as a component of the NORAD sponsored project 'Capacity Building for Mini- and Micro-hydropower Development in Selected Countries of the Hindu Kush-Himalayan Region, Phase II'. It is one of four manuals aimed at the various groups of implementers of MMHP projects, including site surveyors and layout designers; manufacturers of indigenous equipment; installers; managers and operators; and repairers. The first draft of this manual was prepared by DCS-Technology Development, Butwal, Nepal, and was revised at ICIMOD. This is the first concerted indigenous effort to write quality manuals for MMHP which have a specific regional, rather than a general, perspective. DCS, in particular, deserves acknowledgement and encouragement for this work.

The main focus of this manual is on the isolated, indigenous, local entrepreneur-owned plants in the micro-range. Most of these plants installed in Nepal, Pakistan, and India have a capacity of less than 60kW. The manual has been kept simple and brief so that it can be used by managers and operators with limited formal education and training and little technical knowledge. The manual does not cover the specific details of different types of machines and management systems, rather it provides general information that can be applied to all schemes. Any attempt to cover all the managerial and operational aspects in one manual would result in it becoming so unwieldy as to lose its usefulness in the situations for which it is intended. Since this is the first time a manual of this type has been compiled, however, 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 suggestions for improvements or additions for subsequent editions from implementing agencies and operators/managers working with MHP plants and hope in this way to increase the usefulness of the manual in the future.

These remarks notwithstanding, it is hoped that, translated into the relevant languages, the manual will be a significant source of help for practising managers and operators in India, Nepal, and Pakistan. It is also hoped that some training agencies will find it to be useful supporting material for their training programmes.

**Anwar A. Junejo**
Coordinator, MMHP Project
ICIMOD

# Abbreviations and Acronyms

ACSR : Aluminium Conductor Steel Reinforced

ADB/N : Agricultural Development Bank/Nepal

AVR : Automatic Voltage Regulator

DP : Double Pole (switch)

ECC : Electronic Current Cut-out

ELC : Electronic Load Controller

HDPE : High Density Polyethylene

ITDG : Intermediate Technology Development Group

HKH : Hindu Kush-Himalayas

kVA : kilo volt-amperes

kW : kilowatt

LH : Left Hand

MCB : Miniature Circuit Breaker

MHP : Micro-hydropower

MMHP : Mini- and Micro-hydropower

NGO : Non-government organization

NORAD : Norwegian Agency for Development Cooperation

PTC : Positive Thermal Coefficient

PVC : Polyvinyl Chloride

Rs : Rupees

SWG : Standard Wire Gauge

TRS : Tough Rubber Sheathed (insulation)

VIR : Vulcanised Indian Rubber (insulation)

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# CHAPTER 1
# Introduction

Proper resource mobilisation, whether of human or natural resources, plays a vital role in the development of any village, region, or even country. In the Hindu Kush-Himalayan (HKH) region there are few natural mineral resources of worth, but there are abundant water resources and a large pool of human resources, although unskilled. Micro- and mini-hydropower (MMHP) plants can be installed to harness these water resources using currently available technology that is based on practical installation experience. Combined with development of human resources through training, MMHP can play a significant role in the enhancement of living standards in remote and underdeveloped mountain areas.

As we approach the 21st century, electricity is no longer considered to be a luxury, but a basic need of people everywhere. It is synonymous with a better standard of living and is vital for better communications, health care, and reduction of physical labour. In the HKH region, most settlements and houses are scattered and remote from road heads and the national grid. Transmission of electricity or transport of fuel to many of these locations is prohibitively expensive. Old forest trees are felled to provide firewood for cooking, commercial uses, and even lighting. Few new plantations are made to replace cut forests, and deforestation contributes towards problems such as flash floods and landslides. The practical options to mitigate these problems include both new plantation programmes and increased use of MMHP to meet local energy needs.

The capital required for investing in MMHP is beyond the reach of most people in mountain communities, and loans must be taken out for investment. If these loans are not to be a burden, the MMHP schemes must be carefully scrutinised and installed and wisely operated and managed (including proper repair and maintenance) to give long-term benefits. If properly installed, an MMHP plant can provide energy for lighting and for grinding grain, expelling oilseed, and other milling facilities; as well as for use in communication by telephone, radio, and television; and for industries such as sawmills, papermills, and workshops. MMHP may even encourage the development of facilities such as ropeways to reduce the burden of physical portering.

Installation of equipment is not the end of the job in any construction project. Proper operation and management of the plant and organization of repair and maintenance are also essential for satisfactory performance. These can only be achieved through training

Chapter One 1

and back-stopping. Indeed, proper management of these stages is the main determinant of the success or failure of a project.

This manual has been prepared to assist people in the management of MMHP plants so as to ensure maximum returns and benefits from the investment. It assumes that the survey, design, installation, and hand-over work have been completed amicably. The roles of operator and manager now become as important to the investors in the project as the role of a bus driver is to the safe operation of a bus. Carelessness on behalf of either may result in an accident.

The manual is intended for the use of managers and operators of micro-hydropower (MHP) plants of up to 100kW in capacity. However, many chapters may also be relevant for larger MMHP plants of, say, up to 200kW in capacity. Since the manual does not contain chapters on transformers or high-tension transmission lines, such information would have to be acquired from other sources.

Ideally, managers and operators should have attended a training programme based on the manual to obtain maximum benefit from it. However, managers and operators already working in the field who know MHP plants and their parts reasonably well, and who have good comprehension of technical texts, will also find the manual useful. Basically, the manual has been written for electrification schemes. However, the manual can also be used for MHP plants (prime movers) powering other industrial applications such as agro-processing.

The manual is divided into two parts. The first part deals with the general management of the plant: how to manage the operator, dealing with customers, financial management, and organization of maintenance and repairs. The second part describes the actual operation procedures, procedures for routine inspection and maintenance, keeping of the log book, the procedure to be followed during extended shutdowns, and some basic safety considerations and first aid procedures.

# CHAPTER 2
# Plant Management

In small plants the operator and manager are usually the same person, or the manager also assists in operation and maintenance. For plants larger than 50kW, there should be two different positions for a manager and operator; but this also depends on the level of management skill of the operator and the interest and commitment of the manager, who may also be the owner of the plant.

The operator is responsible not just for running the plant but also for maintenance and occasional repair. Therefore, he must understand the location and functions of each machine and component. He should be continually listening, testing, and checking for malfunctions and problems. He needs to keep uppermost in mind that prevention is always better than cure - 'a stitch in time saves nine'. His responsibility will normally be for all equipment and structures from source to distribution and will include routine inspections, operation, loading of the system, distribution, and keeping the equipment in good condition.

The manager is responsible for overall management of the plant — including organization, planning, management, budgeting, tariff setting, and bookkeeping.

## 2.1 Management of Operators

### *2.1.1 Selection and Terms of Employment*

The management selects and appoints an operator who is suitable for the job. The operator should be at least literate, and preferably educated up to class 8. He* should be experienced, sincere, and honest and have the capacity to learn and to build good relationships with others. He should be able to do basic trouble-shooting. If not, he should be trained properly by good trainers at a suitable location; including spending time at a running MHP plant.

A suitable local person should be selected as the operator if possible because such people are less likely to leave the job. This may not always be possible, in which case a more experienced person should be selected from outside and a higher salary offered. A better

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

qualified person will run the project more smoothly, and his higher salary is more likely to keep him there.

An operator can work 8 hours a day normally; but if the plant runs for more than 8 hours per day, an additional operator will be needed to cover leave, illness, and emergencies. (N.B. A person needs rest after eight hours, irrespective of illness and emergencies.) If the owner/manager is capable of running the plant, he may take the place of an emergency operator. Two operators should be appointed if the plant is coupled to agro-processing equipment as well as an electrical generator.

Details of salary, leave, overtime, and other facilities should be made clear at the time of appointment; and it is recommended that a contract be drawn up covering all important conditions so as to avoid disputes later. Terms of resignation and period of notice by both sides should also be specified in the contract. The operator should preferably be appointed during the equipment installation stage of the project and be required to work alongside the installers so that he learns about the procedures for installation, assembly, and so on. If possible, the installers should explain to the operator what can go wrong with each component and how to run the equipment, apply tension to belts, grease the lubrication points, and deal with emergencies.

If the plant is coupled to agro-processing equipment, the operator should also be trained to operate the agro-processing equipment and its accessories, i.e., the shaft pulley, belt, and so on. The operator should know how to change belts safely, and how to fix the alignment and diagnose faults of the agro-processing machines. If the operator leaves the job after only a short time this will not only hinder the day-to-day work but will also cause economic loss to the owner. Thus it is important to select a person who is likely to stay for quite a long period. Adequate incentives, including a good salary, may be helpful in retaining good operators, in addition to considerate behaviour and treatment.

### 2.1.2 *Training*

If the operator (or operator/manager) is hired in the early phases of the project, the subsequent training needs will be less than if an operator were to be hired once the equipment is installed and running. It will be necessary to provide special training if the person is hired after the handover of the project. The owner/community should be aware of the importance of training, without which a project will not run smoothly. The installer provides some basic training at the project site to familiarise the operator with the machines and simple operational procedures. Usually this training is not adequate and additional extensive training should be provided. There are a number of organizations that provide such training throughout the year, often free of charge. The owner/community should make themselves aware of any such opportunities in their country.

### 2.1.3 *Assignment and Supervision of the Operator's Work*

The number of powerhouse operators needed by a micro-hydro project and their work assignments are determined by such factors as the capacity of the project, the complexity of the transmission lines, the headrace, and the penstock. The usual work of the operators can be summarised as follows.

- Regular inspection of the civil work and penstock for damage and need for cleaning
- Flushing/cleaning such things as the intake, the headrace, the desilting basins, and the forebay
- Repairing damage to civil works
- Stabilising/cleaning surrounding areas to prevent landslide damage
- Cleaning and properly maintaining the powerhouse and the equipment in it
- Properly operating the machines within the powerhouse
- Listening for signs of any malfunction or similar problems
- Shutting down the plant if necessary
- Carrying out minor repairs

The job of the manager is to explain these assignments clearly to the operators, to assist and lead them, and to supervise their work, especially during the initial stages of their employment. The manager should also assess the capacity of the operators to learn and perform their duties effectively and amicably. He must also question them and reprimand them if necessary about any laxness in the performance of their duties.

## 2.2 Improving Customer Services

### 2.2.1 *Public Relations*

Both the manager and the operator(s) should speak pleasantly to customers. This is good for business. Any minor problems with customers should be sorted out immediately. For complex problems, a general meeting should be called to which all relevant personnel should be invited. The problems should be discussed and a solution worked out jointly, especially in the case of electrification schemes. Sometimes the operator/manager may himself have to visit local workshops or organizations far from the plant. If he has to leave the plant, another capable person should be instructed to look after the operation and management of the plant. The public should be informed in advance of the reasons for and approximate period of any shutdowns of the plant so that they can make alternative arrangements.

The operator/manager of an electrification plant should visit consumers and discuss with them any problems or complaints they may have regarding the supply; as well as any other issues such as use of electricity, non payment of bills, and low voltage. Every effort should be made to hold such discussions in a cordial manner.

### 2.2.2 *Good Service*

The operator/manager must provide good service to customers on a first-come first-served basis, with a few exceptions. For example, people coming from distant places need to leave for home early, so with the consent of the other customers they may be given priority. When planning the supply of electricity, all houses requesting a fixed wattage supply should be connected first. Only after all such houses have been provided for, should any additional available power be distributed as per the requirements.

Unscheduled and unannounced shutdowns of the plants will lead to loss of revenue, business, and reputation. Therefore, every effort must be made to avoid breakdowns and shutdowns through regular maintenance and by taking care of the small faults and problems that can eventually lead to serious breakdowns.

### 2.2.3 *Load Management*

Sooner or later demand for power will exceed the installed capacity in many plants because, unfortunately, some consumers may take more power then the amount for which they have subscribed. It is necessary to have some sort of monitoring device to make certain that the generating plant is not overloaded and the investor is not suffering losses. It is not practical, however, to install a meter in every household in an MHP scheme. This would only introduce more costs and complications; especially since most consumers will only be subscribing in the range of 50-200 watts.

A flat rate system is generally used in which the consumer pays a fixed rate for the category of wattage for which he/she has subscribed. The maximum power taken by the consumer can be limited through installing some type of current limiting device. Positive thermal coefficient (PTC) controllers are used for the 25 to 50 watt range, electronic current cut-outs (ECC) for the 50-200 watt range, and miniature circuit breakers (MCB) for consumers taking more than 200 watts. Some problems have been experienced with ECC in Nepal, and one of the other two options may be preferable.

Load factors for MHP plants are generally poor, especially in electrification schemes. The electricity is mainly used for domestic lighting. Thus the power demand is for certain hours in the evenings and sometimes in the mornings for a total of about six hours a day. If the available power from the plant is not used during the remaining period there will be less income. Thus the owner/manager should think of ways to increase the utilisation and/or sale of electricity, particularly to industrial or commercial units.

During daytime and the middle of the night, when lighting is not necessary, other end uses can be installed such as small industries, shops with refrigerators, bakeries, and sawmills. The owner of the MHP plant may invest in such applications himself; or he may encourage or seek others to install such units and buy electricity from him. If industrial applications are to be added, power distribution must be carefully managed so that it is acceptable to such customers.

Sometimes there is a lack of interest in industrial development because of the high costs. The manager should motivate people to install industries, and charges should be reduced if the investors agree to operate during off peak hours. Wherever possible, industrial applications should not be run during peak hours, otherwise there will be voltage fluctuations. Rates for such industries should be decided before the industrial plant is installed.

## 2.3 Financial Management

In order to keep track of income and expenditure, proper records and accounts should be kept of income, expenditure, and savings. Repayments of the loan should be planned based on the projected income and savings, and an adequate amount must be set aside each month for this purpose. Usually only one account book is needed for an MHP plant, but it should have many tables. In general, the records will be kept by the owner or manager of the project. The account book should cover the following.

- Daily records of income and expenditure including outstanding amounts.
- Records of assets (property and stock owned, liabilities/bills or money still to be paid) on a monthly basis.
- Amounts spent on major repairs, new equipment, or business expenses, recorded daily, with monthly totals for each sub heading.
- A final table each year showing all the income, expenditure, outstanding income, and liabilities. This table is needed to determine net profit or loss, and the calculations are useful for planning for the following year.

There are two main systems for keeping the accounts of a project: single entry book-keeping, in which the transactions are recorded once; and double entry book-keeping, in which the transactions are recorded twice. Double entry book-keeping means, for example, that when an MHP project purchases spare parts the account for money spent on spares will be increased, and the bank account or cash account will be reduced. Double entry book-keeping is preferred because it is a more systematic and professional method of maintaining accounts, and can help to identify mistakes very easily. However, the double entry system may be unnecessarily cumbersome for smaller MHP schemes, say below 50kW, and single entries for income and expenditure may be good enough.

The types of information and tables that will be needed are shown in the following sections. The examples given refer to the book-keeping entries used for a typical 30kW MHP scheme. They use the single-entry book-keeping system. Examples of double-entry book-keeping can be found in books about accountancy.

The first page of the account book should contain a table showing details of total project costs and sources of funds (see Table 2.1). The second page should contain a table with details of the loan repayment schedule for easy reference (Table 2.2).

**Table 2.1: Details of Total Project Costs (example)**

| S.N | Description | Amount (Rs) |
|---|---|---|
| 1. | Land purchased | 50,000 |
| 2. | Civil construction (canal, powerhouse, desilting basin, forebay) | 300,000 |
| 3. | Mechanical equipment (turbine, penstock, driving systems) | 335,000 |
| 4. | Electrical (generators, ELC, components) | 1,000,000 |
| 5. | Transportation costs | 100,000 |
| 6. | Installation costs | 200,000 |
| 7. | Operator training | 15,000 |
| | **Total Cost** | **2,000,000** |
| | **Sources of Funds** | |
| 1. | Local contribution (or self investment) | 400,000 |
| 2. | Grant from non-government organization (NGO) | 500,000 |
| 3. | Loan from bank | 600,000 |
| 4. | Subsidy | 500,000 |
| | **Total** | **2,000,000** |

### 2.3.1 *Income and Expenditure Account*

Records of income and expenditure should be kept as shown, for example, in Table 2.3. All income should be dated, and sources of income and expenditure clearly detailed. There will be different expenditures such as salaries, travel, other expenditures, and loan installments. The account book should be updated daily and all transactions recorded in chronological order. Income pending (not yet received) and expenditure (necessary, but not yet paid) may be noted down separately but should not be included in the accounts until they are actually received or paid. The final figures for income and expenditure should be worked out for each month and year.

**Table 2.2: Loan Repayment Schedule for the MHP Plant (example)**
The example given is for a total loan of Rs 600,000 at an interest rate of 16%

| Description | Amount (Rs) |
|---|---|
| Complete repayment in 7 yearly installments | 600,000 |
| 1st yr. ending June, 1997 - repayment of capital | 86,000 |
| Interest on 600,000 @ 16% | 96,000 |
| 1st installment of loan and interest to be paid by 15 July, 1997 | 182,000 |
| 2nd yr. ending 30th June, 1998 - repayment of capital | 86,000 |
| Interest on 514,000 @ 16% | 82,240 |
| 2nd installment of loan and interest to be paid by 15 July, 1998 | 168,240 |
| 3rd yr. ending 30th June, 1999 - repayment of capital | 86,000 |
| Interest on 428,000 @ 16% | 68,480 |
| 3rd installment of loan and interest to be paid by 15 July, 1999 | 154,480 |
| 4th yr. ending 30th June, 2000 - repayment of loan | 86,000 |
| Interest on 3,42,000 @ 16% | 54,720 |
| 4th installment of loan and interest to be paid by 15 July, 2000 | 140,720 |
| 5th yr. ending 30th June, 2001 - repayment of loan | 86,000 |
| Interest on 2,56,000 @ 16% | 40,960 |
| 5th installment of loan and interest to be paid by 15 July, 2001 | 126,960 |
| 6th yr. ending 30th June, 2002 - repayment of loan | 86,000 |
| Interest on 170,000 @ 16% | 27,200 |
| 6th installment of loan and interest to be paid by 15 July, 2001 | 113,200 |
| 7th yr. ending 30th June, 2003 - repayment of loan | 84,000 |
| Interest on 84,000 @ 16% | 13,444 |
| 7th installment of loan and interest | 97,444 |

At the end of each year it is useful to record total incomes and expenditures for such things as loan repayment, repairs, income from electricity, and agro-processing separately on a single page, as shown in Table 2.4. The remaining net balance can be used for (divided between) the personal or family expenditure of the owner/investor, for reinvestment, or to provide a fund for unexpected outlays in the coming year.

For electricity sales, it is unlikely that cash payments will be made at the beginning of every month. Sometimes, money or bills may not be received until the following month. In such cases a record of payments due but still pending should be kept at the bottom of the first page for the month and struck off and entered as a regular entry in the account book when received.

**Table 2.3: An Example of Daily Entries in an Account Book for the Month of January 1998**

| Date | Description | Credit (Income) | Debit (Expenditure) | Balance (Net Income) |
|---|---|---|---|---|
| 1st Jan '98 | Money in hand (opening balance) | 10,000 | | |
| 1st Jan '98 | Income from electricity sale from Area 1, 100 customers @ Rs100 each | 10,000 | | |
| 1st Jan '98 | Salary for two staff @ 1,500 each for December 97 | - | 3,000 | |
| 1st Jan '98 | Travel expenses paid | - | 250 | |
| 1st Jan '98 | Repair and maintenance expenses for canal | - | 500 | |
| 1st Jan '98 | Stationery (postage & telephone paid) | - | 10 | |
| 1st Jan '98 | Other expenses | - | 5 | |
| 2nd Jan '98 | Plant closed due to festival | - | - | |
| 3rd Jan '98 | Sale of electricity from area No. 2,75 customers @ Rs 100 each | 7,500 | | |
| 4th Jan '98 | Sale of electricity from area No. 330 customers @ Rs 100 each | 3,000 | | |
| 5th Jan '98 | Sale of electricity from area No. 420 customers @ Rs 100 each | 2,000 | | |
| | **Total for January 1998** | | | |

### 2.3.2 *Budget for the Coming Year*

It is advisable to prepare a proposed budget for the coming year, this would be 1999 in the examples given. The budget should be based on the income, expenditure, and net profit of the previous two to three years. The proposed budget (Table 2.5) should appear on the page after the table showing the total income and expenditure for the present year (Table 2.4). The table should show the anticipated income and expenditure under the various major headings for the next year and include planning for some additional expenditure, for example, major repairs, expansion of forebay, or cleaning and repair of the penstock. The expenditure should also include the personal needs of the owner and show the net savings, which can be spent on repairs or buying new equipment. In the example shown, the final figures in the table show that the owner will have to arrange an additional Rs 27,000 from his own resources if he decides to go ahead with his investment plans. The owner/community must realise that the actual expenditure (and income) may differ significantly from the figures anticipated.

| Table 2.4: An Example of Total Incomes and Expenditures under Various Headings for 1998 | | | |
|---|---|---|---|
| Description | Credit (Income) | Debit (Expenditure) | Balance (Net Income) |
| Balance from 1997 | 21,000 | | |
| Income from electricity | 270,000 | | |
| Income from agro-processing | 180,000 | | |
| Income from sale of agro-processing commodities | 215,000 | | |
| Income from sale of agro-residues | 13,000 | | |
| Staff salaries | | 36,000 | |
| Maintenance | | 18,000 | |
| Repair of generator | | 40,000 | |
| Purchase of spares | | 14,000 | |
| Stationery, telephone | | 600 | |
| Loan instalment (capital + interest) | | 154,480 | |
| Travel & transport | | 19,000 | |
| **Total** | **699,000** | **282,086** | **416,914** |

Net yearly income for 1998 Rs 416,914
Net average monthly income Rs 34,743

### 2.3.3 *Business Expansion*

After the owner/manager of an MHP plant has achieved success in operating and managing the current end-uses optimally, one of his main considerations should be installation of additional end use equipment and/or supplying electricity to additional customers, especially during the off peak hours. In the example shown below, the owner/manager of an existing electrification scheme decided to add some agro-processing equipment to his plant to utilise additional power and thus earn more income. The cost of the new equipment and expected yearly returns are shown in Table 2.6. The figures suggest that the simple payback period will be about four years, and that the simple annual rate of return is about 25 per cent, a healthy profit. There are more complicated methods of financial analysis, but, as the overall investment is small, these simple figures are probably adequate for determining the initial feasibility.

### 2.3.4 *Extending the Supply*

Another method of earning additional income is to extend the electricity supply to areas nearby if additional capacity is available within the plant. This should also mean ad-

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**Table 2.6: Estimated Income and Expenditure (in Rs) for the New Agro-processing Equipment (example)**

| Description | Credit (Income) | Debit (Expenditure) | Balance (Net Income) |
|---|---|---|---|
| **Capital Costs** | | | |
| Cost of grinder, huller, and oil expeller | | 100,000 | |
| Other mechanical equipment (shafts, belts, pulleys) | | 50,000 | |
| Transportation costs | | 25,000 | |
| Civil works (materials, labour) | | 30,000 | |
| Installation costs (materials, labour, testing) | | 15,000 | |
| **Total Capital Costs** | | 220,000 | |
| Estimated average yearly income (from 3 units) | 96,000 | | |
| Salaries | | 24,000 | |
| Maintenance | | 8,000 | |
| Average repair costs per year (4% of total investment) | | 9,000 | |
| **Total (per year)** | **96,000** | **41,000** | **55,000** |

Assuming that the yearly income does not fluctuate severely; the owner would recover his investment in about four years.

After the survey, capital cost estimates can be prepared together with estimates of income and recurrent expenditure. Usually, the net incomes from electrification schemes are quite small, and net yearly incomes of about 15 per cent of the original investment may be considered adequate. If it is necessary to obtain a loan at normal interest rates from a financial institution, then the project may not be viable and the possibilities for getting a subsidy or grant from a donor agency should be explored.

## 2.4 Organizing Maintenance

In order to maintain the MHP plant in the best possible condition, it is essential that routine maintenance be carried out in accordance with a predetermined schedule. Manufacturer's maintenance schedules for items such as bearings and generators should be followed carefully. Routine preventative maintenance will result in extended plant life and reliable operation; and reduce the long-term operating costs. Waiting for the plant to break down and then trying to fix it will result in increased long-term operating costs, reduced plant life, and user dissatisfaction.

The manager should instruct the operator clearly to check items outside and inside the powerhouse on a regular basis to ensure reliable operation. He should also randomly supervise his work. Any problems should be rectified as soon as possible to prevent them from getting worse.

### 2.4.1 *Maintaining a Stock of Spares*

A micro-hydro scheme needs repair and maintenance quite often, and the manager is responsible for organizing this. Some spare parts, such as bearings, tools, grease, oil, and belts, should always be kept in stock so as to avoid delays in procuring them when they are needed. The plant should have a separate locked storage room or a cabinet for tools and spares which is kept clean and secure. Bearings should be stored in the original packing; or coated with grease if this is not possible. Vee or flat belts need to be hung on a wall and not left coiled on the floor. Electrical parts should be packed, labelled, and stored away from moisture.

It is recommended that at least one set of the following spare parts should be kept in stock for an MHP plant.

| | |
|---|---|
| • Turbine bearings | 1 set (usually two) |
| • V-Belts | 1 set |
| • Flat belts | adequate length, enough to cover the longest belt length used in the plant. |
| • Grease | 1 kg |
| • Generator bearings | 1 set |
| • Gaskets | 1 set (for all locations) |
| • Penstock nuts, bolts | 5% of total installed |
| • Expansion joint gasket | 10% of total installed |
| • Fuses | all installed sizes |

In addition, if the funding permits, one turbine runner and an automatic voltage regulator (AVR) should also be kept in stock as spares.

### 2.4.2 *Maintenance Tools*

Good quality tools are essential for good maintenance of the MHP plant. The manager should be responsible for keeping the tools properly and should instruct and guide the operators to use them correcly. The following suggestions will help keep the tools in a good useable condition.

- Clean tools after use and return them to the storage area.
- Lubricate them to prevent corrosion wherever 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 them if they become unusable.
- Store hand tools on a board or in a cupboard.
- Store measuring instruments (multi-meter, vernier, etc) in a cupboard or draw to protect them from dust and impact.

The spares and tools should preferably be kept in a separate room under lock and key, and their issuance and re-storage should be recorded in the log book or a separate register. Figure 2.1 shows the ideal type of storage arrangement for tools.

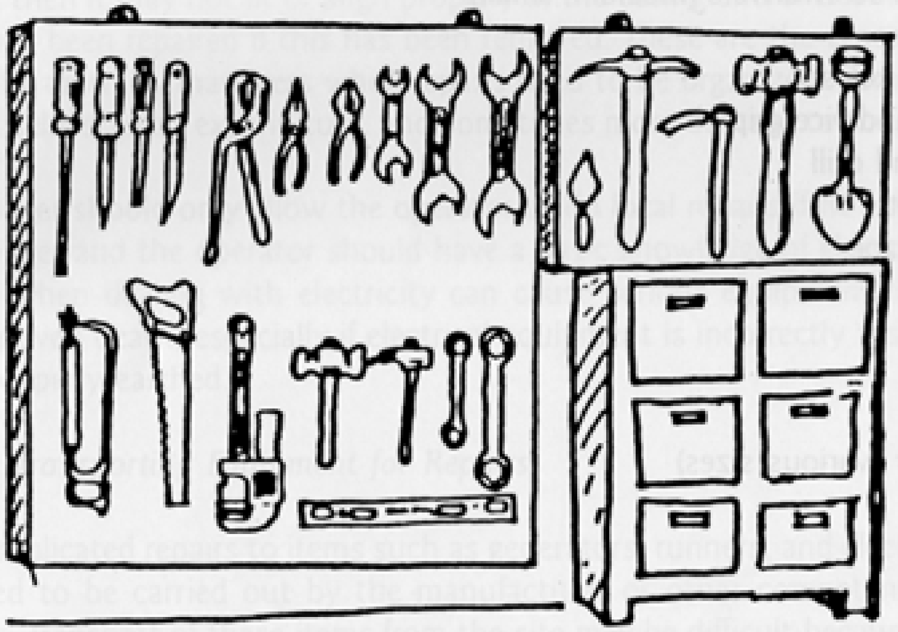


**Figure 2.1: Ideal Storage Arrangement for Tools**

### 2.4.3 *Necessary Tools*

The basic tools needed for maintenance of an MHP plant are listed below.

Electrical

- Combination pliers
- Nose pliers

- Soldering iron and solder
- Hacksaw
- Line tester and multi-meter
- Torch or portable lamp

In addition, if funding is available; a wire puller and safety belt should also be kept in stock.

Mechanical

- Hammer
- File set (flat, round, etc)
- Open and ring spanners, one set each
- Slide wrench (200 mm or 300 mm)
- Screwdrivers (large, small)
- Phillips head screwdrivers (medium, small)
- Grease gun
- Metric Allen key set
- Bench vice and vice grip
- Portable hand drill
- Twist drill set
- Measuring tape
- Paint brush
- Oil can
- Hacksaw
- Wire brush
- Emery paper (various sizes)

Civil

- Pick
- Spade
- Shovel
- Crow bar (lever)

## 2.5 Organizing Repairs

### 2.5.1 *Procedures to Deal with a Breakdown and Fault Diagnosis*

When a breakdown occurs, necessary steps need to be taken to prevent further damage to the plant and possible injury to staff. This usually requires shutting down the plant until the fault is diagnosed and the problem is rectified. Refer to the 'Manual for Maintenance and Repair of MHP Plants' for problem diagnosis and corrective action.

### 2.5.2 *Disassembling and Assembling Equipment*

Before commencing disassembly work, always study the layout of the unit to be dismantled carefully. Decide which components need to be removed and which do not. The manager should decide whether a faulty part or machine can be repaired locally, or whether it should be transported to the manufacturer. If it is not repairable locally, and the operator is not experienced, then components that do not need to be removed should not be removed. With any disassembly and re-assembly there is always a chance of damage to equipment and waste of time. However, in some situations in which the transportation has to be manual, some heavier parts may be removed and not transported. For example, if the turbine runner or shaft is damaged, then it may be cumbersome and unnecessary to carry the whole turbine to the repairers. On the other hand, if the shaft needs to be repaired, then it may not fit or align properly in the casing and/or bearing of the housing after it has been repaired if this has been removed. These are the types of decision that need to be taken by managers when repairs need to be organized. Wrong decisions can result in delays, extra expenditure, and sometimes more damage to the equipment.

The manager should only allow the operator to do local repairs if he is well experienced. The manager and the operator should have a basic knowledge of electricity. Minor carelessness when dealing with electricity can cause serious equipment damage, personal injury, or even death, especially if electrical equipment is incorrectly assembled or wired, or not properly earthed.

### 2.5.3 *Transporting Equipment for Repairs*

More complicated repairs to items such as generators, runners, and electronic equipment may need to be carried out by the manufacturer or other competent repairer on his premises. Transport of these items from the site may be difficult because of poor access. It is important that before transportation care is taken to:

- pack equipment well using timber or thick cardboard;
- protect equipment from water damage by wrapping it in plastic;
- print 'right way up' and 'handle with care' signs; and
- inform the persons responsible for transport about the need for care in handling, especially when loading and unloading from vehicles.

Figure 2.2 also illustrates a few 'rights and wrongs' for transportation of equipment.

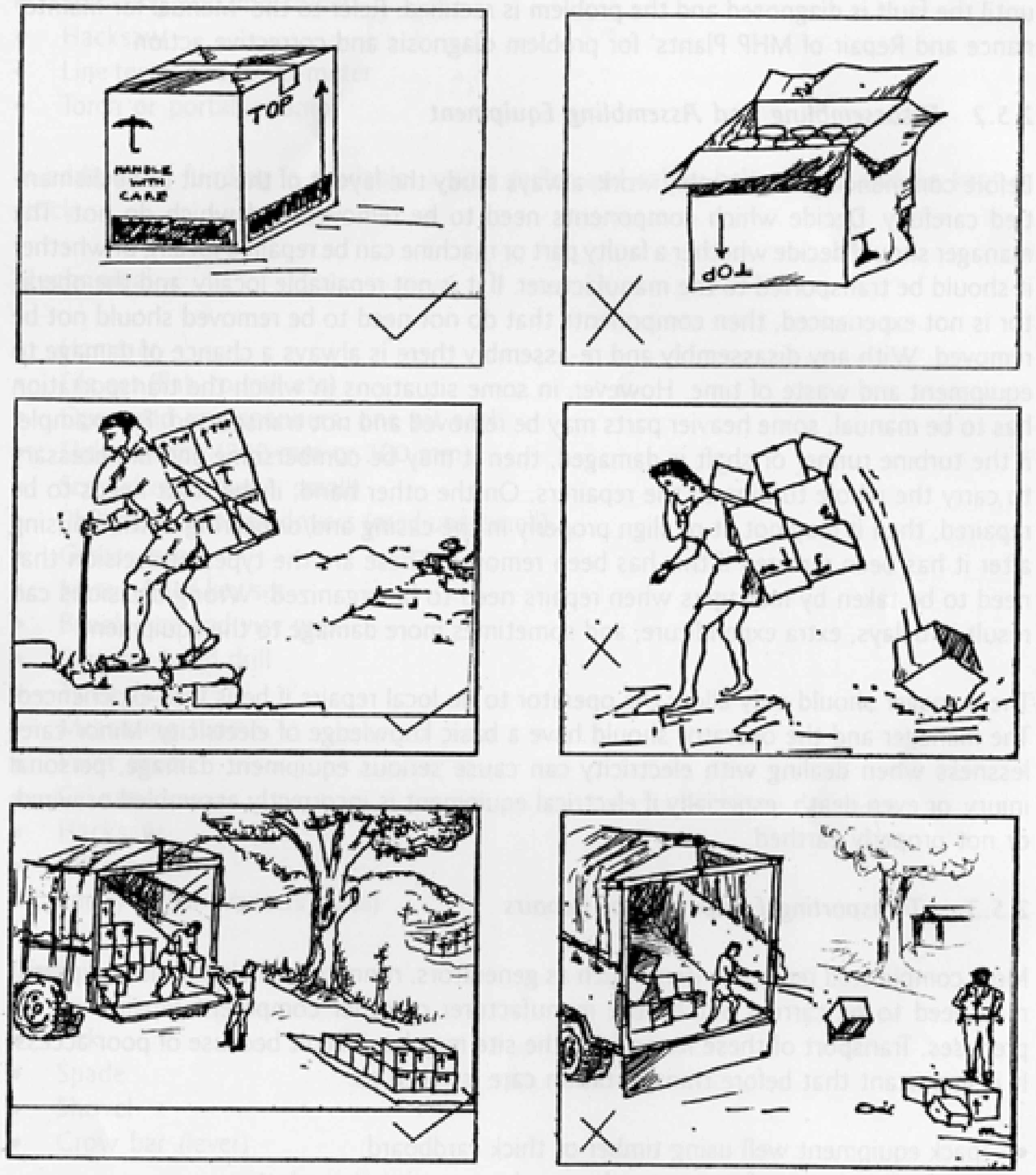



**Figure 2.2: Right and Wrong ways to Transport Equipment**

# CHAPTER 3
# Operation

Correct operation and maintenance of an MHP plant is beneficial in many ways. Managers and operators must be fully familiar with the equipment, its functions, and the operational procedures. The technical specifications must also be known and recorded properly in the Operation and Maintenance Manual provided by the installer and in the log book. Table 3.1 shows a typical example of specifications.

## 3.1 General Operating Procedure

The following checks should be made during starting, stopping, and running of the plant. If a problem is noticed at any stage, for example, an unusual sound, the plant should be stopped and the problem rectified before starting or running the plant again.

### *3.1.1 The Start-up Procedure*

<u>For Water and Turbine</u>

- Follow the specified procedure for cleaning up the civil works as applicable.
- Visually inspect all equipment (e.g., turbine, generator, control panel, isolating switch).
- Check oil levels in any equipment using oil reservoirs.
- Ensure that the penstock and turbine valves are closed.
- Turn on the water at the intake.

<u>For Electricity</u>

- Check that all switches on the load side are in the 'OFF' position (if an electronic load controller (ELC) is installed) alternatively check that all switches on the load side are in the 'ON' position (if there is no ELC).
- Inform users that the plant will be starting (some system for this needs to be developed and put into operation, since it is difficult to inform all consumers separately).
- If belts have been removed, put them on the pulleys. Check belt tension.
- Gradually open the penstock valve (if fitted) to the fully open position.
- Gradually let water into the turbine by opening the turbine valve, while checking the pressure gauge to maintain a smooth rise in pressure.
- If there are any push button switches for exciting the generator, press them until the voltage rises to 200V.

- Increase the water flow by opening the turbine valves until the speed, voltage, and power come up to the desirable/rated level.
- For plants with an ELC, gradually divert power to the load by switching the load switches to 'ON'.
- If there is no load controller, increase the water flow until the voltage rises to 220 V while the load is connected.
- The allowable voltage fluctuation for plants below 25kW is +10 per cent and -14 per cent; for larger plants it should be within ±10 per cent.

For Agro-processing

- Check all nuts, bolts, and similar on the agro-processing machinery; move everything away from the drive system.
- Engage the belt from the turbine to the line shaft and then to the machine.
- If there is no line shaft, place the belt directly from the turbine to the machine; for example a rice huller.
- Admit grains to the huller, oil seed to the expeller, etc.
- Let water into the turbine, gradually opening the turbine valve until the required speed is reached.
- Check the pressure gauge to ensure that pressure is not fluctuating rapidly.
- Listen for any abnormal noise or vibration when the unit is running. Stop the turbine if this happens and look for the fault.
- Check drive systems (e.g., belt or coupling).
- Only connect units simultaneously when power is sufficient.
- If the turbine is powering a generator and agro-processing equipment simultaneously; the electricity generation has priority. Only connect the agro-processing unit if sufficient additional power (i.e., flow) is available.

### *3.1.2 Continuous Checks during Running*

The following checks must be made during the running of the plant. If at any stage an abnormal condition arises, the plant should be shut down and the problem diagnosed and rectified.

- Check the voltage, frequency, and power output every hour and record in the log book once a day. Abnormal readings must be recorded whenever noticed, together with the corrective action taken.
- If the voltage or frequency decreases as a result of overload, remove some loads.
- Compute the power consumed from the panel meter (current and voltage) if no wattmeter is installed.
- If the power consumption is more than design capacity, disconnect some loads from the distribution box.

- Check for abnormal noises and water leaks.
- Check bearing and generator temperatures by touching the housings.
- Periodically check the penstock pressure.
- If overload occurs, it could be that some consumers are using a higher load than permitted (for example a heater) so checks should be made regularly at the premises of such users.

### *3.1.3 The Shutting Down Procedure*

The following procedure should be followed prior to and during shutting down of the MHP plant.

- If time permits, inform users that the plant will be shut down (unless they already know, as in the case of regular shutdowns).
- Switch all connected loads to 'OFF'.
- Close the turbine control valve gradually to prevent a rapid rise in penstock pressure.
- Close the penstock valve.
- Stop water from the forebay tank and intake if necessary.
- Ensure that the powerhouse and equipment are clean and tidy.

If the shutdown is the result of an emergency, action should be quick and emergency devices such as jet deflectors (for Pelton turbines) should be actuated.

## 3.2 Safety and First Aid

Working with electricity can be very dangerous if adequate care is not taken. Thus it is important to be aware of, remember, and comply with safety precautions; and it is essential to know how to perform first aid and primary treatment when an accident happens.

### *3.2.1 Workplace Safety Precautions*

The following precautions should be taken when operating an MHP scheme or working in a powerhouse while it is in operation.

- If possible, shoes should be rubber soled; they must not be damp or wet.
- While working, hands should not be wet.
- If possible the electricity supply to the work area should be turned off before starting work.
- The location of the switch to turn off the whole electricity supply should always be known beforehand to workers.
- Only essential fuses should be left in place while working on an electrical circuit; others should be removed.

- Make sure that metal covered items, such as the main switch and panel box, are properly earthed.
- If a fire or electrical accident occurs, the electric power should be turned off immediately.
- Tools and materials should be kept in their proper place when not in use; and only proper tools and materials should be used for particular work.
- After finishing work, everything should be cleaned and returned to its proper place; this practice should become a habit.
- Work in a systematic way. If any work is unfamiliar, an experienced person should be asked to assist or advise; especially in the case of electrical machines.
- Oil should not be put in a machine that is running.
- Glasses and gloves should be used when working in front of a machine (grinding, drilling, welding, and similar work).
- Keep a straight back and bend your knees when lifting any machine or heavy material.
- Necessary primary treatment (first aid) should be given immediately to an injured person if an accident occurs.
- Repaired machinery should only be operated after it has been carefully tested.
- The worktable should be well insulated (should be wooden).

### 3.2.2 *First Aid for Electrical Shock*

If any person suffers an injury from an electrical accident he should be taken to a doctor as quickly as possible. If this is difficult or not possible (the road may be blocked, transport facilities may be limited, or the distance may be long) the sick person may have to remain in place for some time. In this case, the injured person should be kept calm and first aid should be provided. It would be very beneficial if personnel were properly trained in a suitable place to administer first aid (for example at a civil defence centre or hospital). The following procedure should be adopted for providing first aid to an injured person.

- The electricity line should be disconnected immediately, the main switch turned to 'OFF', and the shocked person separated from the source of the shock. Don't forget clothing which may also be in contact with the electrical supply.
- If the switch cannot be reached quickly, the live wire should be removed from the person with the help of a non-conductor such as wood, plastic, or rubber.
- If the person is unconscious and not breathing, artificial respiration should be administered, as described below, or else the person may die.
- After giving artificial respiration, the area affected by the shock should be massaged because an electric shock causes the blood circulation to stop. The arms, feet, etc should be rotated at the joints.
- Feed the person in shock some warm milk or tea.

- The person in shock should be encouraged to talk and move if possible to give him confidence and help him remain conscious. Don't let him lose consciousness.
- Every effort should be made to make the person in shock as comfortable as possible.
- If the condition of the injured is still serious (say, the breathing is irregular or he is sweating), he should be taken to a hospital or to a good doctor. In all cases the injured person should see a qualified doctor as soon as possible for a check-up and treatment.

### 3.2.3 *Artificial Respiration Techniques*

Anyone who receives a high voltage electric shock may become unconscious, and even stop breathing. If the injured person stops breathing he must be given artificial respiration immediately, until he begins to breathe by himself. The following two techniques are those used most commonly to revive breathing artificially.

#### The Face-down Method

This method is simple and easy to learn and is thus more commonly used. The basic positions are shown in Figure 3.1. The person giving first aid kneels in front of the sick person and lays the sick person face down on the floor between his knees. The two hands of the injured person are folded in front of his head and the forehead rested on them. In this way, the nose air passage remains open. Then the person giving first aid places his two hands with the fingers spread wide on the back of the sick person below the shoulders and, placing his two thumbs equally on the ribs of the sick person, slowly presses downward with his hands, watching carefully to see how much pressure is needed. The pressure should be such that air emerges from the lungs and they are emptied. The hands should then be released slowly. The sick person is then grasped by the upper arms just above the elbows with both hands, and the arms are pulled upwards towards the person giving first aid. In this way, the chest expands and air enters the lungs. The person giving treatment should repeat this cycle at a rate of about 12 times per minute until such time that the sick person begins to breathe naturally by himself.

#### Mouth-to-Mouth Resuscitation

This method is illustrated in Figure 3.2. The sick person should be made to lie flat on his back. First check that the jaws of the injured person can be opened easily; if not, open them by hand. Place one hand under the back of the sick person's neck to raise it a little and use the other hand to hold his nose shut. The person giving treatment should place his mouth over the sick person's mouth and blow into it, whilst holding the nose closed to prevent air escaping, to fill the patient's lungs with air. After that, the nose is released so it can open and the air in the lungs can come out. The nose is then held closed again

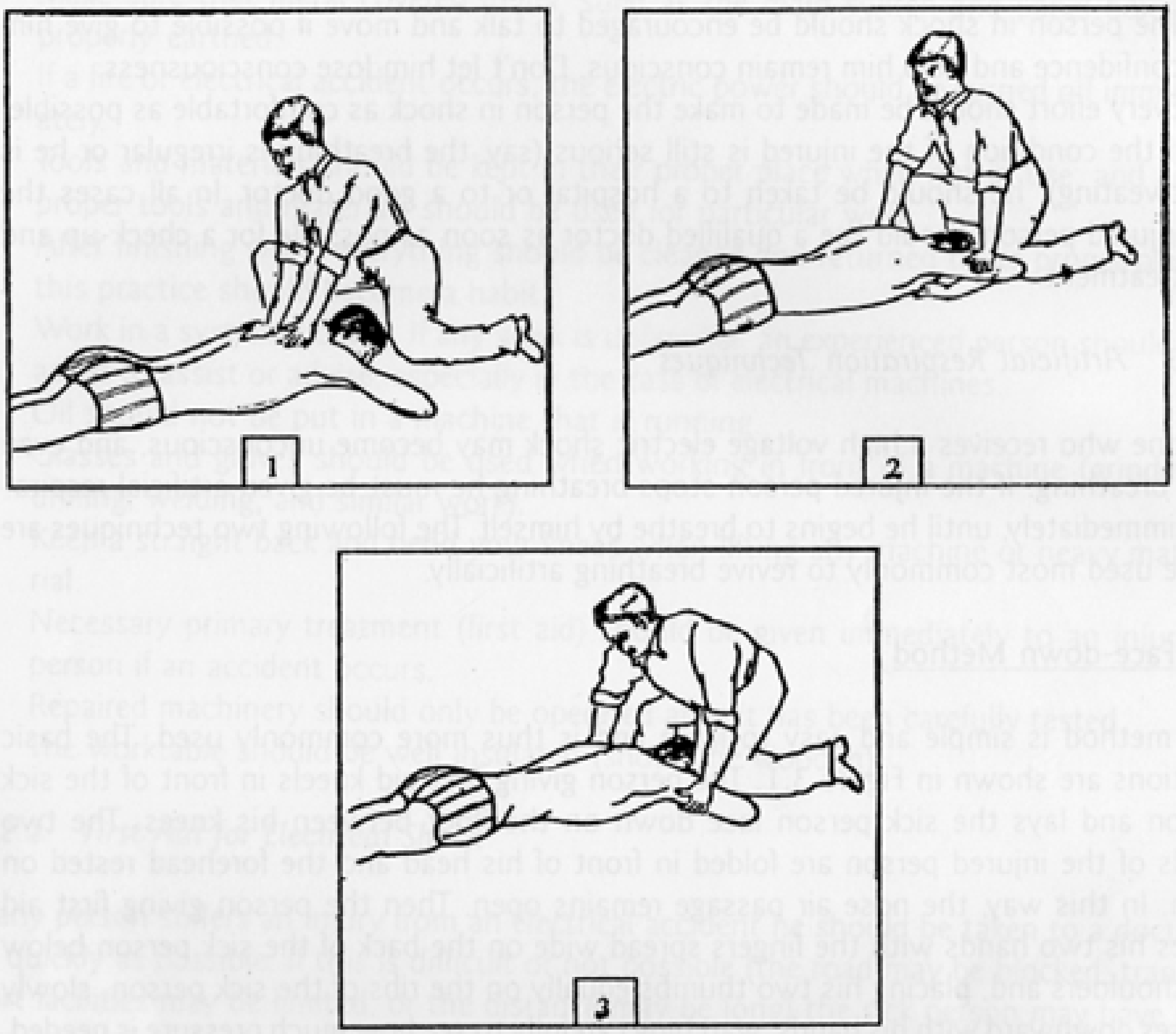



**Figure 3.1: The Face-down Method of Artificial Respiration**

and the cycle repeated at a rate of 10-15 times a minute until the person giving first aid notices that the pressure needed to blow in is becoming less than in the initial stages.

### 3.3 Extended Shutdowns

If a major repair has to be carried out on an MHP plant, the powerhouse will have to be shut down for a long period. If an extended shutdown becomes necessary, the operator/manager should notify the villagers about the situation and about the tentative duration of the shutdown. The equipment remaining within the powerhouse must be protected from corrosion, rain, landslides, pilferage, and other such eventualities. Some items located outside the powerhouse (e.g., trash rack, canal gate) may also be dismantled and stored within the powerhouse or some other safe place.

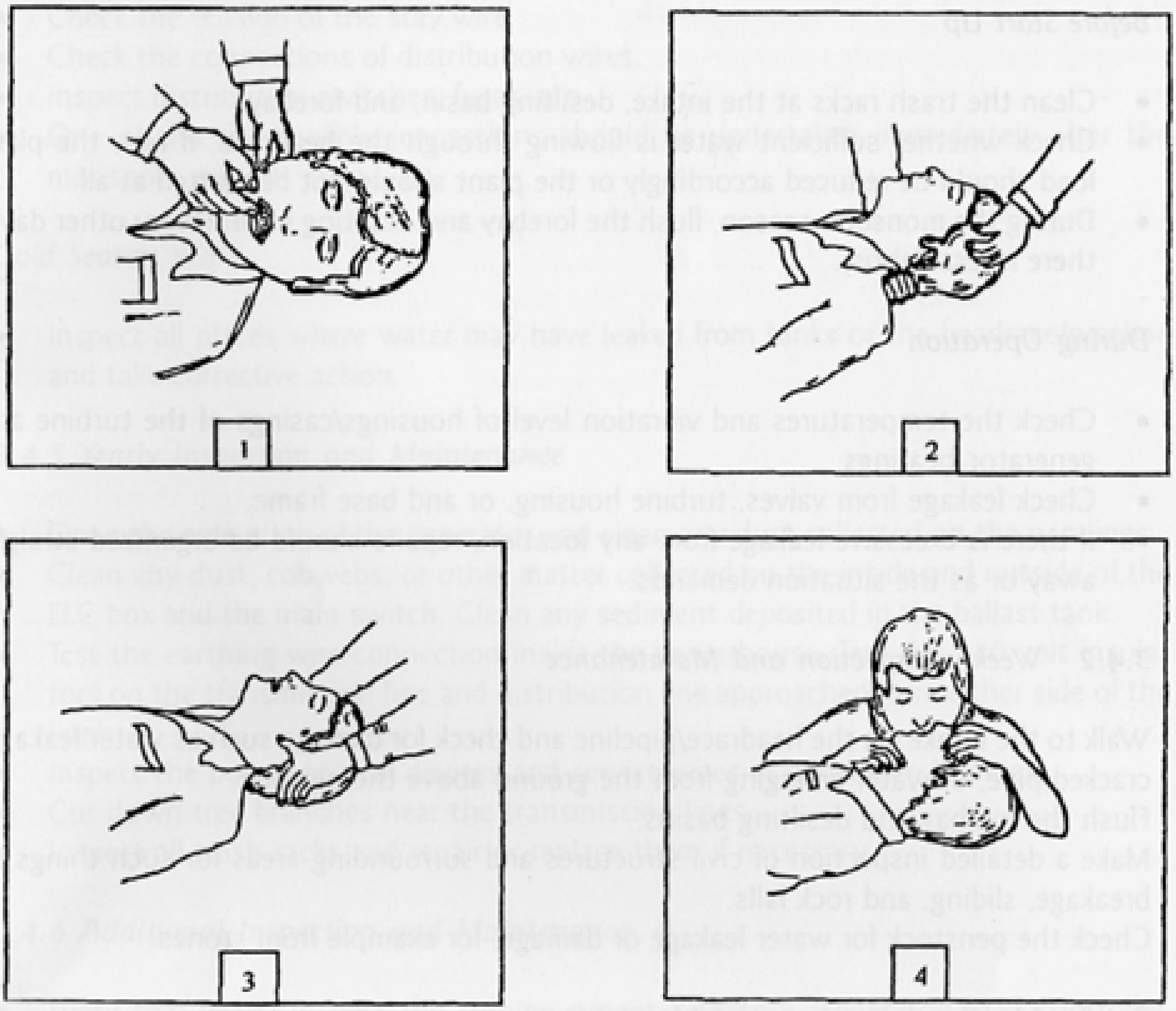



**Figure 3.2: Mouth-to-Mouth Resuscitation**

### 3.4 Routine Inspection and Maintenance

The operator should check the following items inside and outside the powerhouse on a regular basis to ensure reliable operation. The suggested frequency of checking for different items is given below. Any damage noticed during these checks should be rectified as soon as possible to prevent the problem from getting worse.

#### *3.4.1 Daily Inspection and Maintenance*

The following items should be inspected every day and corrective action taken if necessary. See also section 3.1.2.

*Before Start Up*

- Clean the trash racks at the intake, desilting basin, and forebay.
- Check whether sufficient water is flowing through the headrace. If not, the plant load should be reduced accordingly or the plant should not be started at all.
- During the monsoon season, flush the forebay and desilting basin (every other day if there is less debris).

*During Operation*

- Check the temperatures and vibration level of housings/casings of the turbine and generator bearings.
- Check leakage from valves, turbine housing, or and base frame.
- If there is excessive leakage from any location, repairs should be organized straight away or as the situation demands.

### 3.4.2 Weekly Inspection and Maintenance

Walk to the intake via the headrace/pipeline and check for damage such as water leakage, cracked pipe, or water emerging from the ground above the pipeline.
Flush the forebay and desilting basins.
Make a detailed inspection of civil structures and surrounding areas for such things as breakage, sliding, and rock falls.
Check the penstock for water leakage or damage, for example from stones.

### 3.4.3 Monthly Inspection and Maintenance

- Walk from the powerhouse along the penstock to the forebay and check all expansion joints, flanges, and welds for leakage.
- Close all the turbine valves and open up the bearings and put two fingers full of grease in each. Do the same for the generator bearings using a grease gun.
- Inspect the generator, MCB switch, and ELC box and feel the cables to check if they are very hot. Also check to see if the colour of the cables has changed.
- Check the fencing around the high voltage transformer if installed.
- Inspect all the civil structures, including the penstock and surrounding areas, for landslides and damage, or impending signs of landslides.

### 3.4.4 Six-monthly Inspection and Maintenance

- Inspect the condition of poles and repair any damaged ones.
- Check the clearance of the transmission line from the ground and tree branches.
- Check the line connections of lightning arrestors and jumpers.

- Check the tension of the stay wire.
- Check the connections of distribution wires.
- Inspect distribution switches, fuses, etc.
- One of the six-monthly inspections should be undertaken immediately after the monsoon season.

*Cold Season Work*

- Inspect all places where water may have leaked from tanks or the headrace/pipeline and take corrective action.

### *3.4.5 Yearly Inspection and Maintenance*

- Open the side plate of the generator and clean any dust collected on the windings.
- Clean any dust, cobwebs, or other matter collected on the inside and outside of the ELC box and the main switch. Clean any sediment deposited in the ballast tank.
- Test the earthing wire connection inside the powerhouse. Test the 240 volt insulators on the transmission line and distribution line approached from either side of the lines.
- Inspect the power control devices and service wires at consumers' homes.
- Cut down tree branches near the transmission lines.
- Inspect all trash racks and repair or replace them if necessary.

### *3.4.6 Additional Inspection and Maintenance*

- Every two years, inspect the turbine runner, penstock, generator, load controller, and all civil works. If possible, this inspection should be carried out by a competent consultant.
- Every two years, dig up all earthing plates and inspect them for excessive corrosion. If necessary, the plate (s) should be replaced, and several layers of salt and charcoal or coal dust placed in the hole, one after the other, above the plate. If the earth plate connection is loose, it should be tightened or redone.
- Every four years repaint the penstock completely.

### *3.4.7 Additional Suggestions for Operation and Maintenance*

- Except during the cold months of December and January, the penstock should not be left empty on any sunny day when the plant is not running (because the steel pipe can heat up and the expansion may damage the penstock).
- The overflow from the forebay should be as little as possible; to achieve this, allow a small amount of excess water to come from the desilting basin gate.

- If the powerhouse is to be closed for longer than one hour, the flush gate from the desilting basin should also be left open.
- If the powerhouse is to be closed for a full day or longer, the water flow from the source should also be minimised or stopped if possible.
- During operation, adequate ventilation should be provided in the powerhouse so that the generator receives the necessary cooling air.
- The gate valve should be inspected daily to ensure that sufficient water is flowing to the ballast heater tank. If the water flow is insufficient, the valve and union should be removed, tested, and repaired if necessary.

## 3.5 Log Book

A log book should be kept by the manager/operator in order to keep track of such things as routine maintenance, problems, breakdowns/shutdowns, and repairs undertaken. Only unusual happenings or actions should be recorded in the log book. The log book should also contain a complete list of the technical specifications of the plant. The details needed are shown in Table 3.1. An example of a filled page of a log book is shown below.

---

Date ............................ Time.................... Power output ...............................

Bearing temperature of left hand (LH) side of the turbine is hotter than usual. It should be replaced soon.

---

Date ............................Time................ Power output ...............................

There was excessive leakage from the LH side of the turbine. Plant was stopped and the sealing packing was changed. LH side bearing had also been giving trouble for about three weeks; therefore, it was also replaced.

No further problem at these points.

---

Date ......................... Time.................. Power output ...............................

The plant had to be stopped for two hours because there was not enough water. The diversion barrier at the intake mouth needs to be extended and the weir height needs to be increased .

---

Date ............................. Time..................... Power output ...............................

The plant was shut down for two days to carry out the six-monthly routine repairs. The trash rack at the penstock mouth was repaired. The bolts on the first expansion joint were tightened to reduce leakage. The plant was restarted on ………… (date) at …….. (time) and was working fine.

Table 3.1 The Technical Specifications to be Recorded in the Log Book for the MHP Plant

**1. Intake**

Type: ……………………………………………

Weir Type: ……………………………………………

Diversion details: ……………………………………………

**2. Canal**

| | |
|---|---|
| Canal length | ----------m |
| Silt basin(s) | number ---------- |
| HDPE pipe | dia---------- ; length ---------- m |
| Flush pipe | number----------; dia.---------- |
| Gate valve/sluice gate | number----------; dia.---------- |

**3. Forebay tank**

| | |
|---|---|
| Trash rack(s) | size -------- X; ---------- no. |
| Flush pipe(s) | dia.----------;no.----------* |
| Air vent pipe(s) | dia.----------; no.---------- |

**4. Penstock pipe**

| | | |
|---|---|---|
| Steel | thickness ---------- mm; length ---------- m; dia.---------- mm | |
| HDPE pipe | weight---------- kg/cm²; length---------- m; dia.---------- mm | |
| Expansion/joint | dia. ---------- mm | |
| Butterfly valve(s) | number ----------; dia. ---------- mm | |
| Flat gasket for ………….. | | thickness ---------- mm |
| O ring gasket for …… | | dia. ---------- mm |
| Anchor blocks | number ---------- | at ……… metres |
| Support piers | number---------- | at……… m intervals |
| Bends | number----------at ---------- (length from forebay) | |

* dia. = diameter; no. = number

**5. Turbine**

Type---------- size----------
Turbine bearing(s) type----------- ;number ----------;catalogue no.----------
Turbine pulley type---------- ;dia.---------- mm
Generator pulley type ---------- ;dia.---------- mm
Turbine shaft dia.----------mm
Belt type ---------- ;size----------mm

**6. Driving system**

Line shaft dia.---------- mm; length ---------- m
Pulley on line shaft dia.---------- mm
Pulley on turbine dia.---------- mm
Bearing type ---------- no.---------- catalogue no. ----------
Belt type ---------- size ----------

**7. Generator**

Manufacturer's name: ----------------------------------------
Type ----------------------------------------
KVA --------------------
Phase --------------------
Frame No. --------------------
Serial No. --------------------
Generator bearing drive end --------------------
Generator bearing non drive end --------------------
AVR type --------------------; size --------------------

**8. Electronic load controller**

Manufacturer's name: --------------------
kW --------------------
MCB --------------------Amps -------------------- phase
Fuse --------------------Amps
Immersion heater -------------------- kW -------------------- number----------

**9. Ago-processing machines:**

1. Oil expeller ---------- bolts Brand ---------- size ----------kW
2. Rice huller ----------catalogue no. Brand ---------- size ----------kW
3. Grinder ----------inch/mm Brand ---------- size ----------kW
4. ____________________ Brand ---------- size ----------kW

**10. Transmission Line**

Main switch: current ----------Amps; phase ----------; number ----------

**11. Conductor**

| | |
|---|---|
| Type | --------- |
| Length (m) | --------- |
| Size | --------- |
| Service wire | X-section area---------mm² |
| Transmission poles | type ---------length ---------m |
| Distribution poles | type ---------length ---------m |

The main aspects of the specifications of the power plant should be clearly written in the Operation and Maintenance Manual provided by the manufacturer/installer to the owner/manager. These specifications should help the plant manager to operate the plant properly, organize repairs, and order spares.

# CHAPTER 4
# Transmission and Distribution

The quality and complexity of the distribution system depend on the size and capacity of the plant. The main aspects of the distribution system are summarised in Table 4.1 below and described in sections 4.1 to 4.3.

**Table 4.1: Recommended Distribution System for MHP Plants**

| | Small Scheme (Up to 25kW) | Large Scheme (25kW to 50kW) |
|---|---|---|
| 1. Consumer supply | | |
| a) Maximum allowable voltage drop at consumption point. | 14 % | 10 % |
| b) Maximum allowable over voltage at consumption point. | 10 % FOR ALL | |
| 2. Distribution lines | Standard size of either flat twin sheathed solid aluminum conductor cable, or sheathed multi-strand aluminum cable. | Standard size of flat twin sheathed solid aluminum conductor cable in. |
| 3. Distribution poles | Wooden poles | Suitable materials sufficient to support conductors safely (hard wood, steel, RCC) |
| 4. Ground clearance | 2.5m between houses,3m in open areas,5.5m next to motorable roads5.8m across motorable road | |
| 5. Lightning arrestor | Mounted in such a way that every consumer is within 500m of an arrestor | |

## 4.1 House Wiring

In general the local populace in remote and underdeveloped mountain areas does not have the skills needed to undertake wiring in houses and provide connections. Therefore, in such areas the managers or operators of the plant are usually called upon to carry out wiring on the premises of the consumers. The promoters of MMHP recognise this and include house wiring in the training. Therefore some basic details of house wiring are also provided here.

**Table 4.2: ACSR Cable Specifications and Current Ratings**

| Conductor | Diameter (mm) | Area (sq. mm) | Weight (kg/km) | Resistance (Ohms/km) |
|---|---|---|---|---|
| Squirrel | 6.3 | 21 | 85 | 1.374 |
| Gopher | 7.1 | 26.3 | 106 | 1.089 |
| Weasel | 7.8 | 31.7 | 127.7 | 0.9047 |
| Rabbit | 10 | 53 | 213.6 | 0.5404 |
| Dog | 14 | 105 | 394 | 0.2722 |
| Service wire | 1.8 | 2.5 | 66 | 11.4 |
| Service wire | 2.2 | 4 | 87 | 7.2 |
| Service wire | 2.7 | 6 | 107 | 4.8 |

**Current ratings (AC) for three and four core 1100 volts armoured or unarmoured cables according to IS: 1554 (I)-1976**

| Normal cross-sectional area sq. mm | Laid direct in the ground, Amps | | In ducts Amps | | In air Amps | |
|---|---|---|---|---|---|---|
| | Copper | Aluminium | Copper | Aluminium | Copper | Aluminium |
| 1.5 | 21 | 16 | 17 | 13 | 17 | 13 |
| 2.5 | 27 | 21 | 24 | 19 | 24 | 19 |
| 4 | 36 | 30 | 30 | 23 | 30 | 23 |
| 6 | 45 | 35 | 35 | 30 | 39 | 30 |
| 10 | 60 | 47 | 47 | 39 | 52 | 40 |
| 16 | 77 | 60 | 60 | 50 | 66 | 51 |
| 25 | 99 | 77 | 77 | 63 | 90 | 70 |
| 35 | 120 | 94 | 94 | 77 | 110 | 86 |
| 50 | 145 | 110 | 110 | 95 | 135 | 105 |
| 70 | 175 | 135 | 135 | 115 | 165 | 130 |
| 95 | 210 | 165 | 165 | 140 | 200 | 155 |
| 120 | 240 | 185 | 185 | 155 | 230 | 180 |
| 150 | 270 | 210 | 210 | 175 | 265 | 205 |

**Single circuit single core sheathed and unsheathed clipped direct to a surface on cable tray bunched and unenclosed (Cables provided with coarse-excess current protection)**

| Cable size | 2 cables single phase AC or DC | | 3 or 4 cables 3 phase AC | | No and diameter of wires |
|---|---|---|---|---|---|
| No./SWG[1] | Copper Amps | Aluminium Amps | Copper Amps | Aluminium Amps | No. |
| 1/18 | 12 | - | 12 | - | 1/0.44 |
| 3/22 | 14 | 11 | 14 | 11 | 3/0.029 |
| 3/20 | 19 | 15 | 17 | 13 | 3/0.036 |
| 7/22 | 24 | 19 | 21 | 16 | 7/0.029 |
| 7/20 | 31 | 24 | 28 | 22 | 7/0.036 |
| 7/18 | 40 | 31 | 35 | 27 | 7/0.044 |
| 7/16 | 64 | 50 | 57 | 44 | 7/0.64 |
| 19/18 | 73 | 57 | 65 | 51 | 19/0.44 |
| 19/16 | 120 | 94 | 112 | 87 | 19/0.064 |
| 37/18 | 114 | 89 | 104 | 81 | 37/0.044 |

[1]SWG=standard wire gauge

Installation of wiring in a house involves installing a service junction box; making the connection with the incoming line; installing power outlets and switches at the required locations; and then taking the wires to the necessary locations along beams, poles, and such like. Table 4.3 shows some standard symbols for typical features of the house wiring.

It is recommended that every house have a main switch and a fuse. Black sheathing distribution cable should be used as it protects against the sun's ultraviolet radiation. If the connection to the consumer is not through a wattmeter and the tariff is based on maximum allowable power; a PTC, MCB, or ECC should be installed according to the allowable wattage (power) to prevent consumers from taking too much power.

House wiring should be carried out in accordance with a recognised standard; such as the Electrical Guidelines published by the Intermediate Technology Development Group (ITDG) and the Agricultural Development Bank/Nepal (ADB/N), Nepal. Such guidelines are usually available in every country.

The different types of internal wiring that are suitable for use in rural areas are described in the following.

*Batten Wiring*

This is the most common and cheapest type of wiring system. The wires are run on wooden battens fixed to the walls or ceiling. The system is classified into two types.

- TRS (tough rubber sheathed) or PVC (polyvinyl chloride) wiring. In this system, TRS or PVC wires are fixed to well-seasoned straight soft timber battens. Batten wiring, particularly with PVC cable, is widely used for indoor installations.
- Metal sheathed wiring. In metal sheathed wiring, the cables used are TRS or PVC insulated wires with an outer metal covering.

This system is suitable in places not exposed to the sun provided no joint of any kind is exposed. The system may be installed in damp places.

*Conduit Wiring*

This system consists of either VIR (vulcanised Indian rubber) or PVC wires passed through rigid steep conduit pipes. Conduit wiring can be installed on the surface of walls and ceiling or may be concealed under the plaster.

*Cleat Wiring*

In this type of wiring the cables are run over cleats. A special pattern of cleat may be used in which wires pass around corners so that there is no risk of the wires touching the wall. Where cleat wiring lies over metal, the space between the metal and the porcelain cleats should be filled or varnished.

Cleat wiring should not be employed on damp walls or ceilings.

*Wood Casing Wiring*

In this type of wiring the cables are run inside a wooden casing with grooves. The casing is then covered with a wooden capping. VIR or PVC insulated cables should be used.

The casing and capping should be of well-seasoned teak wood or other hard wood, free from knots or any other defects.

*Ready-made Wiring*

The main feature of ready-made wiring is the junction box. The required numbers of power cords of predetermined lengths for different rooms/locations radiate from it, each terminating in a light bulb or power socket. The wires are fastened to wooden columns, beams, or similar, at appropriate locations, and the bulbs or switches are left hanging but properly secured.

### 4.1.1 *The Most Common Wiring Practices*

The houses in mountain areas using MHP are generally one- or two-storey structures with walls made of mud and stone masonry and plastered with mud. The upper floor, supporting columns, and roof are usually made of wood. There may be a very few houses made of bricks and concrete (*pakka* houses) with more durable roofs of corrugated, galvanised iron or even reinforced concrete.

Conventional batten wiring, which looks simple and neat, is commonly used in *pakka* homes with concrete or cement plastered brick walls (Fig. 4.1). However, it is more difficult to install in village homes with mud and stone masonry walls because of the unevenness of the walls and the difficulty of fixing the batten to them. Furthermore, in rural areas the availability of the skills required for house wiring is limited, and the cost of labour for conventional wiring can be significant.

For these reasons, a system of 'ready-made wiring' has been developed in Nepal which is becoming quite popular. Ready-made wiring consists of a current limiter and fuse mounted

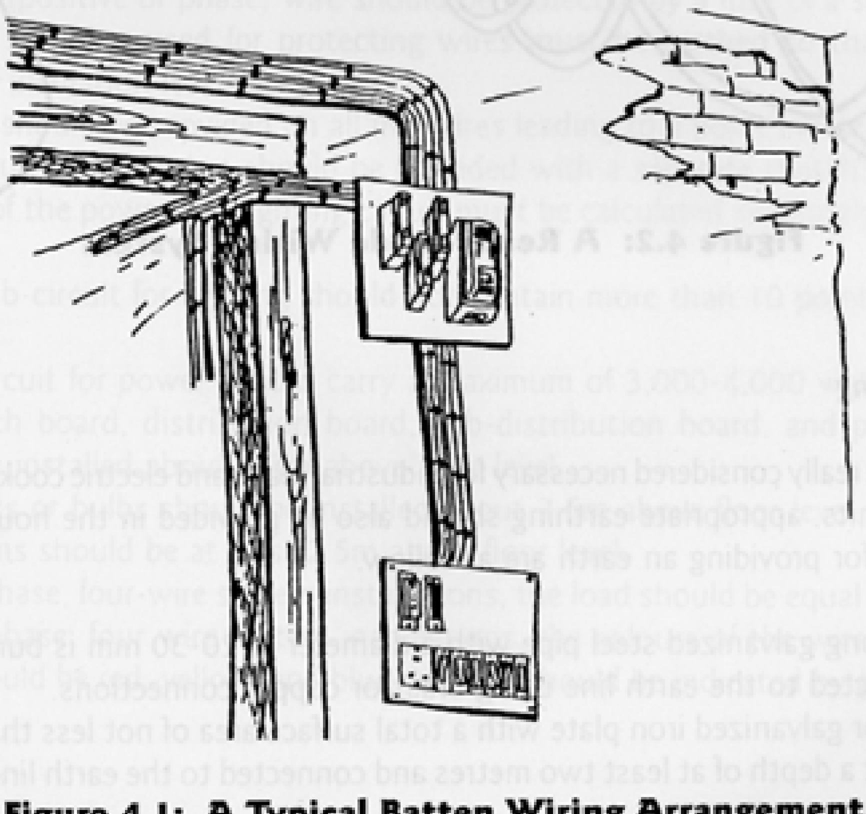


**Figure 4.1: A Typical Batten Wiring Arrangement for a Small House**

on a wooden junction box from which radiate a number of good quality, double insulated, power cords, each terminating in a light bulb or power outlet. The junction box may also have some power outlets. The lengths of wires are predetermined according to the house specifications. The lighting fixtures, switches, and power outlets are fixed permanently into walls, supporting posts, or other parts of the house. The tips of stranded conductors are soldered to ensure good connections and eliminate any problems arising from frayed wires. Figure 4.2 shows the major components of a typical ready-made wiring system, and Figure 4.3 shows a line diagram for the same system.

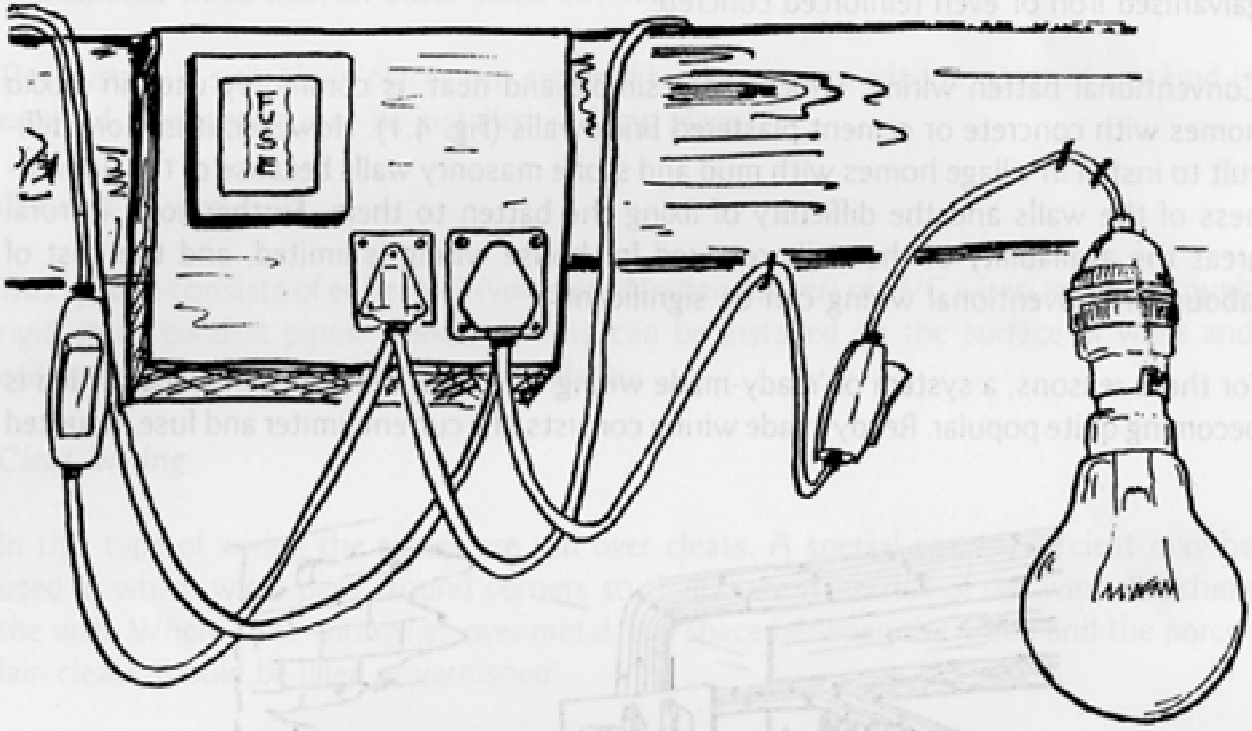


**Figure 4.2: A Ready-made Wiring System**

### *4.1.2 Earthing*

Earthing is only really considered necessary for industrial loads and electric cookers. However, if funding permits, appropriate earthing should also be provided in the houses. Acceptable methods for providing an earth are as follow.

- A 3-4 m long galvanized steel pipe with a diameter of 20-30 mm is buried vertically and connected to the earth line using brass or copper connections.
- A copper or galvanized iron plate with a total surface area of not less than one sq.m. is buried at a depth of at least two metres and connected to the earth line using brass or copper connections.

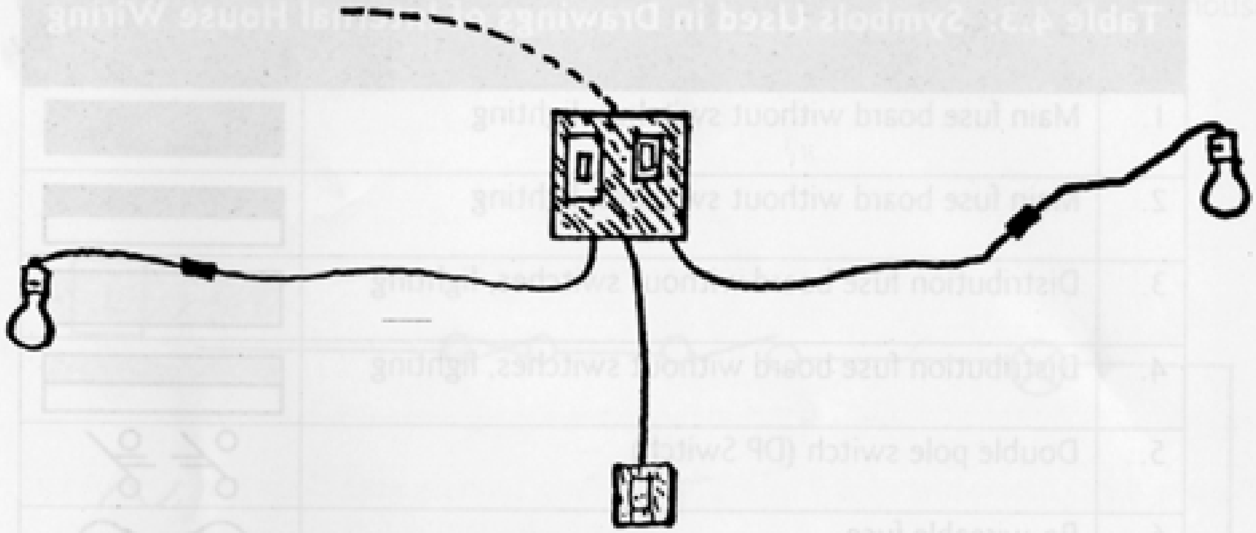
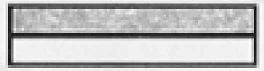
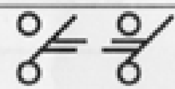
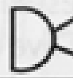


**Figure 4.3: Line Diagram for Ready-made Wiring**

### 4.1.3 *General Rules for House Wiring*

- The current rating of the conductor should be as per the requirement of the load as suggested in Table 4.2.
- Every live (positive or phase) wire should be protected by a fuse of a suitable rating.
- All metal covering used for protecting wires must be earthed so that there is no danger of insulation leakage.
- Switches should be provided on all live wires leading to a point in use.
- Every circuit or apparatus should be provided with a separate switch.
- The size of the power and lighting circuit must be calculated separately according to the load.
    - ♦ One sub-circuit for lighting should not contain more than 10 points or 800 watts.
    - ♦ One circuit for power should carry a maximum of 3,000-4,000 watts.
- The switch board, distribution board, sub-distribution board, and power sockets should be installed about 1.3m above floor level.
- Tube-lights or bulbs should be installed about 2.5m above floor level.
- Ceiling fans should be at least 2.5m above floor level.
- In three phase, four-wire system installations, the load should be equal on all phases.
- In three phase, four wire system installations, the colours of the wires at the main board should be red, yellow, and blue. Neutral should be indicated by green or black.

**Table 4.3: Symbols Used in Drawings of Internal House Wiring**

| | | |
|---|---|---|
| 1. | Main fuse board without switches, lighting |  |
| 2. | Main fuse board without switches, lighting |  |
| 3. | Distribution fuse board without switches, lighting |  |
| 4. | Distribution fuse board without switches, lighting |  |
| 5. | Double pole switch (DP Switch) |  |
| 6. | Re-wireable fuse |  |
| 7. | Fan |  |
| 8. | Incandescent lamp or filament lamp (bulb) |  |
| 9. | Fluorescent lamp (tube light) |  |
| 10. | Two pin socket |  |
| 11. | Three pin socket |  |
| 12. | One-way switch |  |
| 13. | Two-way switch |  |
| 14. | Earthing (earth point) |  |

The following diagrams (Figures 4.4 to 4.14) show some typical circuits used for house wiring.(L= live; N= neutral)

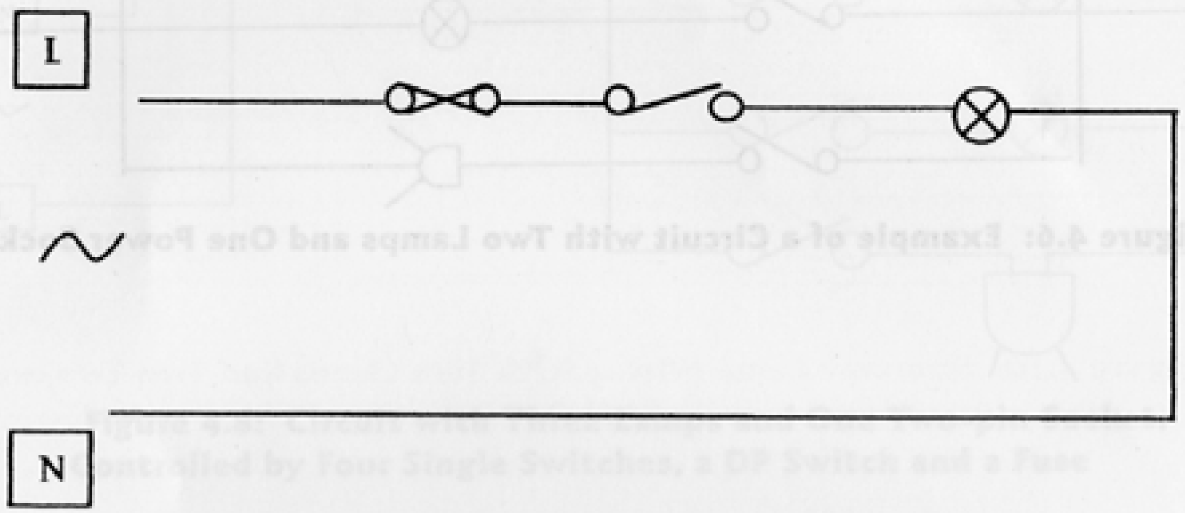



**Figure 4.4: Circuit with One Lamp**

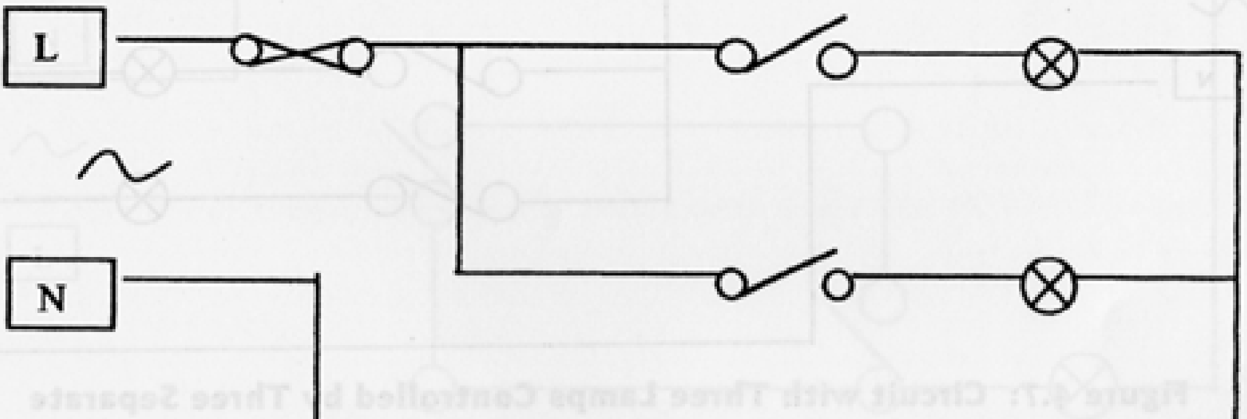



**Figure 4.5: Circuit with Two Lamps Controlled by Two One-way Switches with One Fuse**

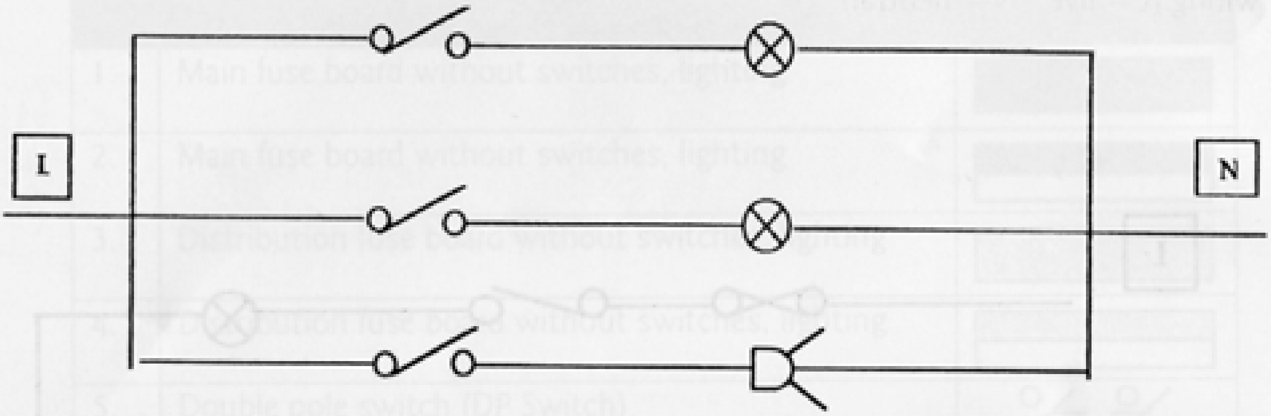



**Figure 4.6: Example of a Circuit with Two Lamps and One Power Socket**

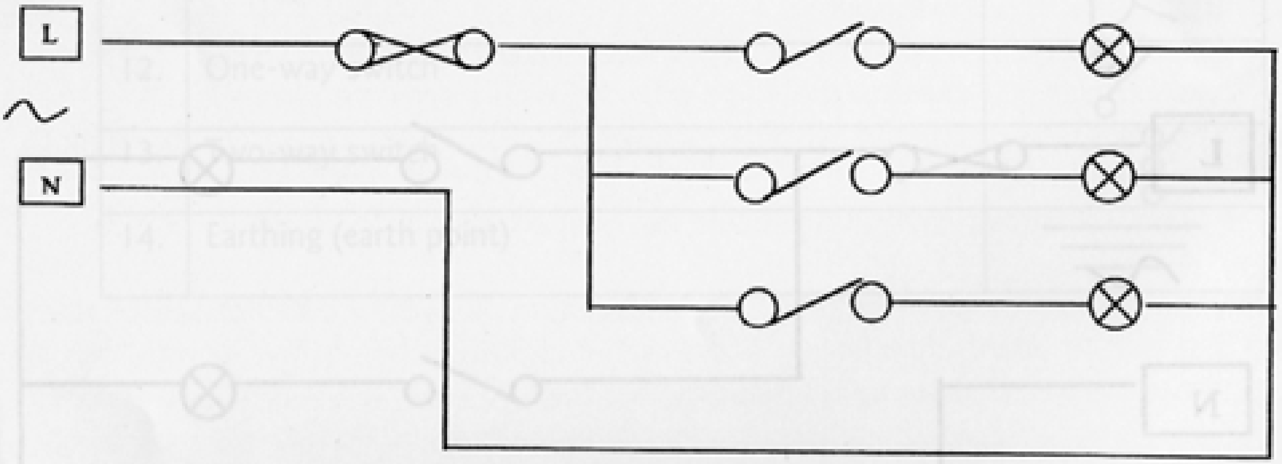



**Figure 4.7: Circuit with Three Lamps Controlled by Three Separate One-way Switches and a Double Pole (DP) Switch, with Fuse. The DP Switch is Useful if a Sub-circuit Needs to be Disconnected from a Different Location**

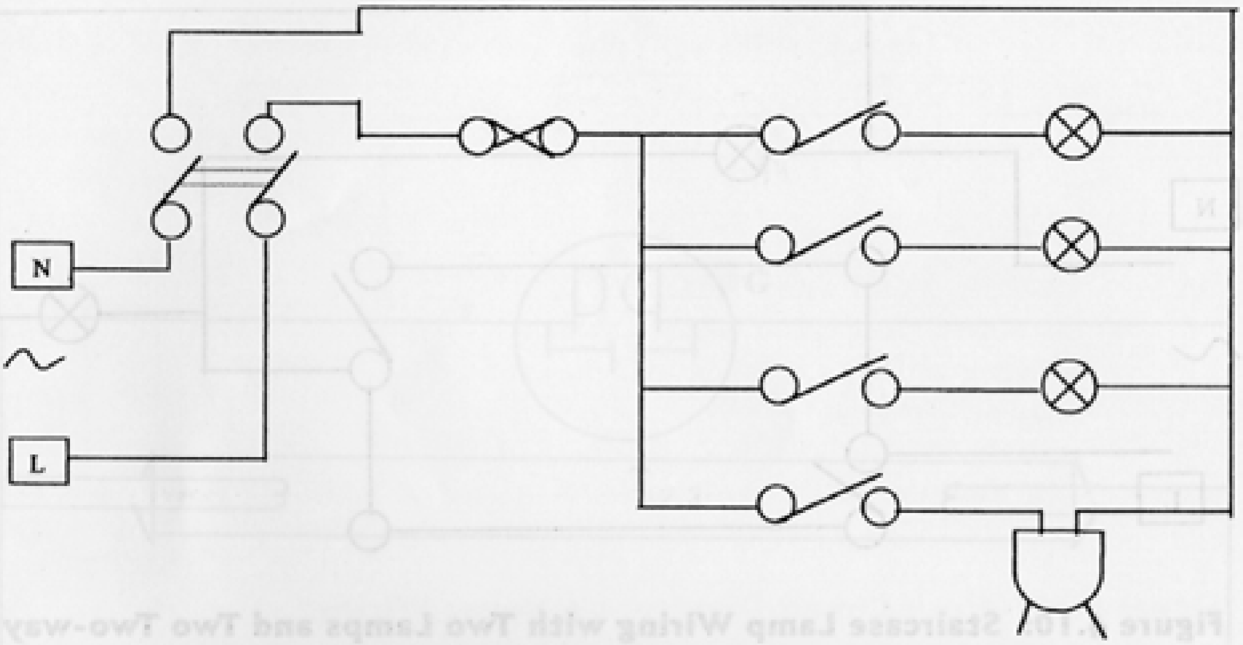



**Figure 4.8: Circuit with Three Lamps and One Two-pin Socket, Controlled by Four Single Switches, a DP Switch and a Fuse**

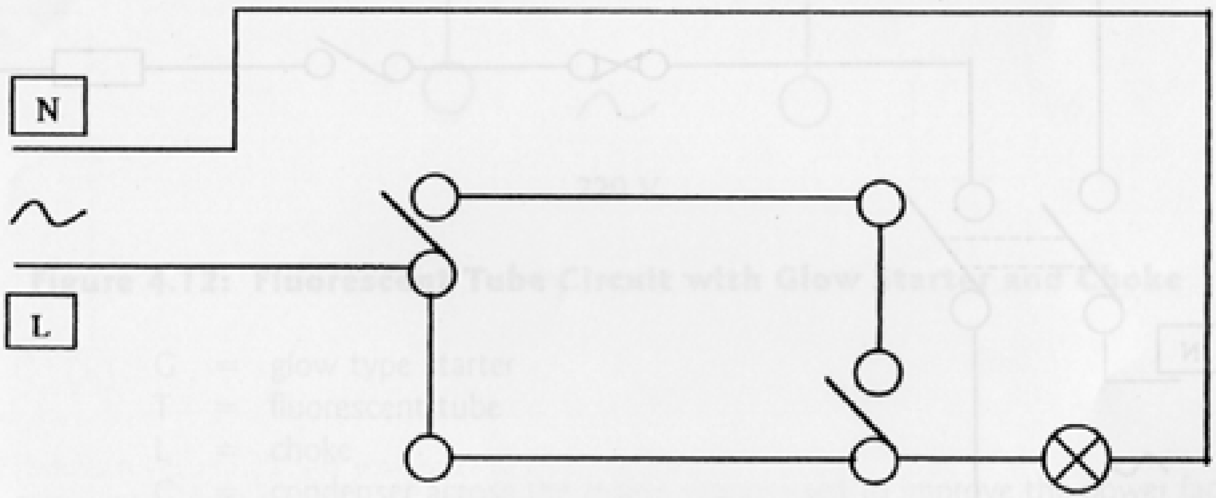



**Figure 4.9: Staircase Lamp Wiring with One Lamp and Two Two-way Switches**

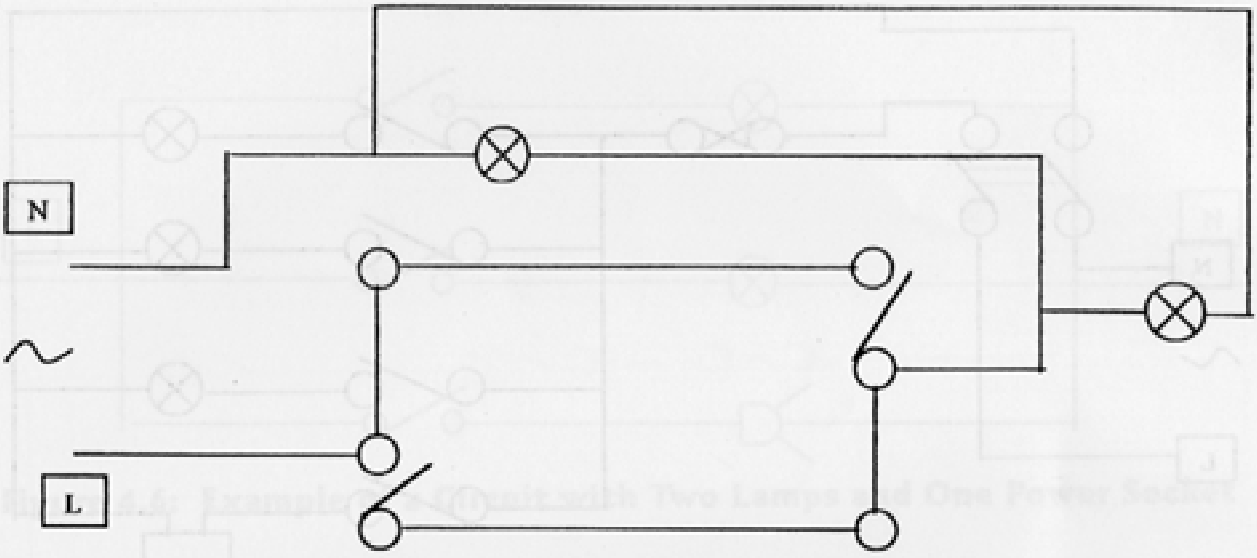



**Figure 4.10: Staircase Lamp Wiring with Two Lamps and Two Two-way Switches**

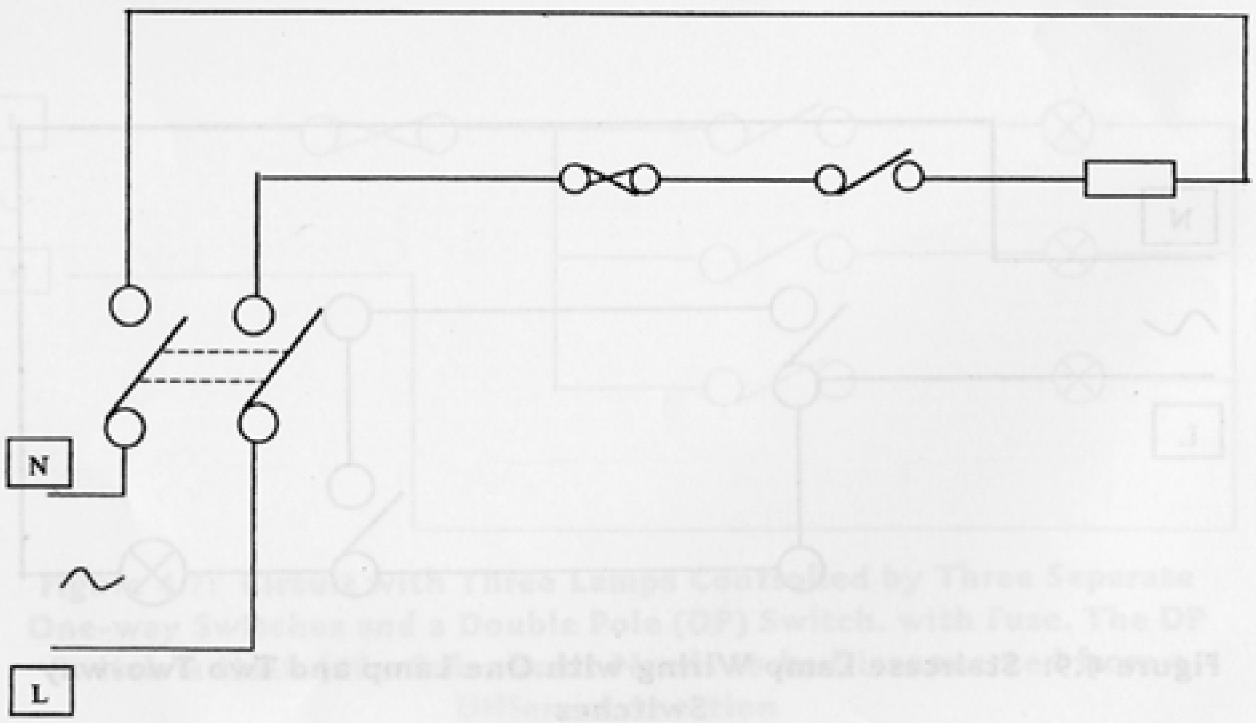



**Figure 4.11: Wiring Diagram for a Fluorescent Lamp. The DP Switch is Optional**

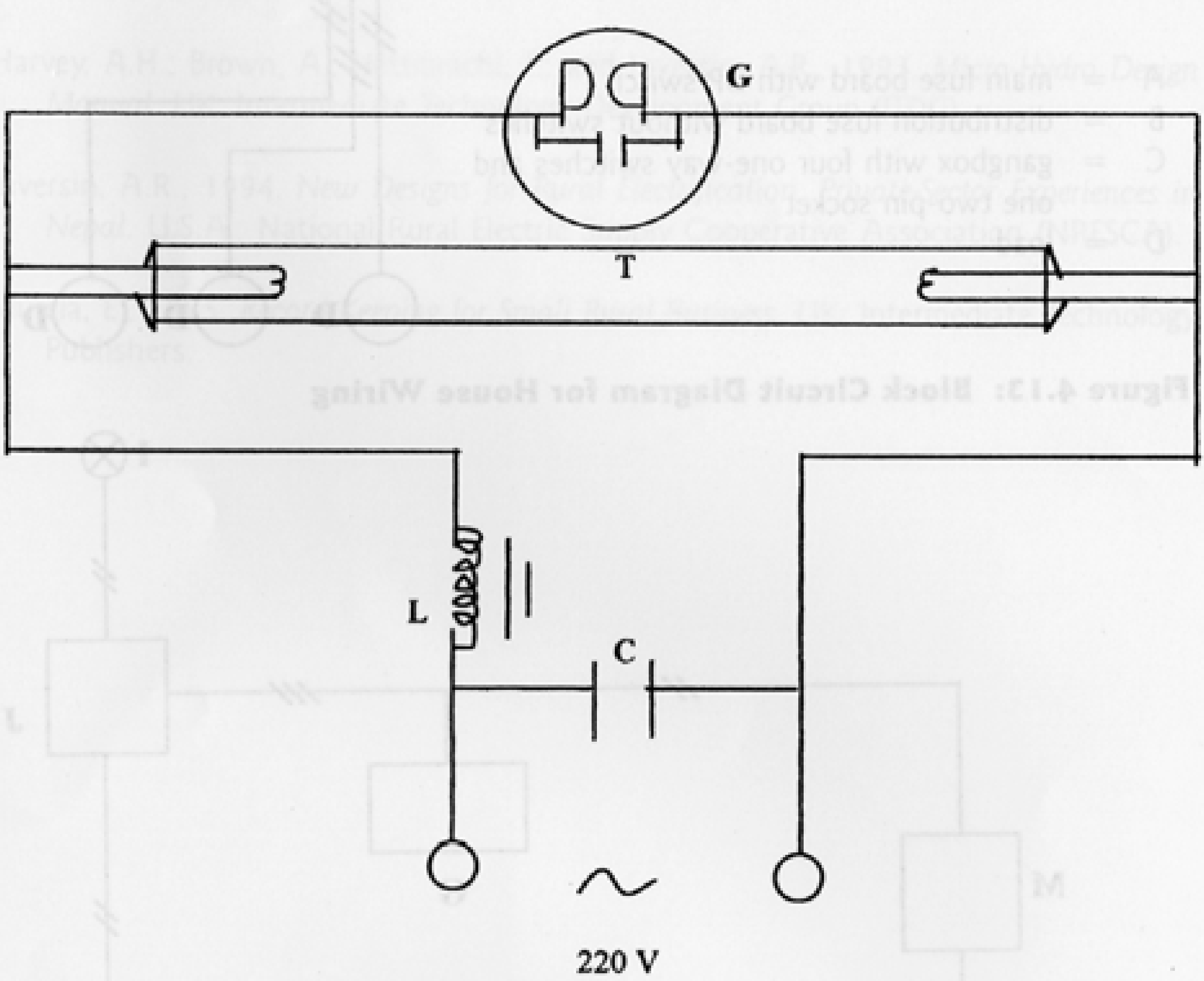
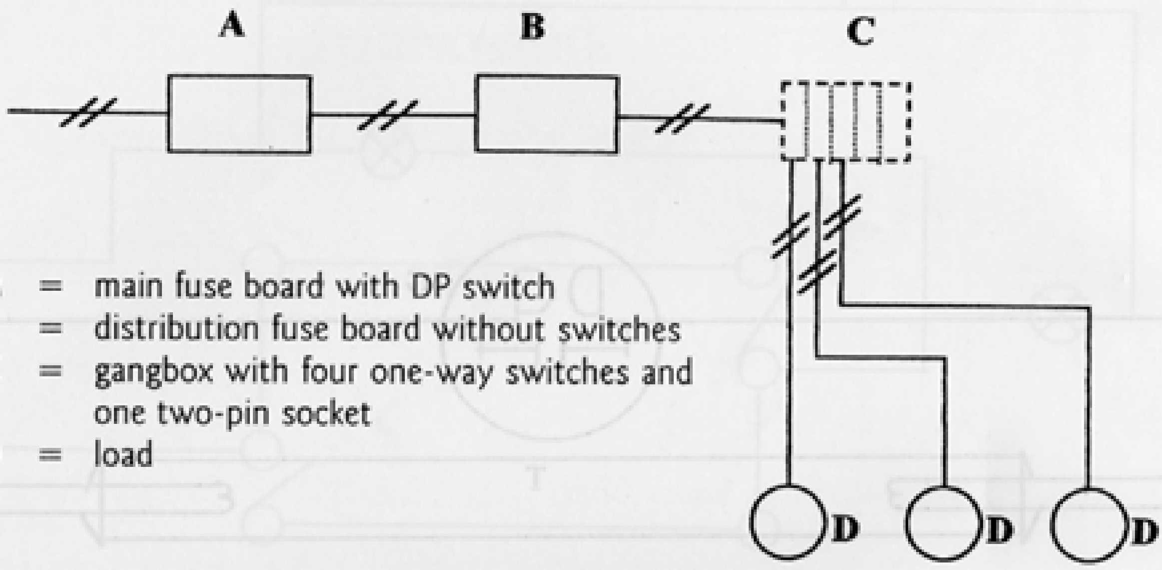


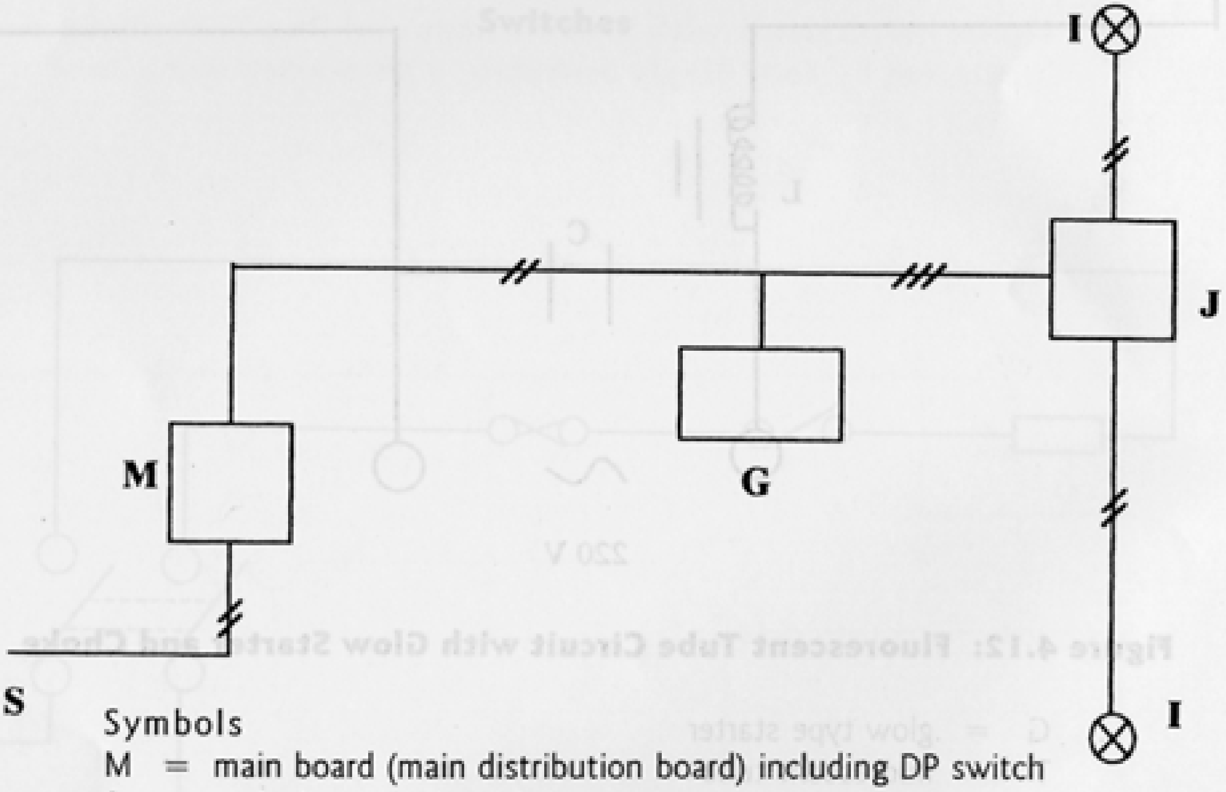

**Figure 4.12: Fluorescent Tube Circuit with Glow Starter and Choke**

G = glow type starter
T = fluorescent tube
L = choke
C = condenser across the mains supply used to improve the power factor




A = main fuse board with DP switch
B = distribution fuse board without switches
C = gangbox with four one-way switches and one two-pin socket
D = load

**Figure 4.13: Block Circuit Diagram for House Wiring**




Symbols
M = main board (main distribution board) including DP switch
S = mains' supply (220V)
G = gang box (4 way; 3 one-way switches, one two-pin socket)
J = junction box
I = incandescent lamp with holder

**Figure 4.14: Block Circuit Diagram of Circuit with Two Lamps and One Two-pin Socket Controlled by Three One-way Switches, a DP Switch and a Fuse**

# Participating Countries of the Hindu Kush-Himalayan Region

| | |
|---|---|
| Afghanistan | Bangladesh |
| Bhutan | China |
| India | Myanmar |
| Nepal | Pakistan |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