TECHNICIAN'S HANDBOOK FOR
COMPRESSION REFRIGERATORS

PART F

INSTRUCTOR'S HANDBOOK

Addendum

INSTRUCTOR'S NOTES FOR PHOTOVOLTAIC REFRIGERATORS

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The **EPI COLD CHAIN TRAINING DOCUMENTS** are produced in three series, as listed below:

(a) Logistics and Cold Chain for Primary Health Care Series
(b) Refrigerator Use, Maintenance and Repair Series:
- Repair Technicians Handbooks
- User and Maintenance Handbooks

(a) LOGISTICS AND COLD CHAIN FOR PRIMARY HEALTH CARE SERIES

This series comprises 28 booklets, which contain detailed guidelines on storage, distribution and estimation of the demand for supplies, as well as technical information on the maintenance of equipment required for storage. (The equipment maintenance booklets in this series are also included in the Refrigerator Use, Maintenance and Repair Series.)

1. How to estimate requirements for an existing store
2. How to store supplies
3. How to distribute supplies
4. How to keep records and calculate wastage
5. How to control quality of stocks
6. How to estimate requirements
7. How to estimate chloroquine requirements
8. How to estimate ORS packet requirements
9. How to estimate vaccine requirements
10. How to estimate contraceptive requirements
11. How to estimate essential drug requirements
12. The cold chain game
13. How to improve communication
14. How to look after a compression refrigerator
15. User's handbook for compression refrigerators
16. How to look after a kerosene refrigerator
17A. User's handbook for kerosene refrig. (Elec. RAK 1302)
17B. User's handbook for kerosene refrig. (Sibir S2325)
18. How to look after a gas refrigerator
19. User's handbook for gas refrigerators
20. How to keep stocks of spare parts
21. How to look after a cold store
22. User's handbook for cold stores
23. Instructor's guide
24. Evaluation questionnaire
25. How to look after a photovoltaic refrigerator
26. User's handbook for photovoltaic refrigerators
27. How to use the vaccine cold chain monitor

(continued on back inside cover)

(continued from front inside cover)

(b) REFRIGERATOR USE, MAINTENANCE AND REPAIR SERIES

This series, which is made up of two sub-series, comprises 21 booklets designed to improve the standards of refrigerator and cold room maintenance and repair:

- **Repair Technicians Handbooks**

The following handbooks are the basic training materials for a 10-day course for refrigerator repair technicians:

A. Servicing and repair techniques
B. Faults and fault-finding
C. Repair Work
D. How to keep stocks of spare parts
E. Task sheets and progress sheets
E/Add.1 Task sheets on photovoltaic refrigerators
F. Instructors handbook
F/Add.1 Instructors Notes for photovoltaic refrigerators
G. Manufacturers' spare parts lists
H. Fault finding and repair of photovoltaic refrig.

- **User and Maintenance Handbooks**

Each of the following pairs of handbooks form a one-day course for people who use cold rooms or compression, kerosene, gas or photovoltaic refrigerators. (These booklets are also included within the Logistics and Cold Chain for Primary Health Care Series, and the numbers given below correspond to the numbers each has been assigned within that series.)

14. How to look after a compression refrigerator
15. User's handbook for compression refrigerators

16. How to look after a kerosene refrigerator
17A. User's handbook for kerosene refrig. (Elec. RAK 1302)
17B. User's handbook for kerosene refrig. (Sibir S2325)

18. How to look after a gas refrigerator
19. User's handbook for gas refrigerators

21. How to look after a cold store
22. User's handbook for cold stores

25. How to look after a photovoltaic refrigerator
26. User's handbook for photovoltaic refrigerators

WORLD HEALTH ORGANIZATION

EXPANDED PROGRAMME ON IMMUNIZATION

TECHNICIAN'S HANDBOOK FOR

COMPRESSION REFRIGERATORS

PART F

ADDENDUM

INSTRUCTOR'S NOTES FOR

PHOTOVOLTAIC REFRIGERATORS

INSTRUCTOR'S NOTES FOR PHOTOVOLTAIC REFRIGERATORS

1. INTRODUCTION

Solar-photovoltaic refrigerators for vaccine storage are increasingly being specified for vaccine cold chains that extend to areas remote from an electrical grid. They are widely recognised as being more reliable than commonly used kerosene fuelled absorption refrigerators, but to ensure satisfactory operation preventative maintenance, fault finding and repair by technicians fully trained on solar refrigerators is required.

2. COURSE PREPARATION

2.1 Ensure safety is given the top priority

Before the training course commences ensure:

(a) a first aid kit is available
(b) the instructors know how to call a doctor quickly in an emergency
(c) all tools and equipment are checked to be safe
(d) all workshop equipment is fitted with safety guards
(e) photovoltaic arrays are secure and access to them is safe (correct ladders and crawling boards if roof mounted)
(f) batteries and battery acid are in a safe well ventilated place
(g) electrical connections on power tools have been checked to be safe.

2.2 Select the participants carefully

It is essential that participants who undertake photovoltaic refrigerator training **have previously undertaken a compression refrigerator Repair Technicians Course.**

Care should also be taken to ensure that participants will be responsible for the servicing and repair of solar photovoltaic refrigerators after the course.

2.3 Give adequate notice of the course to the participants

If participants have to travel a long distance to the training centre it is important they be given at least **2 months notice of the dates** of the course so they or their departmental heads can

make the necessary travel arrangements. This is essential in the case of regional training courses involving participants from several countries. Tickets have to be issued in sufficient time to enable visas to be obtained.

In the case of international travel being involved it is recommended that the **participants arrive one whole day in advance of the course.** The first day of the training course is the introduction to photovoltaic refrigerators, a key part of the course which cannot be missed.

2.4 Ensure the course duration is long enough

If the training on photovoltaic refrigerators is to be undertaken immediately after a compression refrigerator repair technicians course and if full installation training is not required (i.e. the technician will only be responsible for servicing and repair) a one week course is recommended. The outline of a one week course is shown in Table 1.

When more detailed training on installation is required and when the course does not immediately follow a compression refrigerator repair technicians course a two week course is recommended. The outline of a two week course is shown in Table 2.

2.5 Ensure all facilities are available

Basic Facilities

It is important to note the facilities that are required to run a photovoltaic refrigerator training course

- a laboratory/workshop to accommodate the photovoltaic refrigerator cabinets
- a fully equipped workshop
- an area where a trial installation of a photovoltaic array can take place
- transport for bringing the participants to and from the training centre
- transport for taking participants and equipment to the field installation sites (if a field installation is to be done)
- lecture room(s) for theory sessions including slide and overhead projectors

TYPE: L = Laboratory/Workshop
C = Classroom
F = In Field

DAY	MODULE NO.	ACTIVITY	DURATION (HOURS)	TYPE
1	1	Introduction to Photovoltaics	1.5	C
	2	Safety	0.5	C
	3	System Familiarisation	2.0	L
	4	Tools & Instrumentation	1.0	L
	5	Batteries: Charging & Measurements	1.0	L
2	6	Operation & Performance	3.0	L
	7	Preventative Maintenance	2.0	L
	8	Introduction to Installing	1.0	C
3	9	Mock Installation	6.0	L
4	10	Fault Finding	2.0	C/L
	11	Fault Finding Tasks	4.0	L
5	12	Repairs	1.0	L
	13	Repair Tasks	2.0	L
	14	User Training	2.0	L
	15	Review of Course/Close	1.0	C

RECOMMENDED ONE WEEK PHOTOVOLTAIC REFRIGERATOR TRAINING COURSE

WEEK ONE

DAY	MODULE NO	ACTIVITY	DURATION (HRS)	TYPE
1	1	Welcome/Logistics	2.0	C
	2	Introduction to Solar Refrigerators	1.0	C
	3	Principles of Photovoltaics	0.5	C
	4	Safetly	0.5	C
	5	System Familiarisation	2.0	L
2	6	Tools & Instrumentation	2.0	L
	7	Operation & Performance	4.0	L
3	8	Batteries	1.0	C
	9	Battery Measurements	1.0	L
	10	Preventative Maintenance	1.5	L
	11	Maintenance Tasks	1.5	
	12	Introduction to Installing	1.0	C
4	13	Trial Installation	6.0	L
5	14	Maintenance Tasks	2.0	L
	15	Fault Finding	2.0	C/L
	16	Fault Finding Tasks	2.0	L
6	Available for Additional Tasks (or programme slip)			
7	Rest Day			

WEEK TWO

8	17	Fault Finding Tasks (Other Refrigerators)	2.0	L
	18	Repairs	1.0	C/L
	19	Repair Tasks	3.0	L
9	20	User Taining	2.0	C/L
	21	Installation Preparation	4.0	L
10	22	Installation	6.0	F
11	23	User Training (and completion of installation if necessary	6.0	F
12	24	Course Review	4.0	C
	25	Closing Ceremony	1.0	C
	26	Facilitators Meeting	1.0	C

RECOMMENDED TWO WEEK PHOTOVOLTAIC
TRAINING COURSE

- a complete photovoltaic refrigerator including photovoltaic arrays, support structure, all cabling, batteries, regulator and refrigerator cabinet and ice packs. A minimum of one refrigerator per six participants is required. One refrigerator per four participants would be preferable however.

- a selection of different photovoltaic refrigerator models and types (in working order) to familiarise participants with different types

- a health centre nearby where a working photovoltaic refrigerator in normal use can be observed

- a selection of faulty components for fault finding and repair work (compressor, compressor controller charge regulator, flat battery, blown fuses, power cable without electrical continuity, broken indicator lights etc).

Instrumentation and Tools

In order to undertake fault finding, maintenance and repair of solar refrigerators in accordance with the technicians handbooks the tools listed below that are not in the conventional tool kit are required. Ensure there are sufficient tool kits for the number of participants.

- hydrometer for measuring battery electrolyte specific gravity

- one bimetal thermometer

- immersion type mercury in glass thermometer with protective sheath for measuring battery electrolyte temperature: 10^{o} to 60^{o}C range.

- two 20 Amp 200mV current shunts for measuring currents in the Array and either side of the charge regulator

- digital multimeter preferably with 10 Amp d.c. range and millivolt range. (Two multimeters would be preferable as this would allow current and voltages to be measured at the same time). An example is Fluke JP73.

- mini-socket set for small nuts used to affix the compressor controller.

- one pair of plastic gloves for use when working with battery acid
- compass to determine array directions
- spirit level

If a field installation is to take place during the course then as a minimum the following tools are also required:

- complete photovoltaic refrigerator including array support and user service kit
- generator with fuel for power drill
- extension cable
- power drill with masonry and steel drill bits
- full set of sockets, spanners and screwdrivers
- centre punch, hammer, hacksaw
- pliers, wire strippers, crimping tools
- ladders (2), and rope
- level
- solarimeter (A multimeter may be used as a readout of the solarimeter as most types have millivolt output proportional to irradiance and a 0-100 mV range). An example is a Haenni 130.
- spare lengths of cable of all cable types used in the installations
- spare nuts and bolts of all types used in the installations
- plaster and paint to make good the health centre walls after installations

2.6 Ensure sufficient instructors and facilitators

One instructor/facilitator per 4 participants is recommended. In addition one facilitator should always be available for administrative tasks.

2.7 Ensure course material arrives in advance

Each participant should have:

(a) Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook
(b) A Users Handbook for Photovoltaic Refrigerators
(c) Task Sheets for Photovoltaic Refrigerators (Addendum to EPI/TECH. HB/E)

Ensure they are in the correct language.

3. COURSE CONTENT

The recommended course content for the one week course is shown in Annex 1.

The recommended course content for the two week course is shown in Annex 2.

4. INSTRUCTORS NOTES ON THE TASK SHEETS

A: HOW A PHOTOVOLTAIC REFRIGERATOR WORKS

Task Number 1: Identify the parts of the refrigerator

As the participant points out the parts of the refrigerator ask him what the function of each part is.

Ensure the participants know the meaning of the temperature indicators and in which way the thermostat setting is adjusted to make the refrigerator warmer or cooler.

Task Number 2: Identify the parts of the solar electricity supply system

Ensure the participants have a reasonable understanding of how a photovoltaic refrigerator works. This will enable them to better carry out fault finding.

B: SAFETY CONSIDERATIONS

Task Number 3: Batteries

The participants must clearly understand that batteries contain acid which is dangerous and gives off gases that can build up and be explosive.

If you demonstrate how corrosive battery acid is (Action 8) be sure to wear plastic gloves and dispose of all acid contaminated material properly.

Task Number 4: Photovoltaic Array

When a 12 volt or 24 volt photovoltaic refrigerator system is correctly configured the Array is not dangerous but if the modules are incorrectly wired such that the output voltages add up a potentially dangerous voltage can occur. For example 6 modules with an open circuit voltage of 17 volts could produce a voltage in excess of 100 volts.

Except when checking performance a photovoltaic array should be covered when work is being carried out.

Roof mounted arrays must have safe secure ladders, roof crawling boards, safe roof structures and sufficient room to enable cleaning to be carried out.

Task Number 5: First Aid Measures

Ensure all participants know that they should immediately wash acid from their eyes with clean water. Ensure the participants know where the first aid kit is and what all the items are for.

C: HOW TO MEASURE

Task Number 6: Temperature

Check that all participants know what temperature vaccine should be kept at and that they can correctly read a dial thermometer.

Ensure the battery electrolyte thermometer is washed before it is put away.

Task Number 7: Identify Positive and Negative Terminals

Demonstrate to the participants after they have identified the correct terminals how the positive and negative terminals from one component are linked to the terminals of another component.

Advise the participants not to assume that if a red wire is used it always links positive terminals. Sometimes installation teams make mistakes or run out of one colour of wire.

Task Number 8: Measure Voltage

All participants must become familiar with double checking the multimeters are set on the correct ranges to avoid damage to multimeters.

If analogue meters are to be used ensure participants know how to zero meters.

Task Number 9: Measure Current

Ensure the participants understand the principle of a current shunt and how to connect one into a circuit.

Task Number 10: Measure Resistance

It is not possible with a normal multimeter to measure the exact resistance between the compressor pins. The participants need however to be able to determine when there is very low resistance or continuity for testing fuses or for shorted compressor motors. Similarly open circuits (blown fuses) need to be identified. Ensure participants can determine, very low resistances, and open circuits.

Task Number 11: Measuring State of Charge of Batteries

Ask participants to take measurements on several batteries some fully charged, some partly discharged, some close to fully discharged.

Task Number 12: Measuring the Tilt and Direction of the PV Array

Explain that when near the equator arrays are not put horizontal but at a 5^{o} tilt to allow the rain to wash off dust and bird droppings.

Ensure each participant knows the latitude of his region and the tilt angle most common for the region.

Identifying true solar noon and differences between true North and Magnetic North are complex and variable. The participant should be aware however that at about noon the array should face towards the sun.

Task Number 13: Measuring Open Circuit Voltage

The participants should appreciate the V_{oc} is when no current is flowing, i.e. a wire is disconnected.

Task Number 14: Measuring Short Circuit Current

Explain that short circuit current is directly proportional to the solar energy incident on the solar array and so when comparing I_{sc} measurements a period of uninterrupted sunshine is necessary.

D: MAINTENANCE AND SERVICE TASKS

Task Number 15: Checking Daily Records

If at all possible actual daily record sheets from a nearby photovoltaic refrigerator installation would be best. Also, make up some record sheets (prior to the task) which show some deviations from normal operation. This will allow discussions on interpretation of daily record sheets.

Task Number 16: Checking Temperatures and Indicator Lights

Ensure participants understand the significance of when lights are lit and when they are not lit.

Task Number 17: Checking Free Air Circulation

If possible put a refrigerator too close to a wall or block the ventilation grille with a box or similar. Ask the participants to identify what is wrong with the installation.

Task Number 18: Is the Refrigerator Loaded Correctly

Explain that when warm bottles of drink or other items are placed in a refrigerator and then removed later even though nor problem is then apparent problems occur later since the energy taken from the batteries has been greater than designed for.

Task Number 19: Check the Ice Forming around the Freezer Compartment. Defrosting

Explain that the refrigerator compartments should be dry before the refrigerator is switched on again.

Task Number 20: Checking the lid/door Seal

This is the same problem as for a conventional compressor refrigerator, except that the energy available to a photovoltaic refrigerator to compensate for heat gain, from a poor seal, is limited.

Task Number 21: Clean the Photovoltaic Array

Explain that in the same way very little light gets through a vehicle windscreen after a dust storm so very little solar energy gets through the dust on a solar array. It must be cleared regularly.

Task Number 22: Checking for Shadowing of the Array

Shadows near sunrise or sunset are not a problem but any shadowing of the array between 8.00 a.m. and 4.00 p.m. needs to be stopped.

Task Number 23: Cleaning the parts of the Refrigerator

The more efficient photovoltaic refrigerators are those that have well positioned condensers with good air circulation. Keeping the condenser, condenser fan and compressor free of dirt build up is very important.

Task Number 24: Checking the level of acid in Batteries

Ensure that a plastic bottle with spout or a funnel is available.

Task Number 25: Checking for a safe and secure installation

Participants must know to lock for loose components, unprotected or non-ventilated batteries, unsafe access to photovoltaic arrays and poor electrical connections.

E: FAULT FINDING

Task Number 26: Determine the Symptoms

Ensure participants can tell if a compressor is running or not.

Task Number 27: Preliminary Checks and Actions

The problem with a faulty photovoltaic refrigerator might be a simple fault. Advise the participants that if they carry out the preliminary checks they may save themselves time later on by finding a simple easily repairable fault.

Task Number 28: Fault Finding Charts

The participants must know the difference between these charts.

Task Number 29: Thermostat

The importance of waiting for the temperature to stabilise in between thermostat adjustments should be emphasised.

Task Number 30: Fuses

Ensure participants can identify where fuses are and when a fuse has blown.

Ensure participants are aware that fuses blow for a reason and they must find out that reason.

Task Number 31: Batteries

If time and facilities permit put a battery on charge under "field conditions" and explain the limitations (in time) of doing this.

Task Number 32: Wiring

During all fault finding and repair work participants should get into the habit of labelling wires prior to disconnecting them.

Explain what may cause a wiring fault (pests, taut wires, sharp corners, untied wiring looms).

Task Number 33: Photovoltaic Array

In the absence of expensive solar radiation measuring equipment (pyranometers or solarimeters) the only way of checking the performance of the solar array is by ensuring the sum of the short cirucit currents of the modules is equal to the short circuit current of the array (if the modules are connected in parallel as normal). This task must be clearly understood by participants.

Task 34: Compressor Controller

Compressor controllers can fail as a result of lightning induced surges or incorrect installation. It is important that participants recognise that if the correct voltage is at the input terminals and the thermostat terminals are shorted, a working compressor should run.

Task 35: Charge Regulator

It is a complicated task to check if a charge regulator is working correctly. It is however, necessary to replace the charge regulator if by elimination of other faults a faulty charge regulator is suspected.

Task 36: Condenser Fan

Only a few types of photovoltaic refrigerators require a condenser fan to achieve good heat loss for the condenser. A good flow of air when the condenser fan is operating should be apparent.

Task Number 37: Cooling Circuit

All participants should be familiar with refrigerant charging and cooling circuit repairs prior to commencing the photovoltaic refrigerator course. In some photovoltaic refrigerators the amount of refrigerant in the cooling circuit is critical and hence should be charged strictly in accordance with manufacturers' instructions.

Task Number 38: Compressor

REMEMBER: The participants should only change the compressor when they are sure that all steps in the fault finding chart have been carefully checked and they are sure the compressor is faulty.

F: MAINTENANCE RECORD KEEPING

Task Numbers 39/40: Fault Finding and Record Keeping

Ensure participants complete the maintenance records as they undertake the fault finding and repair.

Possible faults to introduce prior to the task are:

(a) incorrectly tilted array
(b) incorrect module interconnections
(c) wiring fault
(d) faulty battery (will not hold charge)
(e) blown fuses
(f) 12 volt battery on 24 volt system
(g) blown lamp on indicator panel
(h) badly set thermostat
(i) freezer/refrigerator thermal barrier removed
(j) freezer/refrigerator thermal barrier incorrectly positioned.

(k) a refrigerator with a refrigerant leak
(l) a faulty charge regulator
(m) a faulty compressor controller
(n) a stuck condenser fan (with discharged batteries)
(o) an overloaded refrigerator (with discharged batteries)
(p) a faulty thermostat
(q) a loose thermostat
(r) a shaded array (with discharged batteries)

Towards the end of the training course two complimentary faults could be introduced. For example a blown fuse and batteries connected with the wrong polarity.

G: USER TRAINING

Task Number 41: User Training

Ideally a whole day should be set aside for user training but if this is not possible participants should be aware that user training is as important as repair work and should take up most of a day when at a site.

5. AFTER THE COURSE

Ensure:

(a) the participants receive recognition for their achievement in completing the course
(b) they receive a WHO certificate for satisfactory completion
(c) they will have a proper tool kit when they return to their duties
(d) their EPI office will provide transport and payment for their repair work away from base when they resume their duties
(e) they know who to contact in case they cannot repair a PV refrigerator
(f) you write to the Cold Chain Unit of the EPI at WHO, Geneva 1211, Switzerland with any comments or suggestions to improve this course.

ANNEX 1

RECOMMENDED ONE WEEK TRAINING COURSE

RECOMMENDED ONE WEEK SOLAR REFRIGERATOR TRAINING PROGRAMME

MODULE 1: INTRODUCTION TO PHOTOVOLTAICS
- Refrigerator options at the rural health centre
- Advantages and disadvantages of each type
- When solar refrigerators should be used
- Principles of operation of a solar refrigerator
- The sun and solar energy

MODULE 2: SAFETY
- Instil in participants the need to consider safety at all times
- Batteries: acid and explosive fumes
- Electrical: potential dangers from shock and how to avoid them
- Mechanical: consideration to safe access to roof, transporting equipment and sharp edges

MODULE 3: SYSTEM FAMILIARISATION
- The system
  - getting to know your solar refrigerator
  - the installation
  - security
  - spare parts and tools
  - proper operation
  - meaning of indicator lights
- Operation procedures
  - temperature control
  - loading the refrigerator
  - freezing icepacks
  - when to use the on/off switch
- User maintenance
  - daily tasks
  - weekly tasks
  - monthly tasks
  - six-monthly tasks
- Repeat for different modules of solar refrigerators

MODULE 4: TOOLS AND INSTRUMENTATION
- The UNIPAC tool kit
- Special instruments for solar powered refrigerator maintenance
  - solarimeter
  - multimeter and current shunts

- hydrometer
- inclinometer

MODULE 5: BATTERIES
- Different types of batteries
- Best types for solar power (and why)
- How to measure the battery capacity
- How to charge a battery
- How to keep a battery in good condition

MODULE 6: OPERATION AND PERFORMANCE
- Determine the characteristics (by measurement) of:
  - solar photovoltaic module (Voc, Isc, IV curve)
  - the charge regulator (efficiency, cut-in/out voltages)
  - the battery
  - compressor (current drawn)
  - refrigerator (temperature distribution)

MODULE 7: PREVENTATIVE MAINTENANCE
- System checks
- Interpreting the log book
- Cleaning
- On going user training

MODULE 8: INTRODUCTION TO INSTALLING SYSTEMS
- Draw up list of components for the solar refrigerator
- Draw up list of tools, instruments and accesaries required
- Discuss logistics

MODULE 9: MOCK INSTALLATION
- Install a complete solar refrigerator under as realistic conditions as possible

MODULE 10: FAULT FINDING
- How to follow the procedures given in the technicians handbooks

- Identifying of symptoms
  - compressor not running
  - compressor running but refrigerator too warm
  - refrigerator too cold

- Types of faults
  - set up
  - electrical
  - component failure
  - cooling circuit
  - installation or site layout
  - system sizing/component incompatability

MODULE 11: FAULT FINDING TASKS
- Identifying faults introduced into refrigerators by the instructors

MODULE 12: REPAIRS
- Types of repairs
- Demonstration of repair work

MODULE 13: REPAIR TASKS
- Undertake repairs on faulty equipment as directed by instructor

MODULE 14: USER TRAINING
- Handing over a solar refrigerator ro a user after installation
- Informing user of:
  - the system
  - its operation
  - maintenance required

MODULE 15: REVIEW OF COURSE
- Invitation for participants to comment on course for the benefit of future participants

ANNEX 2

RECOMMENDED TWO WEEK TRAINING COURSE

RECOMMENDED TWO WEEK SOLAR REFRIGERATOR TRAINING PROGRAMME

'ODULE 1: WELCOME
- Registration
- Introduction to the facilitators
- The training programme
  - objectives
  - activity schedule
- Administration and logistics
  - per diem, transport, return tickets, etc.

.DULE 2: INTRODUCTION TO SOLAR REFRIGERATORS
- Refrigerator options at the rural health centre
- Advantages and disadvantages of each type
- When solar refrigerators should be used
- Principles of operation of a solar refrigerator

ODULE 3: PRINCIPLES OF PHOTOVOLTAICS
- The photovoltaic process
- The sun and solar energy
- Photovoltaic module characteristics
- Photovoltaic arrays and wiring connections

ODULE 4: SAFETY
- Instil in participants the need to consider safety all all times
- Batteries: acid and explosive fumes
- Electrical: potent dangers from shock and how to avoid them
- Mechanical: consideration to safe access to roof, transporting equipment, and sharp edges.

IODULE 5: SYSTEM FAMILIARISATION
- The system
  - getting to know your solar fridge
  - the installation
  - security
  - spare parts and tools
  - proper operation
  - meaning of indicator lights

- Operation procedures
  - temperature control
  - loading the refrigerator
  - freezing icepacks
  - when to use the on/off switch

- User maintenance
  - daily tasks
  - weekly tasks
  - monthly tasks
  - six-monthly tasks

- Repeat for different modules of solar refrigerators

MODULE 6: TOOLS AND INSTRUMENTATION
- The UNIPAC tool kit
- Special instruments for solar powered refrigerator maintenance
  - solarimeter
  - multimeter and current shunts
  - hydrometer
  - inclinometer

MODULE 7: OPERATION AND PERFORMANCE
- Determine the characteristics (by measurement) of:
  - solar photovoltaic module (Voc, ISc, IV curve)
  - the charge regulator (efficiency, cutin/out voltages)
  - the Battery
  - compressor (current drawn)
  - refrigerator (temperature distribution)

MODULE 8: BATTERIES
- Different types of batteries
- Best types for solar power (and why)
- How to measure the battery capacity
- How to charge a battery
- How to keep a battery in good condition

MODULE 9: BATTERY MEASUREMENTS
- Measure battery voltage and capacity (with hydrometer)

MODULE 10: PREVENTATIVE MAINTENANCE (Use Technicians Handbook)
- System checks
- Interpreting the log book
- Cleaning
- On going user training

MODULE 11: PREVENTATIVE MAINTENANCE TASKS
- Conduct preventative maintenance system checks

MODULE 12: INTRODUCTION TO INSTALLING SYSTEMS
- Draw up list of components for the solar refrigerator
- Draw up list of tools, instruments and accesaries required
- Discuss logistics

MODULE 13: TRIAL INSTALLATION
- Install a complet solar refrigerator under as realistic conditions as possible

MODULE 14: MAINTENANCE TASKS (Continued)
- Conduct preventative maintenance tasks on system installed in Module 13. (Also allows some time for completing installation if necessary)

MODULE 15: FAULT FINDING
- How to follow the procedures given in the technicians handbooks
  - compressor not running
  - compressor running but refrigerator too warm
  - refrigerator too cold
- Types of faults
  - set up
  - electrical
  - component failure
  - cooling circuit
  - installation or site layout
  - system sizing/component incompatability

MODULE 16: FAULT FINDING TASKS
- Identifying faults introduced into refrigerators by the instructors

MODULE 17: FAULT FINDING TASKS (on a different refrigerator model)
- Repeat module 16 on a different refrigerator model

MODULE 18: REPAIRS
- Types of repairs
- Demonstration of repair work

MODULE 19: REPAIR TASKS
- Undertake repairs on faulting equipment as directed by instructor

MODULE 20: USER TRAINING
- Handing over a solar refrigerator ro a user after installation
- Informing user of:
  - the system
  - its operation
  - maintenance required

MODULE 21: INSTALLATION PREPARATION
- Prepare for field installation
  - check refrigerator is complete
  - collect together all tools and instrumentation
  - prepare brackets, battery boxes, or any fixtures that may need fabricating

MODULE 22: FIELD INSTALLATION OF A SOLAR REFRIGERATOR
- Installation of a complete system under field conditions

MODULE 23: USER TRAINING UNDER FIELD CONDITIONS
- Participants train the users of the newly installed solar refrigerator

MODULE 24: REVIEW OF COURSE
- Invitation for participants to comment on course for the benefit of future participants

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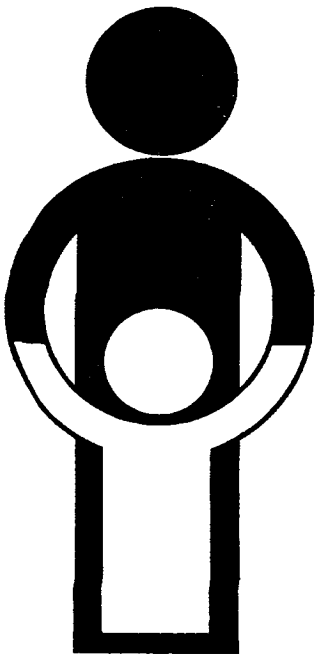

WORLD HEALTH ORGANIZATION ORGANISATION MONDIALE DE LA SANTE

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