Structure of Operation and Maintenance Training Programmes

IEA Technical Report

IEA Hydropowe
Agreement

CANADA CHINA FINLAND FRANCE JAPAN NORWAY SPAIN SWEDEN UNITED KINGDOM

OVERVIEW OF THE IEA IMPLEMENTING AGREEMENT FOR HYDROPOWER TECHNOLOGIES AND PROGRAMMES

The Hydropower Implementing Agreement is a collaborative programme among nine countries: Canada, China, Finland, France, Japan, Norway, Spain, Sweden and the United Kingdom. These countries are represented by various organizations including electric utilities, government departments and regulatory organizations, electricity research organizations, and universities. The overall objective is to improve both technical and institutional aspects of the existing hydropower industry, and to increase the future deployment of hydropower in an environmentally and socially responsible manner.

HYDROPOWER

Hydropower is the only renewable energy technology which is presently commercially viable on a large scale. It has four major advantages: it is renewable, it produces negligible amounts of greenhouse gases, it is the least costly way of storing large amounts of electricity, and it can easily adjust the amount of electricity produced to the amount demanded by consumers. Hydropower accounts for about 17 % of global generating capacity, and about 20 % of the energy produced each year.

ACTIVITIES

Four tasks are operational, they are: 1. upgrading of hydropower installations, 2. small scale hydropower, 3. environmental and social impacts of hydropower, and 4. training in hydropower. Most tasks have taken about five years to complete, they started in March 1994 and the results will be available in May 2000. To date, the work and publications of the Agreement have been aimed at professionals in the respective fields.

UPGRADING

The upgrading of existing hydropower installations is by far the lowest cost renewable energy available today. It can sometimes provide additional energy at less than one tenth the cost of a new project. One task force of the Agreement is studying certain technical issues related to upgrading projects.

SMALL SCALE HYDROPOWER

Advances in fully automated hydropower installations and reductions in manufacturing costs have made small scale hydropower increasingly attractive. The small scale hydropower task force will provide supporting information to facilitate the development of new projects.

ENVIRONMENTAL AND SOCIAL ISSUES

For some hydropower projects the environmental and social impacts have been the subject of vigorous debate. There is a need to communicate objective information to the public, so that countries can make good decisions with respect to hydropower projects. The environmental task force will provide such information on possible social and environmental impacts and on mitigation measures.

TRAINING

The availability of well-trained personnel is a key requirement in the hydropower sector. The training task force is concentrating on training in operations and maintenance, and planning of hydro power projects.

THE INTERNATIONAL ENERGY AGENCY – IMPLEMENTING AGREEMENT FOR HYDROPOWER TECHNOLOGIES AND PROGRAMMES

STRUCTURE OF OPERATION AND MAINTENANCE TRAINING PROGRAMMES

May 2000

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Guidelines on Methodology for the Upgrading of Hydroelectric Generators – to be completed in May 2000.

Guidelines on Methodology for the Upgrading of Hydropower Control Systems – to be completed in 2000.

SMALL SCALE HYDRO POWER TASK FORCE (ANNEX 2)

Small Scale Hydro Assessment Methodologies – to be completed in May 2000 (available to non-participants on request)

Research and Development Priorities for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Financing Options for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Global database on small hydro sites available on the Internet at: http://www.small-hydro.com.

ENVIRONMENT TASK FORCE (ANNEX 3)

Survey on Positive and Negative Environmental and Social Impacts and the Effects of Mitigation Measures in Hydropower Development – 2000 (available to non-participants on request)

A Comparison of the Environmental Impacts of Hydropower with those of Other Generation Technologies – 2000 (available to non-participants on request)

Legal Frameworks, Licensing Procedures, and Guidelines for Environmental Impact Assessments of Hydropower developments – 2000 (available to non-participants on request)

Hydropower and the Environment: Present Context and Guidelines for Future Action
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EDUCATION AND TRAINING TASK FORCE (ANNEX 5)
(All of the following reports are available on the Internet at **www.annexv.iea.org**. Some reports may consist of more than one volume.)

Summary of Results of the Survey of Current Education and Training Practices in Operation and Maintenance – 1998 (available to non-participants on request)

Development of Recommendations and Methods for Education and Training in Hydropower Operation and Maintenance - 2000 (available to non-participants on request)

Survey of Current Education and Training Practice in Hydropower Planning – 1998 (available to non-participants on request)

Structuring of Education and Training Programmes in Hydropower Planning, and Recommendations on Teaching Material and Reference Literature - 2000 (available to non-participants on request)

Guidelines for Creation of Digital Lectures – 2000 (available to non-participants on request)

Evaluation of tests – Internet Based Distance Learning – 2000 – (available to non-participants on request)

Brochure
A brochure for the public is available. It is entitled "Hydropower – a Key to Prosperity in the Growing World", and can be found on the Internet (www.usbr.gov/power/data/data.htm) or it can be obtained from the Secretary (address on the inside back cover).

PREFACE

This report is the result of the work of Sub-task 2 – "Structure Of Operation And Maintenance Training Programme" of the Task Force on Education and Training, which is one of four task forces of the IEA Implementing Agreement for Hydropower Technologies and Programmes. The Sub-task started its work in February 1998 and has drawn on the resources and expertise of the three participating countries in the task force.

The report was partly conducted in co-operation with parallel work in subtask 1, which focuses on the current E&T situation in hydropower planning. Subtask 2 has developed recommendations with respect to the structuring of Operation And Maintenance Training Programs. Subtask 5 of Annex V looks into the implementation of information technology in this sector, including a case study of a selected distance learning set-up.

In this report training is defined as the upgrading of existing skills or recently obtained knowledge, while education is defined in terms of skills obtained from universities or colleges.

The growing need for training of hydropower personnel, and the need for high availability rates of generating units have made training an extremely important task for electricity generators. This report describes various ways of training hydropower personnel to achieve high availability rates and safe power generation. Great progress has been made in this area, and aids for training purposes are still being developed.

The leaders of Subtask 2 have been Mr. Stig Eklund and Mr. Folke Forsgren, of the Jokkmokk Training Centre, Sweden. They have also compiled this report.

We believe that this report is capable of making a useful contribution to the design of Operation and Maintenance Training Programmes.

Tore S Jørgensen
Operating Agent
IEA Annex V

SUMMARY

This report presents approaches to bring the personnel at the power plant up to date with regard to improved methods and equipment for maintenance and operation of power plants.

The conclusion of this report is the importance of good planning of the training and the need to evaluate the proper needs of competence for the personnel for their roles in the organisation to keep the costs down and simplify the proper future updating of obsolete knowledge. Another conclusion of this report is the importance of different factors outside the control of the trainers like social and cultural factors that has to be taken into account to guarantee the quality of the training effort.

The first section describes briefly the roles of the main personnel types responsible for the maintenance and operation of the power plant – the shift charge engineer, the control room technician and the plant operator.

The second section describes briefly the factors to take into account when planning and performing the training efforts.

The third section describes the concept behind levels of competence and some background on the implementations of this concept. It is important that the reader understands the contents of this section to fully understand the implications behind the planning of the training's and the examples of the competence profiles presented in appendix 1 – Competence Profiles.

The fourth and fifth sections describe a simple example of a curriculum's for the theoretical and practical training sessions for the personnel. It is important to recognise the connection between the curriculum's and the demanded levels of competence presented in appendix 1 – Competence Profiles.

The sixth section presents overviews of curriculum's for the laborations that are performed as part of the practical training sessions with sections for mechanical, hydraulic and electronics laborations.

The first appendix presents an example of the usage of competence profiles for different areas of work in the power plant with regard to maintenance and operation.

The second appendix presents and example of usage of the concepts presented in the report in a live situation – a training programme for the Theun-Hinboun power plant in Laos.

The last appendix presents the Vattenfall AB Jokkmokk Training Centre (JTC) responsible for the report and for the training efforts at Theun-Hinboun power plant.

INTRODUCTION

One distinguishing characteristic of hydropower projects is that each project is unique, although each starts off with some features that might be regarded as a foundation of knowledge and existing skills. In some cases, these features are enough to start up a new or existing power plant, but normally, training is needed. Even if the personnel can be regarded as well trained, a certain amount of complementary training usually has to be given. In some projects whose personnel are to be found among newly qualified students, training in hydropower operation and maintenance is necessary to achieve full flexibility within the organisation.

Training must be well planned and must aim to provide a full understanding of the systems and equipment involved. As the hydropower sector becomes more computerised, a well-functioning organisation must include personnel with some computer experience.

This report describes training for three different categories of personnel in an Operation and Maintenance organisation. The categories are Shift Charge Engineer, Control Room Technician and Plant Operator. All the training concerning theoretical and practical subjects is identical for each category, but the level of knowledge needed varies for each category. This is described in more detail in Appendix 1.

The Shift Charge Engineer

The Shift Charge Engineer is responsible to the Operation/Generation Engineer, and the main duties of this position are listed below.

1 To be responsible for the safe and efficient operation of the power station during the shift.

2 To supervise and distribute work during the shift.

3 To receive and carry out instructions from the power station management.

4 To brief, instruct and train subordinate staff according to instructions issued.

5 To issue switching instructions prior to issuing a permit to work if the Operation Engineer does not issue them.

6 To carry out/supervise and ensure that safe and proper switching is carried out.

7 To issue Permit-to-Work, Sanction-for-Test and Limitation-of-Access in accordance with regulations.

8 To supervise work according to routine maintenance schedules for plant and equipment.

9 To carry out switching as authorised by the management.

10 To maintain files and records of instructions, memoranda, etc. in good order.

11 To supervise personnel safety and report all hazardous events and accidents.

12 To report verbally, and in writing, any faults that have occurred.

13 To issue instructions and memoranda.

14 To attend to faults that have occurred in order to rectify them himself or call for assistance as soon as possible (with due regard to instructions issued).

15 At shift change, inform the next shift about the current operating situation, orders, issued Permits-to-Work and any other matters that are necessary to know for the operation of the power station.

16 Be responsible for first-aid equipment.

17 To keep records of operations, faults, switching, hydrological conditions, etc.

18 To supervise the operation of water treatment plant and other power station equipment and to carry out regular inspection of all plant equipment under his charge.

19 To carry out any other instructions/duties delegated to him/her.

The Control Room Technician.

The Control Room Technician reports to the Shift Charge Engineer and is responsible for control room with the following main duties:

1 Control of active and reactive power, voltage, current, temperature, etc. according to settings.

2 To run up, synchronise, lead and shut down turbine generator units as required.

3 In case of system disturbance, normalisation of system through safe and accepted switching procedures.

4 To monitor and record meter and instrument readings in the control room and other equipment as required.

5 To perform all switching that can be done from the control room.

6 To monitor and report alarms, trips, faults and abnormalities observed.

7 To control and record indications and alarms.

8 To maintain control room logbooks.

9 To perform any other duties or instructions delegated to him/her.

The Plant Operator

Responsible to the Shift Charge Engineer for:

1 Supervising casual labourers, entrepreneurs' staff, etc.

2 Checking round the plant according to instructions, taking readings of instruments, gauges, etc.

3 Lubricating, cleaning, adjusting and carrying out minor maintenance work on equipment and machinery, as specified in the scheduled maintenance chart or as instructed by the Shift Charge Engineer.

4 Assisting the Shift Charge Engineer and the Control Room Technician with operation of switching apparatus that cannot be remotely controlled from the Control Room, trouble-shooting, etc.

5 Assisting the Shift Charge Engineer in operational duties outside the Control Room.

6 Reporting abnormal observations, faults, etc. to the Shift Charge Engineer.

7 Maintaining station log books.

8 Carrying out any other duties or instructions delegated to him/her.

ORGANISATIONAL EFFECTS ON HYDROPOWER TRAINING

Training for hydropower projects can be divided into two different areas. The first is where an organisation already exists within the project, and where training can be regarded as an upgrading of existing skills. The other is when the organisation is to be built up from newly qualified students with no existing skills in hydropower technology. The final organisation is affected by four factors that are of importance when training for the organisation is being designed.

Cultural factors

It is of great importance to understand the culture in the country in which the training is to be performed. Certain questions must be considered before the training programme is launched. This is in order to avoid cultural clashes that might negatively affect both the training and the future work of the organisation.

5 How has the work been organised and planned previously?
6 How is the work climate as it affects the number of personnel performing certain types of work?
7 How many persons are involved in various areas of work?

Social factors

- Are there any discrepancies regarding age, knowledge and time of employment, with respect to the working and training situation?
- Are there any communications problems regarding transportation of employees?
- How is the question of accommodation being solved?

Religious factors

- Are there any special holidays that might affect the training?
- Is there anything that is affected by the religion which might affect training, such as special clothing, males and females working together, etc.
- Is there anything about the training that may be considered offensive by the local religion?

Working situation

- Is it possible to find spare parts and material in the local area?
- In what way are the personnel involved in planning of their work?
- How can salary levels affect the working situation?

When these questions have been answered, a range of training courses can be developed.

All persons working in the hydropower sector must be familiar with the fundamental rules of hydropower generation. This basic knowledge is necessary in order to achieve complete flexibility with regard to the operation and maintenance of hydro power plants.
It is wise to investigate the level of competence in order to determine the level of training required.

LEVEL OF COMPETENCE

The level of competence has been classified into five categories. These are:

5	Can perform the task/competence with better than acceptable speed and quality and with initiative and adaptability. Can lead others in performing the task.
4	Can perform the task/competence with better than acceptable speed and quality and with initiative and adaptability to special problems and situations.
3	Can perform the task/competence without assistance and supervision with better than acceptable speed and quality of work.
2	Can perform this task/competence without assistance and supervision.
1	Can perform the task/competence satisfactorily, but requires periodic supervision and some assistance.

All levels should be regarded as guidelines and must be adapted to the local situation for best training results.

For a detailed description of the different levels, please see Appendix 1.
All courses will be “tailor-made” for each group of trainees, and should therefore be seen as individual training programmes. Training is divided in two sections, one of which are theory and the other, practice.

THEORETICAL TRAINING

All theoretical training provides a base for each trainee in which he will upgrade skills in theoretical subjects. It is also a means of becoming familiar with the plant and involved equipment. Normally, all basic theoretical training is provided in a training centre. This is convenient when the trainees are newly graduated from college. They are familiar with classroom teaching and are therefore more open to pedagogical training methods. Training centres have one advantage for hydropower training because equipment is often available for simulations of different operational analyses.

Theoretical training which is provided as on-site training in power station facilities can be seen as a natural way to familiarise students with systems and equipment used in power generating facilities. This is the subsequent step for trainees from the training centre; to associate their theoretical knowledge with real-life situations. For more experienced trainees such as older employees and/or existing staff at hydropower stations, hands-on training, or on-site training is a more efficient way of obtaining a complete theoretical understanding of the equipment in use.

Theoretical training comprises:

Introduction to the course

The course will start with an introduction, in which the instructors, teachers and other people responsible for the course offer a brief overview of the course. It is important that the introduction should give the trainees a general understanding of how the course is built up.

The Introduction consists of:

- Information about the training centre organisation and a general layout of the power station. Study visits to the powerhouse, switchyard and dam should also be included.
- A visit to mechanical and electrical workshops and main stores should be included to familiarise students with these localities and brief information about safety rules should be included.

During this period students and instructors can get to know each other better. Parts of the plant that should be specially explained to the trainees this time, include:

- Penstock, turbines, spherical valves and cooling-water system.
- Generators and transformers.
- Switchyard and cables.

Mathematics

This part of the course is to make the trainees familiar with the basics of mathematics. It is also a means of upgrading existing skills, and includes the following subjects:

- Introduction to mathematics
- Fractions
- Ratios and proportions
- Simple equations
- Formulae
- Simultaneous equations
- Graphs
- Quadratic equations
- Powers (indices)
- Simple trigonometry

Engineering science

Engineering science is one way of applying mathematical theories to practical applications. Actual examples from the power station can be used as examples. The subject comprises:

- Introduction to mechanics
- Vectors
- Parallelogram and triangle of forces
- Equilibrium and centre of gravity
- Friction
- Velocity, acceleration and speed
- Work
- Energy
- Potential
- Kinetic
- Power
- Hydrostatics and hydrodynamics
- Instrumentation and meters
- Pressure
- Flow
- Temperature
- Level

Electrical theory

Electrical theory is another way of enabling trainees to apply mathematics and practical knowledge to actual working situations related to their field of work. The subject comprises:

- Units and definitions
- Ohm’s law
- Series and parallel connection of resistances
- Internal resistance, terminal voltage and E.M.F.
- Series and parallel connection of E.M.F.
- Electromagnetism theory
- Resistance, inductance and capacitance
- Power and power factor
- Power losses in transmission lines and windings
- 3-phase supply
- Over-voltage
- Cables - types, sizes and construction
- Fuses and overload protection
- Contactors and relays
- Circuit breakers and insulators
- Atmospheric disturbances, lightning etc
- Protection against over-voltage damage
    - Sparkgaps
    - Capacitors
    - Surge arrestors

Electrical Equipment

This part of the course describes in detail the systems involved and how they interact in the power station.

- DC motors and generators
  - Principles and main parts of a D.C. machine
  - Induction of E.M.F. in the machine
- AC motors and generators
  - Principles and main parts of a synchronous generator
  - Speed, number of poles, frequency
  - Stator winding, E.M.F. of a synchronous generator
  - Introduction to Induction Motors
- Rotating Electric Machine
  - General
  - Principles of generators
  - DC current
- Alternating current machines
  - Synchronous machines, single-phase generators, multiphase machines, asynchronous motors
  - Rotating fields, idle and short-circuit characteristics
  - Construction, design
- Power Transformers
  - Introduction
  - Principles of transformers
  - The transformer on zero load
  - The transformer under load
  - Losses and efficiency
  - Voltage loss in a transformer
  - Three-phase transformer connections
  - Parallel connection of transformers
- Measuring transformers
  - Voltage and current transformers
- Reactors
  - Introduction, performance and maintenance of reactors
- Rectifiers and inverters
  - Introduction
  - Types of rectifiers
  - Applications
- Batteries
  - Types of cells
  - Method of connecting cells
  - Applications
  - Safety
  - Charging and servicing
- Electrical Measurements
  - Types of meters
  - Measuring transformers
  - Voltage transformers
  - Current transformers

- Special measuring instruments
- Synchronoscope
- Frequency meters
- Wheatstone bridge meters
- Registering meters, kVAh meters
- D.C. meters
- Tachometers

- Elementary protective relaying

Prime movers

This part describes the different parts of prime movers in a hydropower plant. It also covers part of the maintenance of equipment of this sort. It consists of the following subjects:

- Water turbines
- Types of turbines
- Some construction details
- Wear of turbine parts
- Governors
- Accessories
- Diesel engines
- Principles of operation
- Maintenance

Engineering drawings

It is necessary to be able to understand technical drawings and symbols to follow drawings and diagrams of the power plant. This part of the course introduces the subject.

- Introduction to engineering drawing
- Projections and sectional views
- Diagrams
- Symbols

Engineering components

A brief understanding of engineering components is included in the course in order to provide an understanding of how systems are built up and work together.

- Bolts, nuts and washers
- Split pins, cotters and keys
- Shafts, couplings and clutches
- Types of bearings and applications
- Gears, belts, chains and ropes
- Pipes and valves
- Springs

Materials

This part of the course is important for understanding the importance of various materials and how they can affect each other.

- Iron and steel
- Copper and aluminium
- Magnesium, lead, zinc and nickel
- Non-metallic materials
- Insulating materials
- Non-destructive testing

Auxiliary equipment

Auxiliary equipment is an important part of the total system, which must work well for safe generation. This is a major block of the course and consists of:

- Auxiliary services
  - General auxiliary services
  - Local power and lighting
  - Air conditioning
  - Ventilation
  - Water supply
  - Sewage
  - Drainage
- Operational auxiliaries
  - Governor oil system
  - Lubricating oil system
  - Cooling water system
  - Compressed air system
- Maintenance auxiliaries
  - Cranes and hoists
  - Turbine de-watering system
  - Oil purification plant
- Liquid pumps
  - Single and double acting piston and plunger pumps
  - Centrifugal pumps
  - Characteristic diagrams
  - Maintenance
- Fans
  - Mechanics of fans
  - Axial flow fans
  - Radial flow fans
  - Characteristics of operation
- Compressors
  - Expansion and compression of gases
  - Single-stage compressors
  - Multiple-stage compressors
  - Principles of refrigeration and air conditioning

- Vacuum pumps

Paint and varnishes

An important part of maintenance is protecting surfaces from corrosion and wear. This part of the course deals with these matters, and consists of:

- Protection of metal surfaces
- Painting of iron and steel
- Zinc and galvanised surfaces
- Colours

Workshop technology

It is important from a maintenance point of view that all personnel should have a basic knowledge of workshop technology. This part of the course consists of:

- Machine shop
  - Drilling machines
  - Grinding machines
  - Welding equipment
  - Bench fitting
  - Basic lathe operation
  - Hand tools

Safety rules, regulations, fire protection and first aid

This is an important part of the operational work and training must be given frequently.

8 Operation instructions
  9 Permit to work
10 Industrial safety and protection
  11 Industrial safety
  12 Non-mechanical accidents
  13 Mechanical accidents
  14 Electrical accidents
15 Electrical safety rules at power stations
  16 General
  17 Electrical equipment rooms
  18 Working with high-voltage equipment
  19 Dangerous incidents and accidents
  20 Objections to instructions
21 Fire protection and the use of fire-fighting equipment
22 First Aid

Demonstrations

The theoretical training is composed of well-defined modules, each corresponding to a certain subject and its application in hydropower plant technology.
The training programme is designed to provide the trainee with sufficient technical theory to understand the principles of operating a large power station, and enough practical on-the-job training to enable him to perform his duties in an efficient manner. However, it is most important that the theoretical parts of the programme should also include some demonstrations in the power station in order to acquaint trainees with actual equipment and procedures. For this reason, a "theoretical" module is designed to cover such training.
In many cases, the demonstrations will have to be adapted to the availability of the relevant systems for demonstration purposes. For this reason, all demonstrations are collected into one training module although they should be regarded as complements to the corresponding theoretical module.

The following demonstrations are included:

- Types of valves used in a power station.
- Components and working principles of pumps.
- Dismantling, working principles of a hydraulic system oil cooler.
- Working principle of a central lubricating system.
- Working principle of a compressor.
- Various types of relays used in a power station.
- Cylinder gate manual operation.
- De-watering the draft tube/penstock.
- Filling the draft tube/penstock.
- Running the oil pressure system of a turbine unit.
- Running booster pumps and regulating cooling water.
- Running diesel units.
- Liquid chillers start-up with all valves closed.
- Resetting of mechanical over-speed guard. speed governor ??
- Preventive maintenance, inspection-examination.
- Personal safety, practical examples.

Final Tests

Tests are given after each theoretical unit. A final practical test is given at the end of the course.

PRACTICAL TRAINING

Practical training is intended to give trainees the opportunity to train on equipment related to their field of work. Some assistance might be needed to provide complete understanding of the equipment and its function in the system. Supervisors or plant management can provide such assistance since they are supposed to be familiar with the equipment involved. The practical training consists of modules, each of which corresponds to a certain group of exercises that utilise the components and systems of a modern power station. It also includes training according to ordinary shift rota as well as practical demonstrations in the powerhouse of apparatus and equipment used in hydroelectric power plants.

The intention of this training is for the trainee to follow the ordinary routines of a power station, in order to provide an understanding of the organisation and everyday work.

The purpose of the practical periods is to give the trainee on-job training in power station operation and maintenance, through which the following abilities are gained:

- Familiarity with the power station's layout, systems and components.
- Awareness of the knowledge and skills required by a power plant operator.
- Consciousness of the importance for a power station operator to be observant, sensitive and critical in his work (ears: noise, eyes: leakage, nose: smell, and touch: temperature).
- Ability to perform the activities involved in the inspection, operation and light maintenance of power station equipment.
- Good knowledge of personal and industrial safety, including the handling of equipment and protective devices.
- Ability to transfer information accurately to colleagues and supervisors.
- Ability to distinguish between normal, abnormal and tolerable conditions in some cases.
- Ability to accept and carry out directions and written instructions.

LABORATORY EXERCISES

The practical training also includes laboratory exercises. These aim to give trainees practically oriented education in electricity, electronics, hydraulics and workshop technology. All trainees will be trained in laboratory works, but at different levels as described in Appendix 1.

Mechanical laboratory experiments

- To determine the moduli of elasticity for steel and aluminium, by means of a tensile test within the range of elasticity.
- Determine the relation between stress and strain at increased load, and at a reduced load. Draw a stress-strain diagram.
- Determine how the load influences the deflection of a beam. The beam is placed on two supports and subjected to a concentrated load in its centre.
- Determine how the deflection of a beam is influenced by the span. The beam is subjected to a concentrated load in its centre.
- Determine the relation between the deflection and the height and width of the beam. The beam is positioned on supports and subjected to a concentrated load in its centre.
- Determine the modules of elasticity for various materials by means of a bending test. The beam is subjected to a concentrated load in its centre.
- Determine the relation between the torsional force and the angle of twist.
- Determine the relation between the loading length and torsional moment of a rod with a circular cross-section, which is subjected to a torsional moment.

Mechanical engineering practice

- Reading mechanical drawings, symbols and tolerances.
- Hand tools, descriptions and uses.
- Machine-shop work, descriptions of some modern machines, together with illustrations, marking out, drilling and honing, turning. (i.e. lathe-work comprising plain machining and screw-cutting, etc.), planing, slotting, shaping, milling, grinding, boring, buffing and polishing, welding, etc.
- Instruments and aids for condition monitoring, an introduction to the methods and procedure practised in engineering workshops.
- Repair technology, erection and installation of machinery etc.

Hydraulics bench and accessories

- Calibrating a Bourdon type pressure gauge.
- Demonstrating the characteristics of flow over a rectangular notch.
- Demonstrating the characteristics of flow over a vee notch.
- Determining the coefficient of discharge.
- Demonstrating Bernoulli's Theorem and its limitations.
- Directly measuring the static and total head distribution along a Venturi tube.
- Determining the meter coefficient at various flow rates.
- Establishing the coefficient of velocity for a small orifice.
- Experimentally determining the coefficient of discharge for a small orifice with flow under constant and varying heads.
- Comparing the measured trajectory of a jet with that predicted by simple mechanical theory.
- Reproducing the classic experiments conducted by Professor Osborne Reynolds concerning fluid flow condition.
- Observing laminar, transitional, turbulent flow and velocity profiles.
- Directly comparing flow measurement using a Venturi meter, variable area meter and orifice plate.
- Calibrating each flow meter using a bench volumetric measuring tank.
- Comparing pressure drops across each device.

Determining the head/flow rate characteristics

- A single centrifugal pump at a single speed.
- Two identical pumps operating in parallel at the same speed.
- Two identical pumps operating in series at the same speed.

Fluid friction measurements

- Determining the relationship between head loss due to fluid friction and the velocity of a flow.
- Determining the head loss associated with flow through a variety of standard pipefitting.
- Determining the relationship between pipe-friction coefficients and Reynolds number for flow through a pipe with roughened bore.
- Demonstrating the application of differential head devices in the measurement of flow rate and velocity.
- Practical training in the use of manometers.

Turbines

- Turbine outputs at design shaft speeds and constant head.
- Turbine efficiencies at optimum design shaft speeds and constant head.
- General characteristic curves of the turbines under constant head at varying shaft speeds.
- Runaway speed envelope curves at constant head and various openings.
- Stalling torque at various heads and openings.
- Electro-hydraulic servos.

Electronics Laboratory

- Basic principles of electricity.
- Physical and electrical characteristics of commonly used semiconductor components.
- Semiconductor amplifier configurations.
- Design of common electronic circuits.
- Measurements of power supply performance, e.g. regulation, efficiency and current-limiting characteristics.
- Transducers and systems utilising variations in resistance.
- Transducers and systems utilising variations in capacitance.
- Transducers and systems utilising variation in inductance.
- Temperature transducers.
- Light transducers.

Electrical Workshop

The electrical machines laboratory offers a dynamic approach to the understanding of electrical machines. Experiments include:

- AC generators and motors.
- DC generators and motors.
- Elementary single-loop AC/DC generator.
- Effects of commutation.
- Induction motor starting techniques.
- Single-phase repulsion motor characteristics.
- Variable ratio transformer. Motor-generator set.
- AC generator synchronised with main supply.
- Characteristics of synchronous motor.
- Measuring benches for temperature, pressure and level are intended for teaching components and methods for sensing temperature, pressure and level, and converting units to digital and analogue signals.

APPENDIX 1 – COMPETENCE PROFILES

Position **Subject**	**Plant Operator**	**Control Room Technician**	**Shift Charge Engineer**
Mathematics	**Levels**		
Introduction	2	2	2
Fractions	2	3	3
Ratios and proportions	3	3	3
Simple equations	3	3	4
Formulae	3	4	5
Simultaneous equations	2	3	3
Graphs	3	3	4
Quadratic equations	1	2	3
Powers (indices)	2	2	3
Simple trigonometry	1	3	3

Position **Subject**	**Plant Operator**	**Control Room Technician**	**Shift Charge Engineer**
Engineering Science	**Levels**		
Introduction to mechanics	2	2	2
Vectors	3	3	3
Parallelogram and triangle of forces	2	2	3
Equilibrium and centre of gravity	2	3	3
Friction	2	3	4
Velocity, acceleration, speed	3	3	3
Work	3	3	4
Energy; potential and kinetic	2	3	3
Power	3	3	4
Hydrostatics and hydrodynamics	2	3	4
Instruments and meters			
- Pressure	3	3	4
- Flow	3	4	4
- Temperature	3	4	4
- Level	3	3	4

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Electrical Theory	**Levels**		
Units and definitions	3	4	5
Ohm's law	3	4	5
Series and parallel connection of resistances	4	4	4
Internal resistance, terminal voltage and E.M.F.	3	4	5
Series and parallel connection of E.M.F.	3	4	5
Electromagnetic theory	2	3	4
Resistance, inductance and capacitance	3	3	4
Power and power factor	3	3	4
Three-phase supply	3	4	5
Over-voltage	3	3	4
Cables: types, sizes and construction	2	3	3
Fuses and overload protection	3	3	3
Contactors and relays	2	4	2
Circuit breakers and isolators	3	4	4
Atmospheric effects, lightning, etc.	4	4	4
Protection against over-voltage damage	3	4	4
Sparkgaps, capacitors, surge arrestors	2	3	3
Electrical Measurements			
Types of meters	4	4	4
Measuring transformers	3	4	3
Voltage transformers	3	4	3
Current transformers	3	4	3
Special measuring instruments	3	5	5
Synchronoscope	3	4	4
Frequency meters	2	4	3
Wheatstone bridge meters	2	4	3
Registering meters, kVAh meters	3	3	4
D.C. meters	3	3	4
Tachometers	4	4	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Electrical Machines and Equipment	**Levels**		
DC Motors and Generators			
Principles and main parts of a D.C. machine	4	4	5
Induction of E.M.F. in the machine	3	3	4
Series, shunt, compound and separate excited machines	4	4	4
AC Motors and Generators			
Principles and main parts of a synchronous generator	3	3	4
Speed, number of poles and frequency	3	3	4
Stator winding and E.M.F. of a synchronous generator	3	3	4
Introduction to induction motors	3	4	5
Asynchronous and synchronous machines	4	4	5
Rotating electrical machinery			
General	2	2	2
Principles of generators	3	3	4
DC current	4	4	4
Alternating current machines			
Synchronous machines	3	3	4
Single-phase generators	2	3	3
Multiphase machines	3	3	3
Asynchronous motors	3	3	3
Rotating fields, idle and short-circuit characteristics	3	4	3
Construction and design	4	4	4
The synchronous three-phase generator, design and characteristics	3	3	3
Maintenance of the machines	3	4	4
Excitation system	4	4	5
Voltage regulation	4	4	4
Rectifiers and Inverters			
Introduction; performance and maintenance of reactors ?? Rectifiers ??	2	2	2
Types of rectifiers	2	4	3
Applications	2	4	3
Batteries			
Types of cells	4	5	3
Methods of connecting cells	2	5	4
Applications	2	5	5

Safety	5	5	5
Maintenance	4	5	4

Position **Subject**	**Plant Operator**	**Control Room Technician**	**Shift Charge Engineer**
Power Transformers	**Levels**		
Introduction	2	2	2
Transformer principles	4	4	5
The transformer at no-load	3	4	4
The transformer at load	4	4	5
Losses and efficiency	2	2	2
Voltage loss in a transformer	1	1	2
Three-phase transformer connections	2	3	3
Parallel connection of transformers	2	2	3
Powerformer	1	2	2
Measuring transformers			
Voltage transformers	3	3	4
Current transformers	4	4	4
Reactors			
Introduction to reactors.	2	2	2
Performance and maintenance of reactors	3	3	3
Series and shunt reactors; their design and use	3	4	4
Switchyards			
Different types	1	2	2
Breakers	3	3	4
Isolators ?? Insulators	3	4	4
Busbars	2	2	3
Surge Arrestors	3	3	3
HF equipment	3	4	4
Cables; types, sizes and construction	3	3	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Prime Movers	**Levels**		
Laminar and turbulent flow	2	2	3
Losses in pipes	1	2	2
Valves	2	2	3
Types of turbines	2	3	3
Wear of turbine parts, cavitation etc.	2	2	2
Surge problems	3	4	5
Maintenance	3	3	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Mechanical diagram reading and drawing	**Levels**		
Basic engineering drawing	2	3	4
Projections and sectional views	2	3	3
Diagrams	3	3	4
Symbols	2	3	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Mechanical engineering and workshop technology	**Levels**		
Bolts, nuts and washers	2	2	2
Split pins, cotters and keys	2	2	2
Shafts, couplings and clutches	2	2	3
Types of bearings and applications	3	3	3
Gears, belts, chains and ropes	2	3	4
Pipes and valves	2	3	3
Springs	1	1	1
Bench fitting	1	1	1
Tools	2	2	2
Drilling	2	2	2
Turning	1	1	1
Milling	1	1	1
Grinding	2	2	2
Filing	2	2	2
Engineering of materials	2	2	3
Iron and steel	1	2	2
Copper and aluminium	1	1	1
Magnesium, lead, zinc and nickel	1	1	1
Non-metallic materials	1	1	1
Insulating materials	2	2	2
Non-destructive testing	2	2	3
Protection of metallic surfaces	2	3	3
Painting of iron and steel	2	3	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Electrical diagram reading and drawing	**Levels**		
DC systems	4	4	5
Electrical symbols	4	4	5
Contactors and relays	4	5	4
Binary logical symbols and elements	3	4	4
Principles of drawing	4	5	3
The Combiflex system	4	4	5
Drawing exercise	4	4	5

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Auxiliary equipment	**Levels**		
General auxiliary services	2	3	3
Local power and lighting	4	5	3
Air conditioning			
Principles of air-conditioning	2	3	3
Types and applications	3	4	4
Cooling water systems			
Power station cooling water	3	4	4
Ventilation			
Principles and applications	3	3	3
Fans			
Mechanics of fans	2	2	3
Axial flow fans	1	2	2
Radial flow fans	1	2	2
Characteristics in operation	2	3	3
Compressors			
Expansion and compression of gases	2	2	2
Single-stage compressors	2	2	2
Multiple-stage compressors	2	2	2
Principles of refrigeration and air conditioning	2	3	2
Operational auxiliaries			
Governor oil system	2	3	3
Lubricating oil system	2	3	3
Cooling water systems	3	4	3
Compressed air systems	3	4	3
Maintenance auxiliaries			
Cranes and hoists	2	3	3
Turbine de-watering systems	4	4	5
Oil purification plant	3	3	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Basic maintenance	**Levels**		
General maintenance planning	3	3	4
Preventive maintenance	3	3	4
Stock-keeping systems	3	3	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Operation of hydropower plants	**Levels**		
Control-room equipment	4	4	5
Relay protection philosophy	4	4	5
Alarm systems	4	5	5
Operation during disturbances	4	5	5

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Oil hydraulics	**Levels**		
Hydraulic symbols	3	3	4
Valves and linear motors	3	3	3
Pumps	2	3	3
Hydraulic systems in power plants	3	4	4
Servo motors for guide vanes and runner	3	3	4
Hydraulic governor	3	4	4
Bearings and seals	2	3	3

Position Subject	Plant Operator	Control Room Technician	Shift Charge Engineer
Safety regulations, fire protection and first aid	**Levels**		
Operating instructions			
Permit to work	5	4	5
Certificate of commissioning	5	4	5
Industrial safety and protection			
Industrial safety	3	3	4
Non-mechanical accidents	4	4	4
Mechanical accidents	4	4	4
Electrical accidents	4	4	5
Electrical safety rules at power stations			
General	4	4	4
Electrical equipment rooms	5	4	5
Working on high-voltage apparatus	5	5	5
Hazardous incidents and accidents	4	4	4
Objections to instructions	4	4	5
Fire protection and use of firefighting equipment			
Types of fire extinguishers and their applications	3	4	5
Breathing apparatus	5	5	5
First aid			
Artificial respiration	3	3	3
Stretchers	3	3	3
Heart massage	3	3	3
Splinting fractures	3	3	3
Rescuing casualties from restricted areas	4	4	5

APPENDIX 2 – TRAINING PROGRAMME FOR THE THEUN-HINBOUN POWER PLANT

This training program was developed for an existing operating and maintenance organisation in Laos, the Theun-Hinboun Hydropower Project. It can be seen as an example of training that can be performed in the course of commercial operation.

General

This training programme was drawn up by the O&M management at Theun- Hinboun Power Plant.

A suitable time schedule for the training programme in individual departments was hard to set out, as all training has to be performed during commercial operation. Any deviations from normal operation could thus result in changes in the training programme. Most of the personnel working at Theun-Hinboun Power Plant have already taken a year of theoretical and practical hydropower training at the EdL Training Centre in Vientiane. Some of the key personnel have also attended a four-month training course at Jokkmokk Training Centre in Sweden. Special training has also been performed at EGAT Training Centre outside Bangkok in Thailand. To maintain skills and upgrade the level of knowledge, this complementary training programme will be given to all personnel during the operational phase. It should be regarded as a continuously running programme intended to maintain and improve the knowledge of the personnel. The programme includes hydropower technology for the civil maintenance group in order to broaden the range of understanding in this department. As many persons within this group possess little or no knowledge of power plants and personal safety, this group will be given special training.

Courses for all departments

Electrical safety
Objectives: Frequently repeated training in electrical safety advice (ESA) with the aim of keeping the safety procedures updated. Running over routines and forms included in the work in order to maintain high standards and avoid accidents. Running through methods and routines for switching orders and work permits etc. This training can be given by internal instructors such as the Operation Manager.

Personal safety
Objectives: Frequently repeated training with the aim of maintaining a high level of safety during work. This includes training in handling certain situations such as:
Fire fighting, first aid and evacuation training. This training can be given by internal instructors, or in certain cases by specialists.

Firefighting
Objectives: Frequently repeated fire drills with the aim of training personnel in handling different types of fire-fighting appliances.
Carbon dioxide extinguishers, powder extinguishers, water extinguishers, etc. This training can be provided by internal instructors, or in certain cases by specialists such as the fire brigade.

First aid
Objectives: Training in actions to be taken following burns, electrical accidents, drowning and other types of accidents. Life-saving training. This training must be provided by external instructors and specialists such as the doctor or nurse at the site clinic.

Disaster training
Objectives: How to react in specific situations such as flooding of the power plant, earthquakes, landslides, fires or other unforeseen catastrophes. How to recognise different alarm system sounds. To be able to evacuate the powerhouse in the case of disasters. This training can be provided by internal instructors such as engineers from different departments.

Environmental care
Objectives: To make employees aware of the necessity for care of the environment. How to save natural resources, handle chemicals, etc.

English language courses.
Objectives: To maintain a high level of English and improve employees' ability to read and understand English.

These courses should be held at regular intervals, while the other courses might be offered as and when needed.

Transmission department training

This department, which works mainly on or close to the transmission line and the substation at Thakhek, will be given training in Mechanical Maintenance, Electrical Maintenance and Operations. As this group also carries out some civil engineering operations, this will also be included in their training.

<u>Lifting and climbing equipment inspection course.</u>
Objectives: To make sure all lifting equipment such as wire ropes, slings, gripping clamps, tir-for lifting blocks etc. is kept in good working order and safe to use. Climbing equipment such as ladders or scaffoldings must be inspected in the same way. This training may need a specialist or certified person if normal safety regulations are applicable.

<u>Chain saw course/ Inspection of bush clearing.</u>
Objectives: To be able to operate and maintain a chain saw. Guidelines for bush clearing. This training can be provided by internal instructors provided by internal instructors such as the Transmission Engineer.

<u>Grounding</u>
Objectives: To be able to carry out grounding (earthing) work along the transmission line according to regulations, when repairs are required on insulators or conductors, etc. This training can be provided by internal instructors, for example the Transmission Engineer.

<u>Replacement of insulator set</u>
Objectives: To be able to repair or replace suspension and tension insulator sets along the transmission line. This training can be provided by internal instructors.

<u>Replacement and repair of conductor and overhead ground wire</u>
Objectives: To be able to repair and join conductors and overhead ground (earth) wire along the transmission line. This training can be provided by internal instructors, suitably the Transmission Engineer.

<u>Designation system</u>
Objectives: To be able to use a designation method to be used in the inspection report. This training can be provided by internal instructors.

<u>Measuring of ground resistance</u>
Objectives: To be able to carry out measurement of ground resistance and structure ground resistance. This training can be provided by internal instructors, for example the Transmission Engineer.

<u>Inspection of towers and foundation</u>
Objectives: To be able to carry out visual check of towers and foundations and to report. This training can be provided by internal instructors such as the Transmission Engineer.

<u>Inspection of insulator and fittings</u>

Objectives: To provide guidelines for inspections and report to supervisors. This training can be provided by internal instructors, for example the Transmission Engineer.

Inspection of conductor and fittings
Objectives: To provided guidelines for inspecting joints, clamps and connectors and report to supervisors. This training can be provided by internal instructors, for example the Transmission Engineer.

Inspection of grounding
Objectives: To be able to check ground connections and to report.
This training can be provided by internal instructors, for example the Transmission Engineer.

Mechanical Maintenance training.

The mechanical department will be trained in subjects close to their field of work. However, some additional training might be necessary, if new types of equipment are purchased. Most of the training on the mechanical department is equipment-specific.

Inspection of lifting and climbing equipment
Objectives: To ensure that all lifting equipment, like wire ropes, slings etc. is in good working order and safe to use. Climbing equipment such as ladders or scaffoldings should be inspected in the same way. This training might need a specialist or certified person if safety regulations are applicable.

Welding; Arc welding.
Objectives: To train and keep up the working skills in welding. To achieve good welds in different positions. This training can be provided by internal instructors, for example the Mechanical Engineer.

Welding; TIG welding.
Objectives: To be able to weld stainless cooling water pipes and aluminium.
This training can be provided by internal instructors, for example the Mechanical Engineer.

Turning and milling; A.
Objectives: Basic knowledge of turning, cutting speeds, etc. This training can be provided by internal instructors, foremen or the Mechanical Engineer.

Turning; B.
Objectives: More advanced knowledge of turning. Taper turning, inside turning, making threads etc. This training can be provided by internal instructors such as the Mechanical Engineer.

Power-station hydraulics
Objectives: To impart familiarity with the hydraulic system of Theun-Hinboun Power Plant. This training can be provided by internal instructors.

Crane operator
Objectives: To be able to operate the cranes in the powerhouse and warehouse. The cranes at the dam site are also included. This training can be provided by internal instructors such as the Mechanical Engineer.

Compressors
Objectives: To understand the principles of compressed air. To be able to repair and maintain compressors belonging to the project. This training can be provided by internal instructors.

Pump
Objectives: To be able to repair and maintain pumps belonging to the project. To be familiar with the hydraulic systems, including the cooling water system at Theun-Hinboun Power Plant. This training can be provided by internal instructors, such as the Mechanical Engineer.

Bearings
Objectives: Understanding of the importance of bearings in the maintenance of motors, pumps and other auxiliary systems such as ventilation. This training can be provided by internal instructors, for example the Electrical Engineer and the Mechanical Engineer.

Lubrication and oils
Objectives: To be familiar with the lubrication systems used in the plant. To know the function and composition of the various lubricants and oils used in the systems. Personal and environmental safety related to lubrication, grease solvents and fuels. This training can be provided by internal instructors with the help of external instructors and specialists.

Rust protection and painting
Objectives: To understand the necessity for rust protection. To know how different materials can result in oxidation when put together inappropriately . How to measure the thickness of painted coatings. How to choose a suitable paint for a given material. Basic knowledge of epoxy painting. This training can be provided by internal instructors.

Turbine inspection
Objectives: To be able to inspect the turbine runner with respect to cavitation. To be able to adjust the guide vanes . To check the spiral casing for damage, rust, cavities or other damage. To inspect gates, gate seals, inspection ladders, platforms, etc. This training can be provided by internal instructors.

Management
Objectives: Training in leadership and management with the objective of training the operators to act as independent leaders. The importance of delegating responsibility and authority. The Operation Manager should preferably carry out this training.

Electrical Maintenance training

Ventilation systems
Objectives: Ventilation is among the tasks of the electrical department.
This training can be provided by internal instructors, most suitably the Electrical Engineer together with specialists as required.

bearings
Objectives: Understanding of the importance of bearings in the maintenance of motors, pumps and other auxiliary systems such as ventilation. This training can be provided by internal instructors, most suitably the Electrical Engineer together with the Mechanical Engineer.

Joining fibre-optic cables
Objectives: The correct joining of fibre-optic cables in the case of disturbance or failure. This training can be provided by internal instructors.

Joining power cables
Objectives: To be familiar with methods of joining power cables. This training can be provided by internal instructors.

Air conditioning
Objectives: To understand the principles of compressors and cooling techniques. To be able to repair and maintain air conditioners and refrigerating equipment belonging to the project. This training can be provided by internal instructors, for example the Electrical Engineer and the Mechanical Engineer.

Generator inspection
Objectives: To t carry out independent generator inspections. To check rotor-stator alignment. To measure the air gap. To be able to check poles and connections with respect to resistivity, etc. This training can be provided by internal instructors.

Operation training

<u>Facility Protection</u>
Objectives: The function and design of different relays and protections. Going through protection settings for safe achievement of selectivity. The operators will be able to make simple fault analyses with the information given by the protection equipment and perform correct actions, in order to shorten the time required for trouble-shooting. This training can be provided by internal instructors, for example the Electrical Engineer.

<u>Operation and Production Philosophy</u>
Objectives: Surveying various operational strategies in order to optimise total production with respect to contracts, manuals, availability and disturbances. This training can be provided by internal instructors, for example the Operation Manager.

<u>Hydrology</u>
Objectives: To understand various hydrological situations and how these affect production. Calculation of water flow to predict future water flows in good time. To learn how to use the equipment available for this purpose. This training can be provided by internal instructors, for example the Operation Manager.

<u>Simulating contingency situations</u>
Objectives: Simulating various disturbances in order to train operators to handle equipment and instructions in a safe and reliable way. Training in the importance of being able to solve problems even under stress. This training should preferably be given by the Operation Manager.

<u>Management</u>
Objectives: Training in leadership and management to enable operators to act as independent leaders. The importance of delegating responsibility and authority. This training should preferably be given out by the Operation Manager.

<u>Facility operating training</u>
Objectives: The function and handling of different equipment and their functions. The purpose of this training is to diffuse understanding of the power plant to all employees. This training can be provided by internal instructors such as managers and engineers.

<u>Contract reading</u>
Objectives: Frequently repeated training on the most important contracts, PPA and OMA. The purpose is to improve understanding of how these contracts affect our ability to comply with the contracts. This training should preferably be given by the Operation Manager.

<u>Reading electrical diagrams.</u>
Objectives: Frequently repeated training how to read and understand electrical diagrams and drawings. This training should preferably be offered by the Operation Manager or the Electrical Engineer.

Civil Engineering Maintenance

As this department is responsible for a wide range of activities, some special courses are required.

Driving excavators and tractors
Objectives: This course is needed for the civil maintenance group when minor maintenance work needs to be done in the operators village or close to the power house. As a Tractor/Excavator has been purchased to the project, some regular drivers will be trained. This training can be provided by internal instructors, most suitably the Maintenance Engineer or the Mechanical Engineer. A certificate will be issued to the trained drivers.

Maintenance philosophy
Objectives: To understand the meanings of, and difference between, preventive and corrective maintenance. To understand the importance of cleaning and keeping equipment and tools in good order. This training can be provided by internal instructors, such as the Maintenance Engineer and Mechanical Engineer.

Air conditioning
Objectives: To understand the principles of compressors and cooling techniques. To be able to repair and maintain air conditioners and refrigerators belonging to the project. This training can be provided by internal instructors, for example the Electrical Engineer and Mechanical Engineer.

Water treatment plant
Objectives: To be able to maintain the water treatment plant. Checking pH, making adjustments and carrying out minor repairs. The function and design of the plant. This training can be provided by internal instructors with the help of external instructors and specialists.

Sewage treatment plant
Objectives: As above.

Inspections of grounds and buildings
Objectives: To be able to design a maintenance programme for the facilities around the project. This training can be provided by internal instructors.

Rust protection and painting
Objectives: To understand the necessity for rust protection. To know how different materials can result oxidation when put together inappropriately. How to measure the thickness of painted coatings. To be able to choose a suitable paint for a given material. Basic knowledge of epoxy painting. This training can be provided by internal instructors.

Hydropower technology.
Objectives: To improve trainees' understanding of hydropower plants. Many persons in this group have little or no knowledge of the function and construction of power plants.

APPENDIX 3 – DESCRIPTION VATTENFALL AB JOKKOMOKK TRAINING CENTRE (JTC)

Organisation

Jokkmokk Training Centre (JTC) is located on the River Lule, the biggest river in Sweden. Since the beginning of the 20th century the Lule has been used for hydroelectric generation, and operating and maintenance experience have been accumulated and used for more than 80 years.

In 1981 Jokkmokk Training Centre started training operation and maintenance staff for the Swedish State Power Board Company and in the Operation and Maintenance programme at the Senior High school. The objective was to build up a centre for training in hydroelectric technology. Within a radius of 50 km there are more than ten power stations, two remote control centres for training and field trips, and plants utilising a wide range of differing technology and designs.

Today Jokkmokk Training Centre can offer "tailor-made" courses for individual customers. About 50% of the workload of the Training Centre currently consists of international projects which are run as individual projects, to some extent in co-operation with SwedPower.

The range of training programmes at Jokkmokk Training Centre is built up in three stages:

1. Stage one consists of pure theoretical training in hydropower technology.
2. Stage two is practice and trouble-shooting on JTC’s power station simulators at the training centre.
3. Stage three is practice and troubleshooting on a new hydropower training and research centre at Porjus, 45 km north of Jokkmokk.

Jokkmokk Training Centre has technical equipment for simulating all of a power station's supervision and control equipment and grid, with power line models. There is also equipment to simulate a small power station with less complex supervision equipment without automation, transmission equipment, including substations (400 kV/130 kV/40 kV/10kV), remote control and a simpler hydropower station with supervision equipment. The Centre also has hydraulic equipment for experiments, and complete turbine governing equipment.

The next step in expanding the operations of the school is training, including the use of a full-scale unit in a modernised power station, where the unit can be used freely without concern for commercial production. Because there is access to a modern training unit, both theory and practice can be combined in a natural way.

The training programme includes the following:

- basic operational training
- maintenance training
- supplementary training
- specialised training
- operational engineer training
- further education for teachers
- university education.

The training unit is built as a modern Francis unit, with all the functions normally required for the operation of a power station.

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