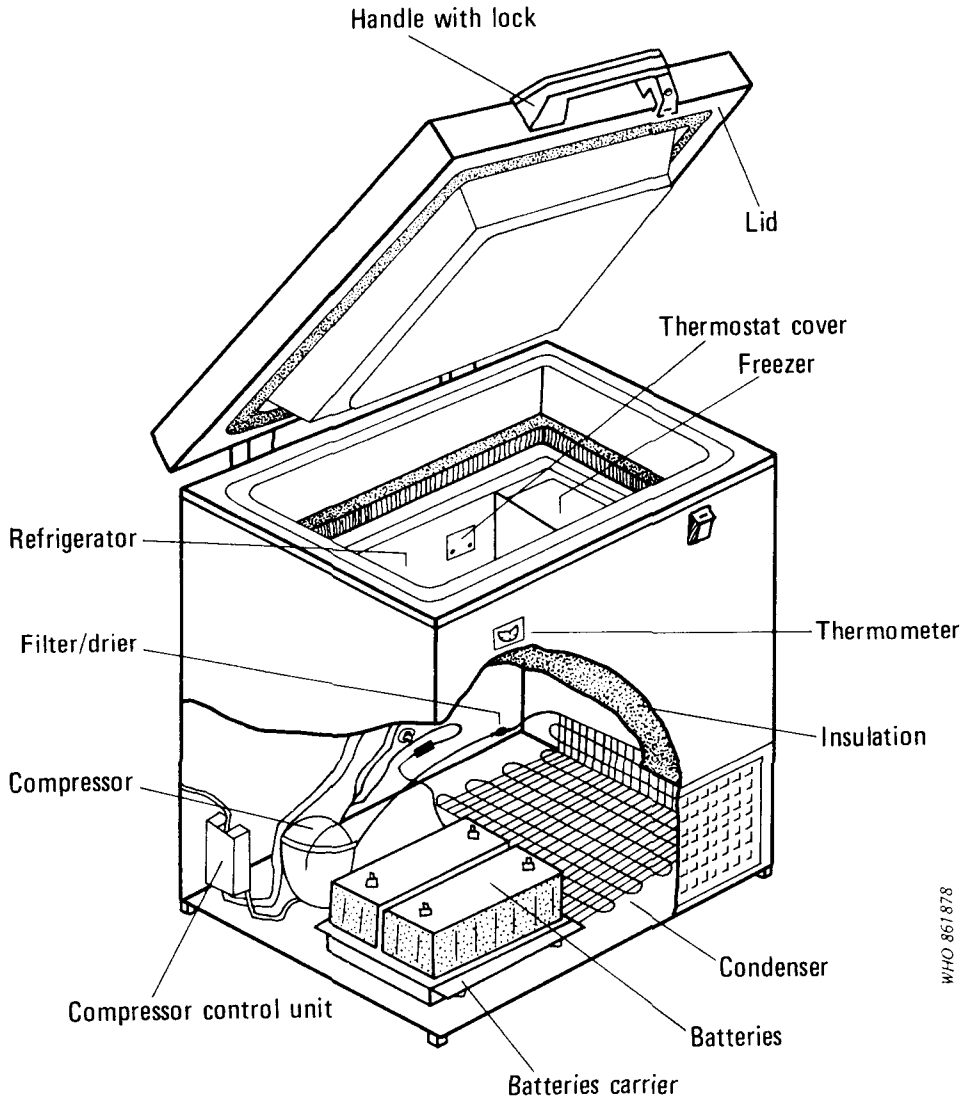
TECHNICIAN'S HANDBOOK FOR

COMPRESSION REFRIGERATORS

PART H

FAULT FINDING AND REPAIR OF PHOTOVOLTAIC REFRIGERATORS



Ordering Code: WHO/EPI/TECH.HB/H Rev. 1
(Printed March 1988)

This document is included in the EPI Cold Chain Series of Training Documents and is produced and distributed by:
Expanded Programme on Immunization
World Health Organization
1211 Geneva 27, Switzerland

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)

WORLD HEALTH ORGANIZATION

EXPANDED PROGRAMME ON IMMUNIZATION

FAULT FINDING AND REPAIR

OF

PHOTOVOLTAIC REFRIGERATORS

A TECHNICIANS' HANDBOOK

FAULT FINDING AND REPAIR OF PHOTOVOLTAIC REFRIGERATORS

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*Revised February 1988

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PART 1: INTRODUCTION

A: SCOPE

This handbook is published by the World Health Organization Expanded Programme on Immunization.

It is a general handbook for use by service and repair technicians responsible for the maintenance and repair of solar photovoltaic powered refrigerators. These refrigerators are used for storing vaccines and freezing ice-packs in health clinics.

This handbook applies specifically to 12 or 24 volt stand-alone photovoltaic powered refrigerators and should not be used for any other type of refrigerator. Stand-alone means here that the solar array does not power any other device (e.g., lights) and the refrigerator is powered only from the solar array.

The handbook should be considered a supplement to Maintenance and Repair Manuals suplied by the solar refrigerator manufacturer which define maintenance and repair activities specific to their model of refrigerator.

Each technician should have their own copy of this handbook. This handbook is one in a series of Technicians handbooks for medical refrigerators and makes reference to other WHO handbooks on compression refrigerators. A complete list is shown on the inside front cover of this document. You should ensure you have copies of these also.

In addition to this handbook two others are available for Solar Photovoltaic Refrigerators:

- A **USERS HANDBOOK** for Photovoltaic Refrigerators
- An **INSTALLATION HANDBOOK** for Photovoltaic Refrigerators

You should ensure you have copies of the USERS HANDBOOK in case a user responsible for a solar refrigerator you visit does not have one.

It is not necessary for you to have a copy of the INSTALLATION HANDBOOK unless you are responsible for installing or relocating solar refrigerators in addition to servicing and repairing them.

B: HOW A SOLAR PHOTOVOLTAIC REFRIGERATOR WORKS

A photovoltaic refrigerator is similar to an ordinary compressor refrigerator except that the compressor is powered from direct current (d.c.) electricity supplied from a solar array. A photovoltaic refrigerator system comprises the following principal parts:

- The solar photovoltaic array containing solar cells which convert sunlight into direct current (DC) electricity. It has no moving parts and is a highly reliable component.

- Batteries which are used to store electricity for periods when there is no sunlight.

- A charge regulator (an electronic unit) which is used to prevent the batteries from being damaged by too much electricity from the array or from too much electricity being drawn by the refrigerator.

- A compressor which is a sealed unit.

- A compressor controller which:

  - converts the d.c. current electricity provided from the array and/or batteries into a form which will drive the compressor

  - prevents damage to the compressor if overloaded, and also protects the batteries against deep discharge.

These parts are connected together to make:

- A Solar Powered Battery Charger, and

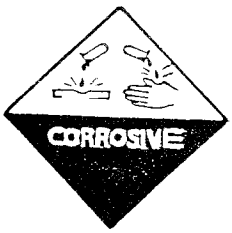
- A Battery Powered Refrigerator,

which when combined, becomes a refrigerator powered by sunlight which we call a Solar Photovoltaic Refrigerator (and can be called a Solar Refrigerator, Photovoltaic Refrigerator or PV Refrigerator).

C: SAFETY CONSIDERATIONS

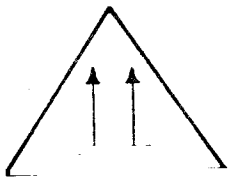
TECHNICIANS and USERS **MUST ALWAYS** take the following precautions when transporting, handling, installing, maintaining and using photovoltaic refrigerator systems:

BATTERIES



BATTERIES CONTAIN ACID WHICH CAN CAUSE ACID BURNS ON SKIN OR BLINDNESS IF IN CONTACT WITH THE EYE. The acid will also damage clothes.

- avoid spilling or splashing battery acid especially in transport.
- always keep the batteries upright.
- carry batteries carefully (do not carry them on your head).



- attach batteries when transporting them.
- always use a funnel or plastic bottle with a spout to add distilled water.
- do not let children touch them.

BATTERIES ALSO GIVE OFF GASES WHICH ARE EXPLOSIVE:

- make sure that the containers provided are well ventilated and that they are placed in a well ventilated room.
- keep naked flames and lighted cigarettes well away from batteries.
- always switch off power from the array and to the refrigerator before disconnecting the batteries (to prevent sparks). Provide well ventilated containers if special containers were not provided when installed.
- keep uninsulated tools and metal jewellery away from batteries as they may cause a spark if they come into contact with the terminals.

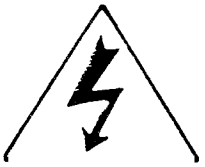
SOLAR ARRAY

Photovoltaic modules have a glass cover; always carry and transport them carefully.

There is a risk of receiving an electric shock from a solar array.

Always take the following precautions when undertaking servicing or repair work:

- cover the solar array with a sheet or cloth.
- use insulated tools.



Solar arrays are often mounted on a roof but must, however, be cleaned regularly. There is a risk of falling from a roof.

- make sure that the user has an easy and safe way of access to clean the array.
- always use good ladders and position them firmly
- use crawling boards when walking on roofs

FIRST AID MEASURES

- if battery acid splashes in your eye, wash your eye IMMEDIATELY with lots of clean water,
- if battery acid gets on your skin, wash IMMEDIATELY with soap and water.
- if you fall from the roof or a high place, do not move until professional help arrives.
- make sure that someone at the health center knows how to treat persons suffering from electrical shock.
- carry a first aid kit.

PART 2: MAINTENANCE AND SERVICING WORK

A. PREPARATION

(a) Before starting service or repair work make sure you are familiar with the location of the components of the solar refrigerator. (See pages 6 and 7)

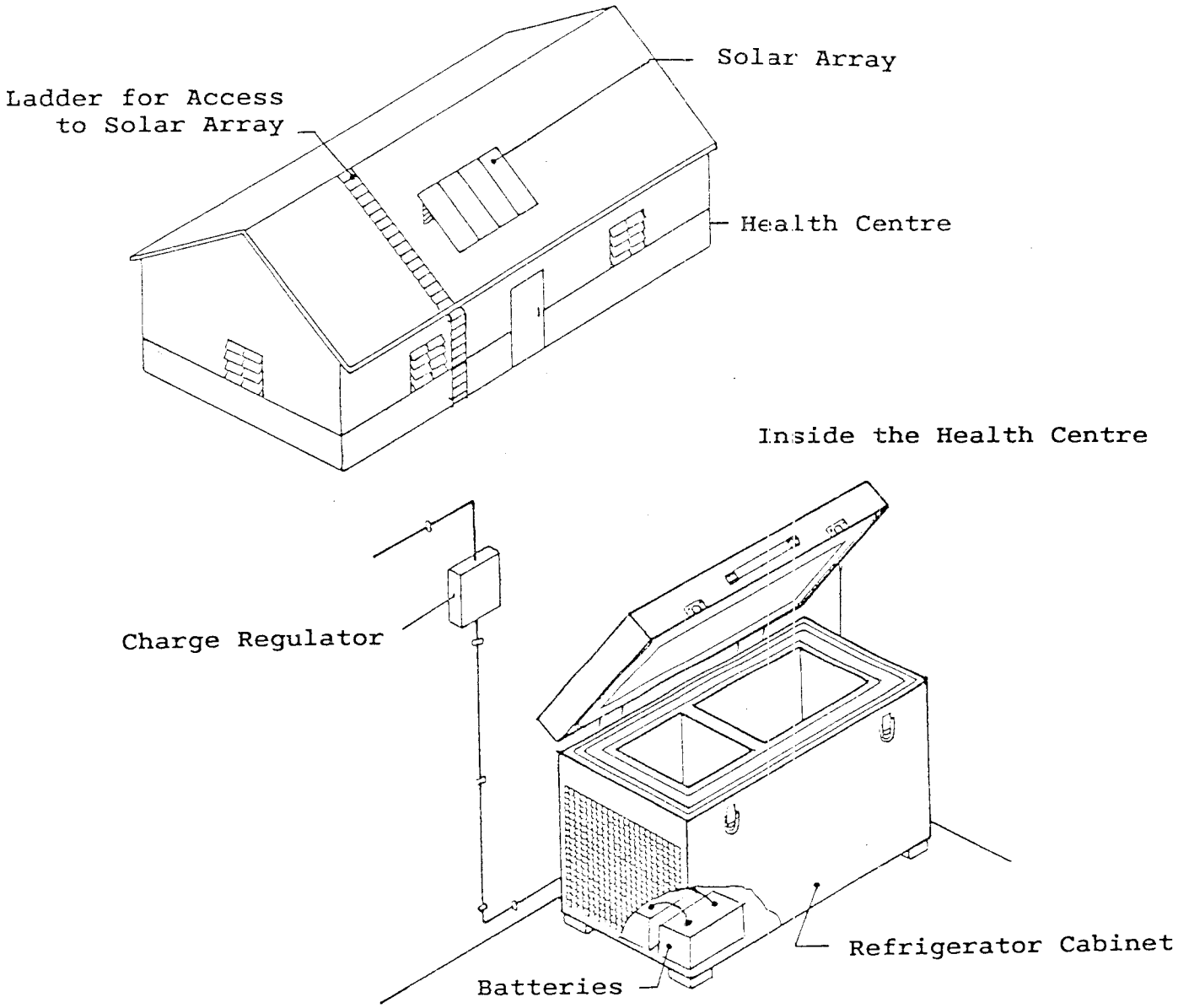
(b) Layouts of components in some commonly used solar refrigerators are shown in Annex 1. Make sure you also have the manufacturer's maintenance and repair manual for the refrigerator.

(c) **REMEMBER:**

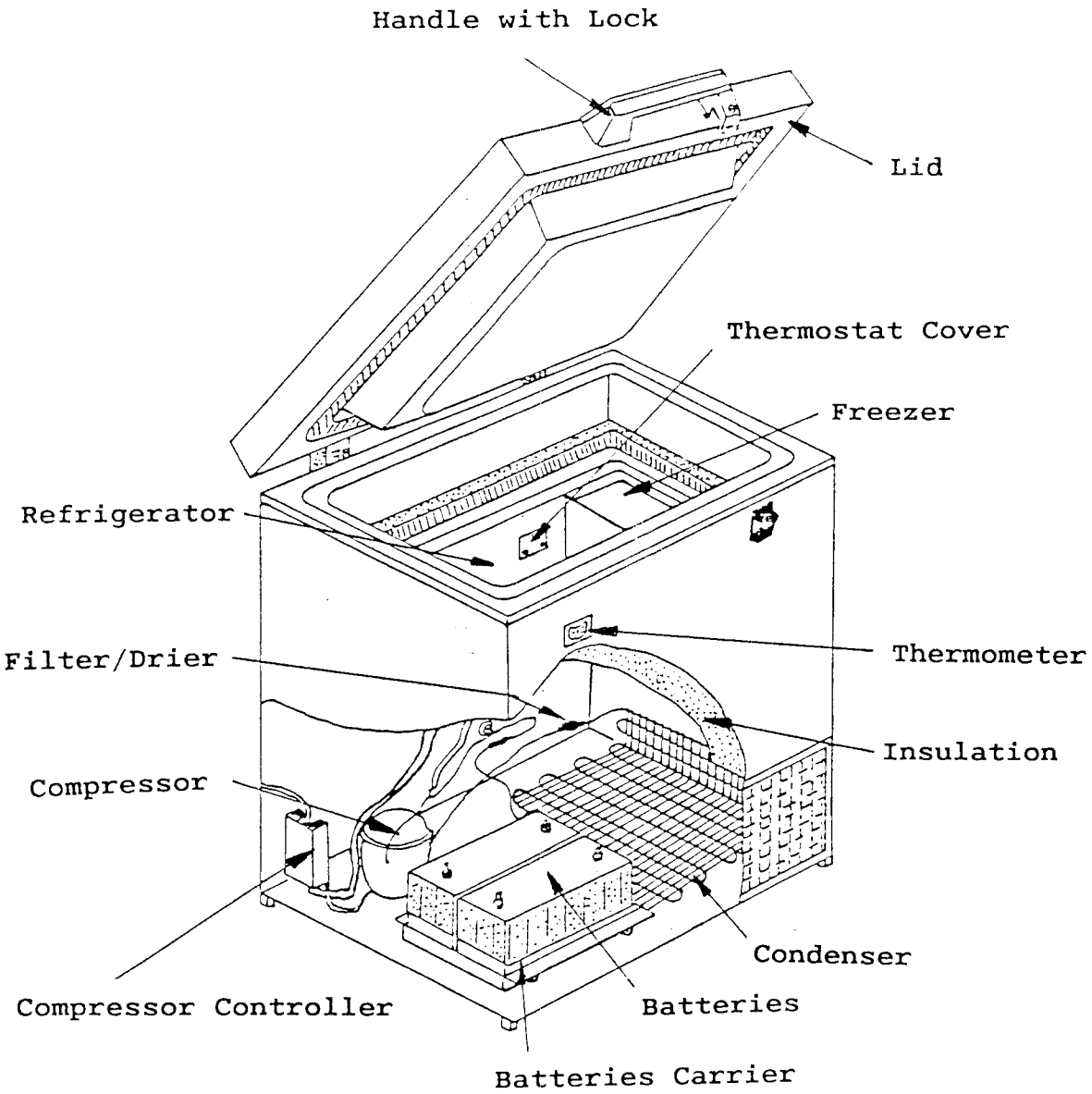
There is a risk of electric shock from the solar array.

There is the risk of acid burn or explosion from batteries.

ENSURE THAT YOU TAKE THE SAFETY PRECAUTIONS DESCRIBED ON PAGES 3 AND 4.



COMPONENTS OF THE POWER SUPPLY OF
A SOLAR PHOTOVOLTAIC REFRIGERATOR



COMPONENTS OF A TYPICAL SOLAR
PHOTOVOLTAIC REFRIGERATOR

B: HOW TO MEASURE

1. TEMPERATURE

Temperature is measured with thermometers. There are many different types of thermometers. The choice of thermometer should depend upon the degree of accuracy, the reliability, the response rate, the temperature range required and budget available.

1.1. Refrigerator and freezer temperatures

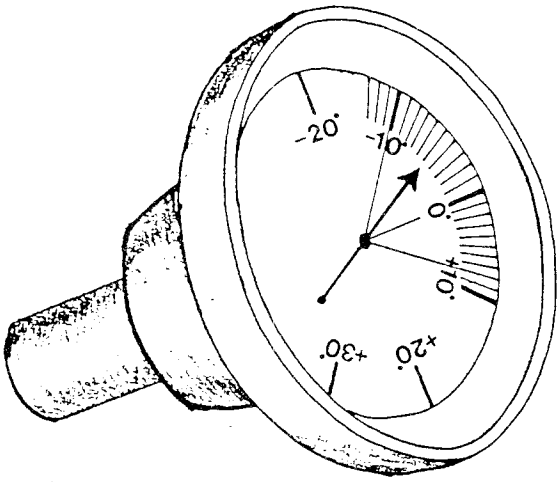
Temperatures are usually measured in the refrigerator and freezer compartments of photovoltaic refrigerators with low-cost, simple, low-precision bi-metal thermometers. This type of thermometer is robust, stable and simple to read.

It is easy to check the accuracy of a bi-metal thermometer by removing it from the freezer or refrigerator compartment and placing it alongside another thermometer for several minutes at room temperature. If the thermometers give the same reading, then most likely they are reading correctly.

Thermometers used in the compartments of refrigerators frequently have red and/or green ranges marked on the scale which indicate the correct temperature range at which the compartments should be operating.

The procedure is to read the temperature directly from the scale, which should be marked in degrees Centigrade (^{o}C).

REMEMBER: THE VACCINE COMPARTMENT OF A REFRIGERATOR SHOULD ALWAYS BE BETWEEN $0^{o}C$ AND $8^{o}C$.



TYPICAL REFRIGERATOR THERMOMETER

1.2. Battery temperature

The temperature of the electrolyte in the battery cells must be measured with a mercury in glass thermometer. The thermometer should have a range of not more than 0°C to 8°C; otherwise it will not be sufficiently accurate. The thermometer should be encased in a metal shell to protect it from breakage.

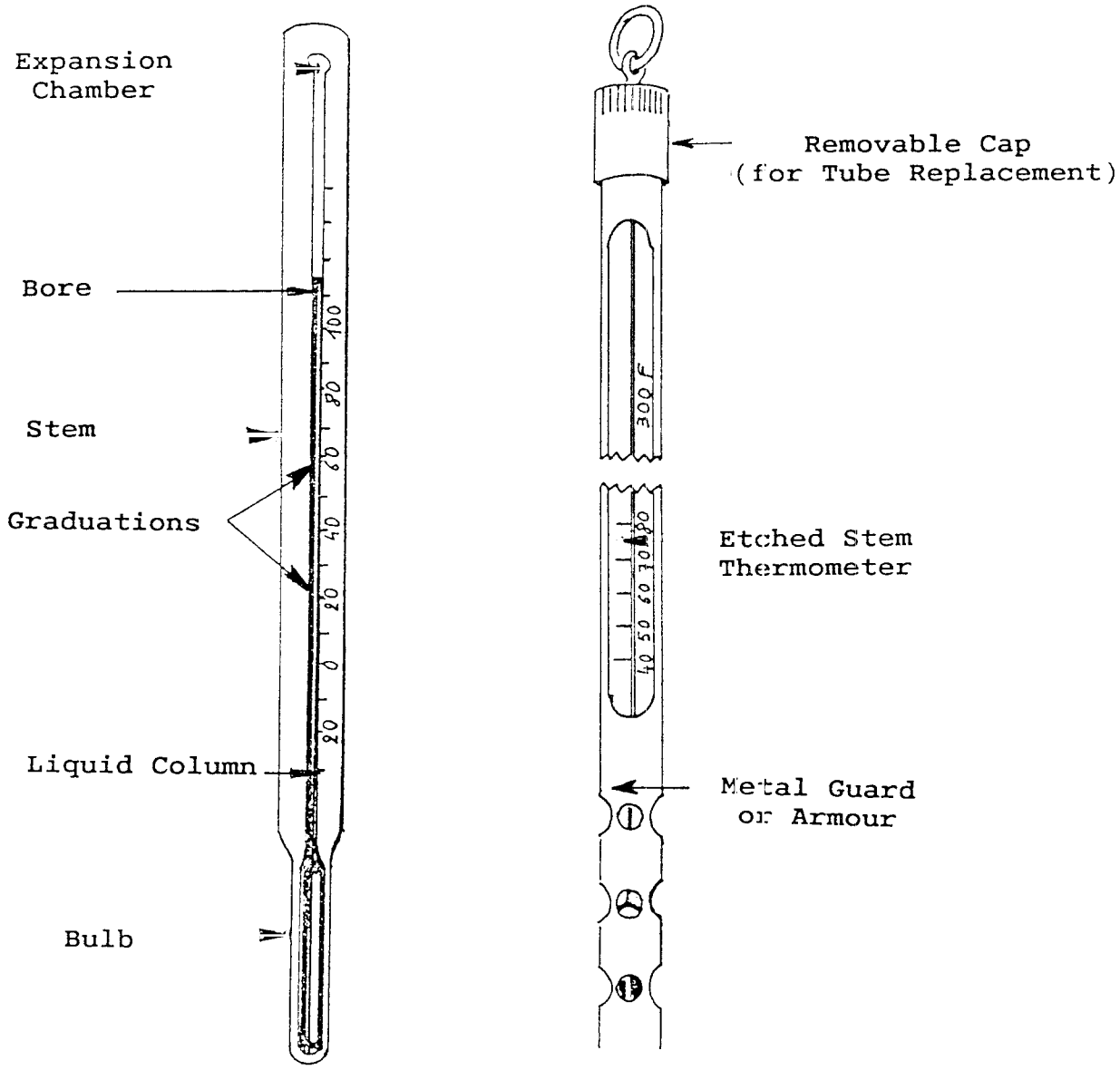
The temperature is read directly from the scale on the thermometer and should be in Centigrade (°C).

To take a measurement:

1. Put the bulb of the thermometer in the electrolyte and hold it in the electrolyte carefully for about 30 seconds. (You must be careful not to press the thermometer bulb against the metal plates in the battery because they are delicate and easily damaged.)

2. Read the temperature directly from the thermometer.

3. After using the thermometer, wash it thoroughly in cool water. Do not use hot water, you may break the thermometer.



THERMOMETER TO MEASURE BATTERY ELECTROLYTE TEMPERATURE

2. ELECTRICITY

2.1 General

When doing fault finding and repairs on photovoltaic refrigerator systems, it is necessary to measure the voltage, current and resistance at various points in the circuit.

The type of voltage measured is DC (Direct Current) volts and not AC (Alternating Current) volts as is normally observed in the electrical supply of houses.

The type of current measured is DC (Direct Current) amps and not AC (Alternating Current) amps as is normally observed in the electrical supply of houses.

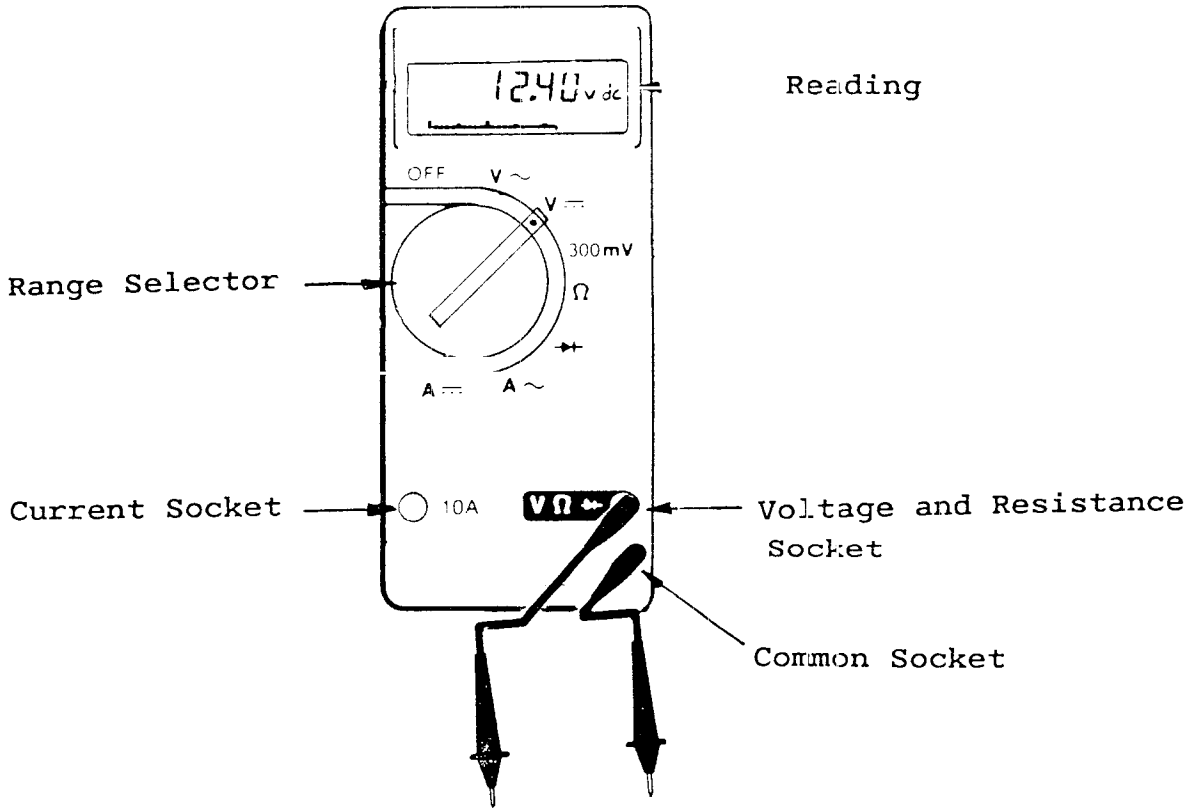
The instrument which is found in the UNIPAC maintenance kit supplied to repair technicians is a multimeter. This multimeter has the capacity to measure DC volts, AC volts, resistance, AC current and DC current. It has a digital display and when set correctly is very easy to read. The accuracy of the instrument provided in the maintenance kit is sufficient for all fault finding and repair tasks you may need to do.

There are three basic rules which MUST BE OBSERVED when measuring electricity.

1. Voltage is always measured by putting the probes of the multimeter between (across) two points in the circuit. The meter is connected in PARALLEL with the circuit which you are measuring.

2. Current is always measured by disconnecting the two points where you wish to measure current and putting the probe between the two disconnected points of the circuit. The meter is connected in SERIES with the circuit you are measuring.

3. Resistance can only be measured when the power has been removed from the circuit.



TYPICAL DIGITAL MULTIMETER

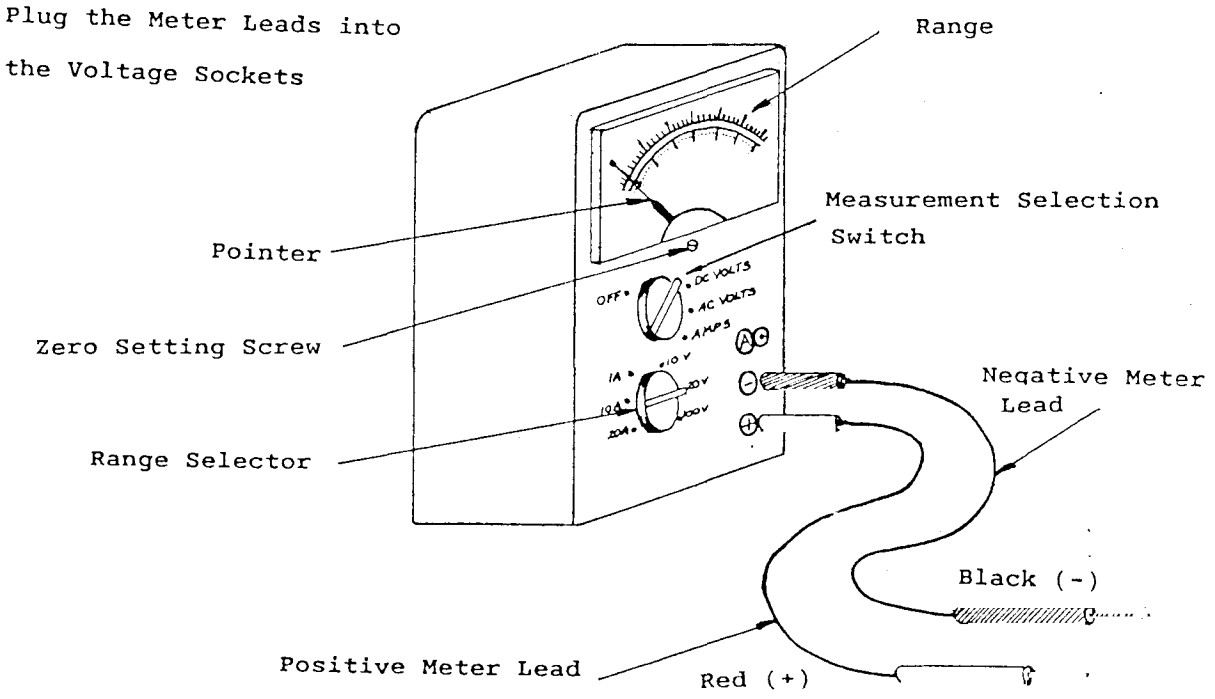
2.2. Measuring Voltage

Use a multimeter or DC Voltmeter to measure DC voltage in the following manner:

1. Set the multimeter to measure DC voltage.

2. Set the range on the meter so that it includes the voltage that you expect to measure. For example, if you expect that the voltage you are going to measure will be about 12V, set the range to 0-20V.

3. Plug the meter leads into the meter sockets. Make sure that the negative (black or -) lead goes into the negative (or 'common') socket, and that the positive (red or +) lead goes into the positive socket.



4. Make sure that the meter is switched ON and that it has charged batteries inside. Some types of multimeter are switched on automatically when you turn the measurement selection knob.

5. (a) **If the meter is an analogue type** as shown on page 13, make sure that the needle points to 0 volts when the metal tips of the meter leads are not touching anything. If the needle does not point to 0 volts, adjust the zero setting screw until it does. Look at the scale with it straight in front of you so that you can read it accurately. Do not look from an angle.

   (b) **If the meter is a digital type**, make sure it reads 0.0 Volts when you touch the meter leads together.

6. Touch the metal tips of the meter leads to the electric terminals across which you want to measure the voltage. Be careful not to short-circuit the terminals by touching both the terminals with the same probe. If you short-circuit the terminal large currents may flow and cause damage to components.

7. Read the voltage from the meter. Make sure that you read from the correct range on the scale.

8. **SWITCH THE METER OFF** after you have finished taking the measurement. If you do not do this, the batteries may become drained.

2.3. Measuring Current

2.3.1. Use a multimeter or DC ammeter to measure current in the following manner:

1. Set the multimeter to measure current. The setting on the selection knob may be labelled "current", "amperes", "amps" or just "A".

2. Set the range so that it includes the current that you expect to measure. If you expect the current to be about 5A, set the range to 0-10A.

3. Plug the meter leads into the correct sockets in the meter. Make sure that the negative (black or -) lead goes into the negative (or "common") socket, and that the positive (red or +) lead goes into the current (A) socket.

4. Make sure that the meter is switched ON and that it has batteries inside. Some types of meter are switched on automatically when you turn the measurement selection knob.

5. If the meter is an analogue meter as shown above, make sure that the needle points to 0 amps when the metal tips of thermometer leads are not touching anything. If the needle does not point at 0 amps, adjust the zero setting screw until it does. Look at the scale with it straight in front of you so that you can read it accurately. Do not look from an angle.

6. Switch OFF the circuit. Disconnect at one terminal the wire through which you want to measure the current.

7. If you have disconnected the positive wire, connect it to the black (common) meter lead. If you disconnected the negative wire, connect it to the red lead. To make the connection use a crocodile clip to hold the lead and the wire together.

8. Touch the metal tip of the other meter lead to the terminal from which you disconnected the wire.

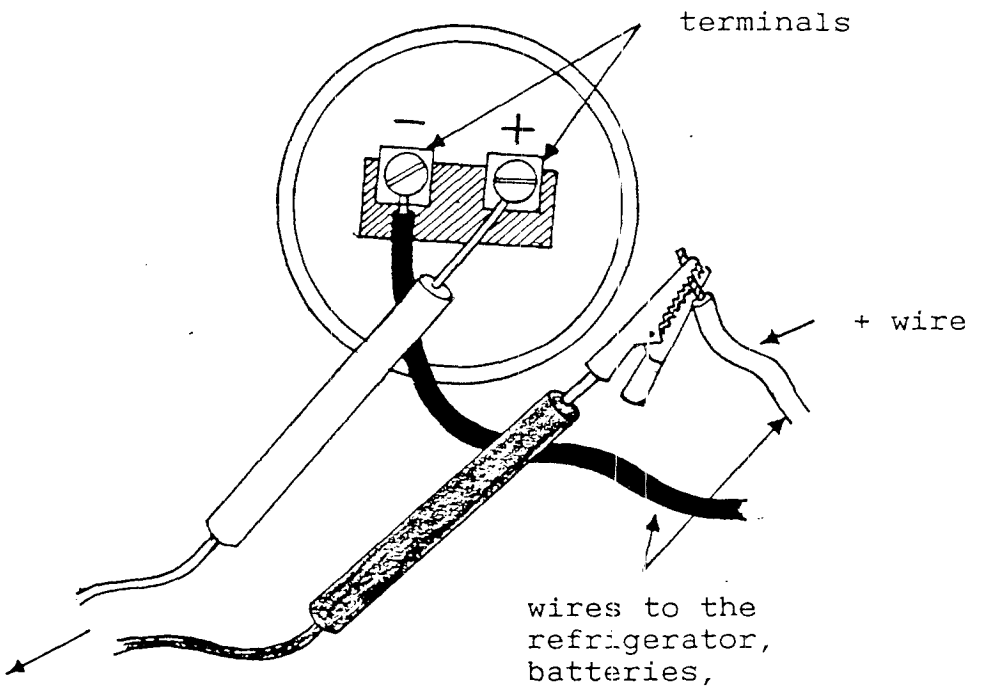
9. Switch ON the circuit. **Be careful** not to make a short-circuit between the terminals by accidently touching both terminals.

10. Note down the reading. Make sure you read from the correct range on the scale if the meter is an anologue ammeter.

11. **SWITCH THE METER OFF** after you have finished taking the measurement so that you do not drain the batteries.

12. **Switch OFF the circuit** and **reconnect the wire** to its terminal.

13. Switch back ON the circuit.



MEASURING CURRENT

2.3.2. Using a current shunt with a multimeter or millivolt meter to measure current.

1. Switch OFF the system. Disconnect the wire at the terminal where you want to measure the current.

2. Select a current range that includes the current you expect to measure. Connect the shunt between the disconnected wire and the terminal, and connect the probes of the multimeter to each terminal of the current shunt.

3. Select the millivolt range on the multimeter which includes the millivolt range identified on the current shunt, and proceed to measure the millivolts across the current shunt as shown below.

4. The value read on the meter in millivolts is converted to current (amperes) by multiplying this number by the number of amperes which are equivalent to 1 millivolt as indicated on the current shunt.

Example:

Current shunt is marked 20A. 200mV

Hence 200 mV is measured if 20 Amps is flowing the wire

So, 1 mV is measured if 0.1 Amps is flowing in the wire
(We divide by 200 to find the equivalant of 1 mV).

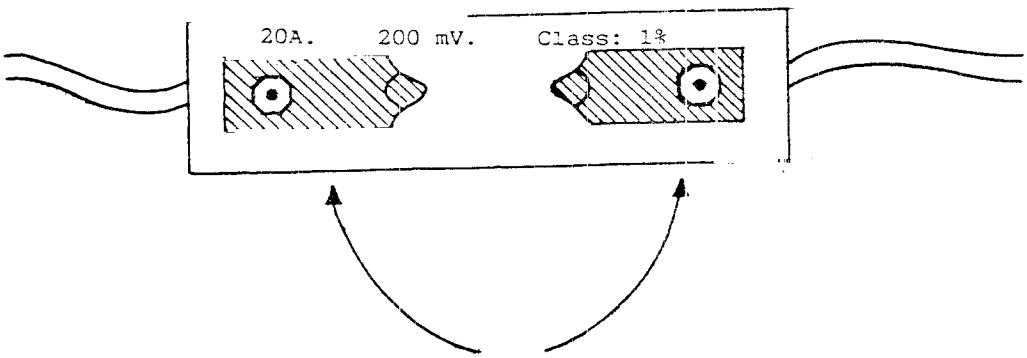
So, 1 mV = 0.1 Amp

If, for example the reading on multimeter is 55 mV

Across the shunt connections we have 55 mV (millivolts)

Therefore in the circuit we have 55 x 0.1 Amps = 5.5 Amps

Current in circuit = 5.5 Amps



Measure the millivolts between these metal contacts

USING A CURRENT SHUNT

3. RESISTANCE

In fault finding and repairs of photovoltaic refrigerator systems it is necessary to measure the electrical resistance of the compressor windings and to determine if these windings are adequately insulated. The multimeter provided in the UNIPAC maintenance kit (or any other multimeter) is adequate for these tasks if the following procedure is observed:

1. Switch OFF the refrigerator.

2. Disconnect the wires from the positive terminal of the battery.

3. Set the multimeter to measure resistance.

4. (a) **If you want to measure small values of resistance**, set the range on the multimeter to 'one ohm' (which may be indicated 1).

   (b) **If you want to measure high values of resistance** set the range to 100,000 ohms or the largest range of resistance on your multimeter.

5. Switch ON the meter, plug in the meter leads to the correct sockets in the meter, and hold the tips of the probes together.

6. If you have an analogue meter adjust the meter so that the resistance between the probes reads zero. If you are unable to adjust the meter so that it reads zero, this means that the batteries in the meter are discharged and should be changed.

7. Hold the probes between the two points in the circuit where you want to measure resistance.

8. Read the resistance value directly on the meter if you have a digital meter, or on the appropriate scale if you have an analogue meter.

9. **SWITCH THE METER METER OFF** when you have finished.

4: STATE OF CHARGE OF BATTERIES

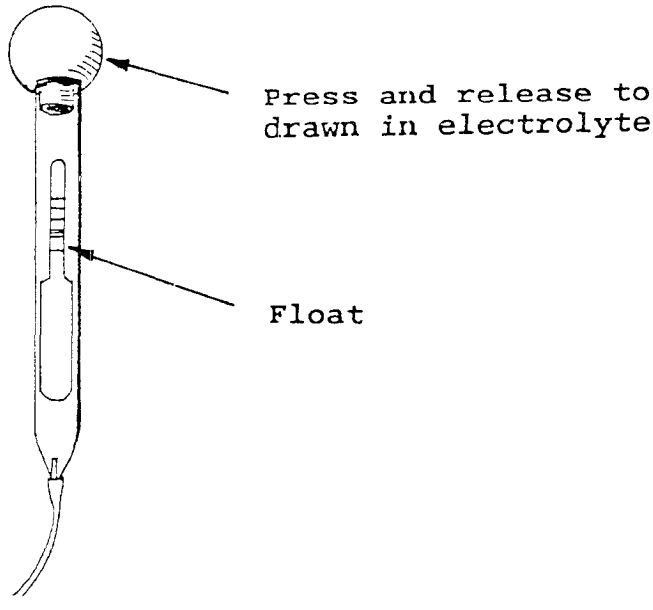
The amount of energy stored in a battery at any time is called the "State of Charge". The "State of Charge" can be approximately estimated by measuring the voltage across the battery terminals when the battery is being discharged under known conditions of current and temperature and is the only way to measure the State of Charge of sealed batteries.

The State of Charge of lead-acid batteries which are not sealed can also be determined by measuring the specific gravity of the electrolyte (the acid and water mixture in the battery) and the temperature of the battery. This is the most practical way to measure the State of Charge of batteries which are not sealed.

The following procedure explains how to do this:

1. Top up the battery with clean distilled water to the maximum level indicated on the battery.

2. Leave the battery for one hour to allow the acid and water to mix.



HYDROMETER FOR MEASURING THE SPECIFIC GRAVITY

3. Insert the hydrometer into the electrolyte in a cell of the battery, squeeze the rubber bulb, and draw enough electrolyte into the hydrometer to make the indicator float freely.

4. Record the Specific Gravity reading as indicated by the float and adjacent scale.

5. Return the electrolyte to the same cell in the battery being careful not to spill it.

6. Insert a thermometer (mercury in glass type) into the battery so that the bulb of the thermometer is covered in electrolyte but not touching the battery plates. Wait until the temperature shown has stabilised, and record the electrolyte temperature.

7. Using the table below, which shows the temperature correction to specific gravity, record the correction value.

Temperature Corrections to Specific Gravity Readings (to 15 °C)

Electrolyte Temperature °C	Correction to Specific Gravity
55	+0.028
50	+0.024
45	+0.021
40	+0.017
35	+0.014
30	+0.010
25	+0.007
20	+0.003
15	0.000
10	-0.003
5	-0.007
0	-0.010

TEMPERATURE CORRECTION TABLE

Example:

For 30 degrees Centigrade the correction is +.010

Add this value to the reading obtained from the hydrometer.

The answer gives the Specific Gravity of the electrolyte if at 15 degrees Centigrade.

8. Convert the Specific Gravity into a measurement of the State of Charge by looking at the table below.

Specific Gravity at 15 Degrees C vs State of Charge

Specific Gravity	State of Charge %
1.225	100
1.216	90
1.207	80
1.198	70
1.189	60
1.180	50
1.171	40
1.162	30
1.153	20
1.144	10
1.135	0

STATE OF CHARGE TABLE

Example:

A Specific Gravity of 1.202 corresponds to a State of Charge of between 70 and 80%.

5: TILT AND DIRECTION OF PHOTOVOLTAIC ARRAY

5.1. General

The tilt of a photovoltaic array is the angle created between the surface of the array and the horizontal.

The tilt should be approximately equal to the latitude of the site, except in cases where the latitude is less than 5^{o} either North or South, in which case the tilt should be maintained at 5^{o}.

A line normal to the surface of the array points out the direction of a photovoltaic array.

A photovoltaic array should always slope towards the South when mounted in the Northern hemisphere and always slope towards the North when mounted in the Southern hemisphere.

For photovoltaic refrigerator installations, neither the tilt or direction needs to be measured with any great accuracy, but both should be correct within 10 degrees.

Array Tilt may be measured with an inclinometer, which is an instrument designed especially to measure slope or a spirit level and ruler or tape measure and some simple calculations. These methods are described in the INSTALLATION HANDBOOK for Photovoltaic Refrigerators.

The best method however is to use a **TEMPLATE** (triangle) and **SPIRIT LEVEL** as described on the next page.

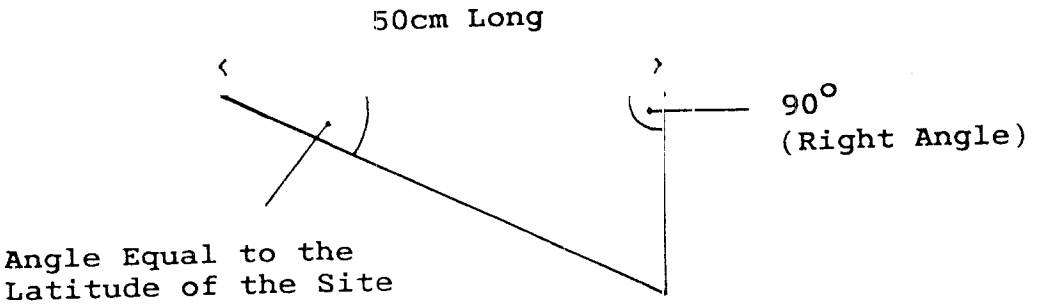
Array Direction may be measured with a compass.

5.2 How to measure tilt with a template and spirit level.

1. If you do not already know, find out the approximate latitude of the place where the refrigerator is installed.

2. Cut out a triangle from cardboard if you do not plan to use it often, or from wood if you have several solar arrays to check. (DO NOT MAKE IT FROM METAL). The triangle should have:

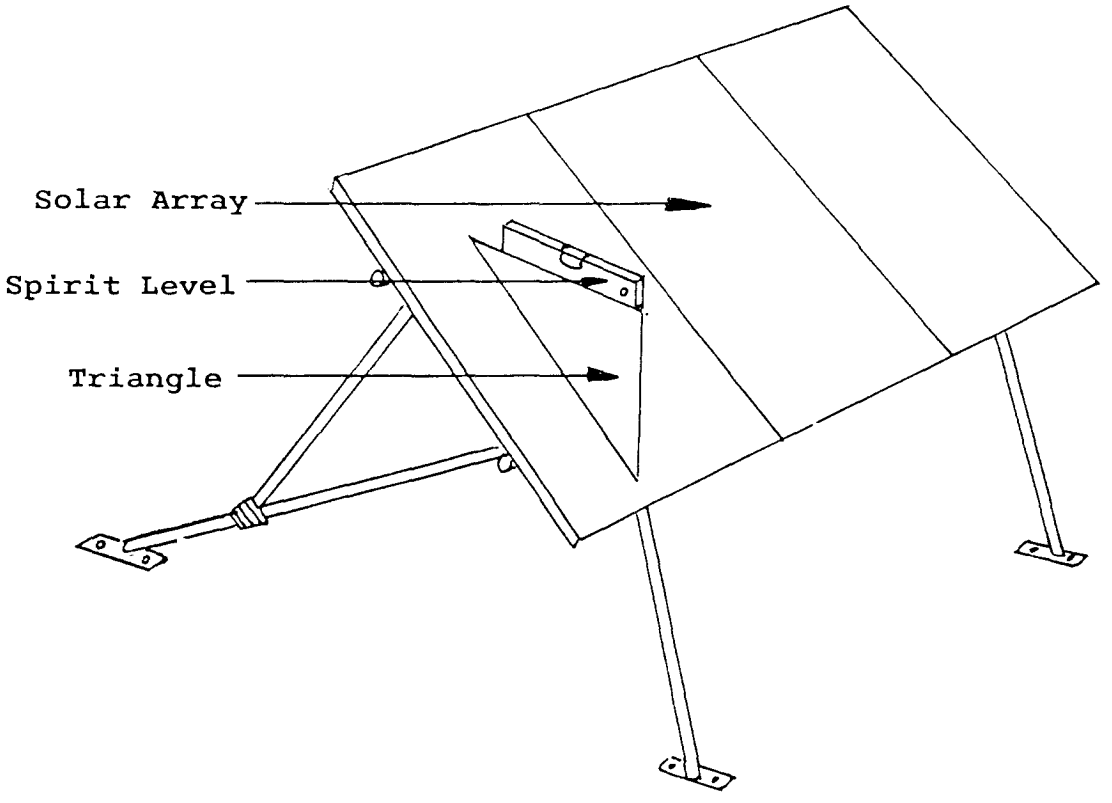
   - one side 50 cms long
   - one angle of 90 degrees, and
   - one angle equal to the latitude where the refrigerator is installed.



TRIANGLE TO MEASURE TILT

3. Place the triangle on the surface of the array so that it is parallel to the sloping sides of the array and so that the angle which is equal to the latitude points away from the equator.

4. Place a spirit level on the upper edge of the triangle. If the bubble in the level indicator shows that it is level, then the photovoltaic array is set at an angle which is equal to the latitude.



TRIANGLE AND SPIRIT LEVEL TO MEASURE TILT

5.3 How to measure direction

The only practical method to measure direction of the array with sufficient accuracy is with a compass. The procedure is as follows:

1. Place the cardboard or wooden template which you used to check the tilt of the array on the surface of a module so that it is parallel to the sloping sides of the module and so that the angle on the template which is equal to the latitude points away from the equator.

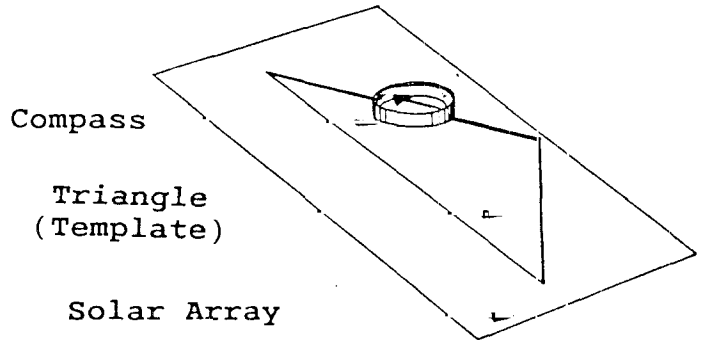
2. Place the compass horizontally on the top edge of the template.

3. **The magnetic needle on the compass should point along the line of the edge of the template if the array slopes (faces) towards the equator as it should.** Also note that:

   - The magnetic needle will point down the slope of the panel. If your refrigerator is installed in the southern hemisphere

   - The magnetic needle will point up the slope of the panel if your refrigerator installation is in the Northern hemisphere

4. The direction of the array only needs to be positioned to within an accuracy of about 10^{o} based on measurements with a compass.



MEASURING THE DIRECTION OF THE ARRAY WITH A COMPASS AND TEMPLATE (TRIANGLE)

6: OPEN AND SHORT CIRCUIT MEASUREMENTS ON THE PHOTOVOLTAIC ARRAY

Two simple measurements are possible to show whether a photovoltaic array is operating correctly. These are the measurement of **SHORT CIRCUIT CURRENT** and **OPEN CIRCUIT VOLTAGE**.

Measurements are made as follows:

6.1. Using a multimeter or voltmeter to measure open-circuit voltage (Voc)

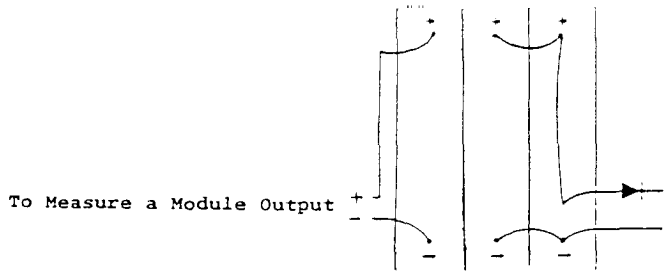
1. To test the solar array or one of the solar modules in the array, you need to be able to measure the open-circuit voltage (Voc).

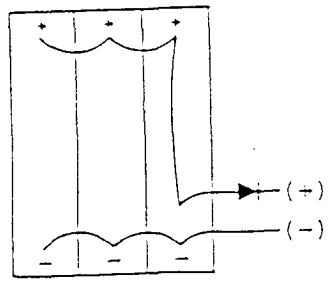
2. Measure Voc at around 12 noon on a very sunny day.

3. Voc is the voltage across the two output terminals when no electrical current is flowing. So you must disconnect one wire from the terminals. If you are measuring Voc for the solar array, disconnect one solar array output wire from the terminal box. If you are measuring Voc for one of the solar modules, disconnect the module from the solar array at the module box.

4. After you have disconnected the output wires, measure the voltage across the solar array or module output terminals.

5. Reconnect the wires to the correct terminals after you have finished.





6.2. Using a multimeter or ammeter to measure short-circuit current (Isc)

1. To test the solar array or one of the modules you need to be able to measure the short-circuit current (Isc).

2. Measure Isc at around 12 noon on a very clear sunny day and during a long period of uninterrupted sunshine (no clouds).

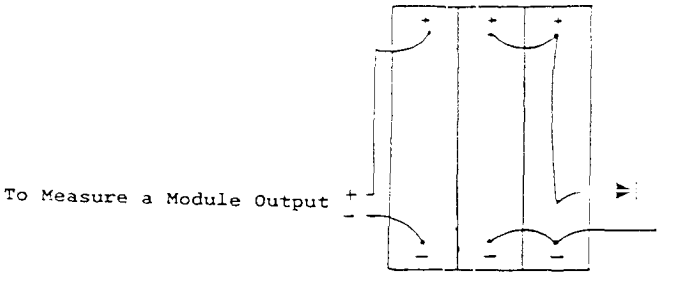
3. Isc is the electrical current flowing between the two output terminals when they are short-circuited by the multimeter or a shunt. You must disconnect one output wire from the terminals when you make this measurement.

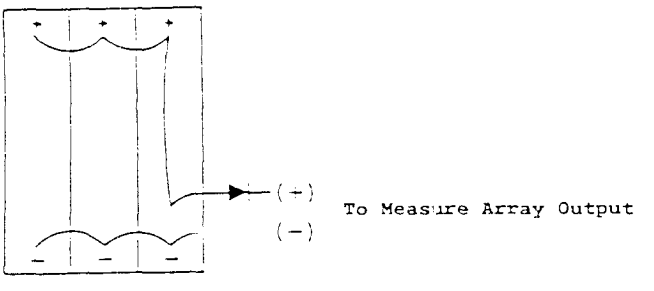
   - **If you are measuring Isc of the solar array**, disconnect a solar array output wire from the array junction box.

   - **If you are measuring Isc of one of the solar modules** disconnect the module from the solar array at the module junction box.

4. After you have disconnected the output wires, measure the current between the solar array (or module) output terminals.

5. Reconnect the output wires to the correct terminals after you have finished.





C: MAINTENANCE AND SERVICE TASKS

C.1. Introduction

The service tasks described here should all be done every time you visit a solar refrigerator.

BEFORE YOU START THE SERVICE TASKS DO THE FOLLOWING:

a) **Check that the temperature of the refrigerator is normal** (between +0°C and +8°C) before you start the service.

b) **Ask the person in charge** of the refrigerator if there have been any problems with it. Inspect the log book and temperature record sheets to see if a problem is indicated.

c) **Enter into the refrigerator log book** the date of your visit, and at the end of your visit write down the tasks done and measurements taken.

WHEN YOU FINISH THE SERVICE TASKS:

a) **Check that he temperature of the refrigerator is normal.**

b) **Check all components to ensure the installation is safe and secure.** There should be no loose components or bare wires and the batteries should be in a secure place out of reach of children.

C.2. Cleaning the Solar Array

You should clean the surface of the solar array whenever you visit the health post.

(a) Clean the array in the early morning or in the evening when it is not in strong sunlight.

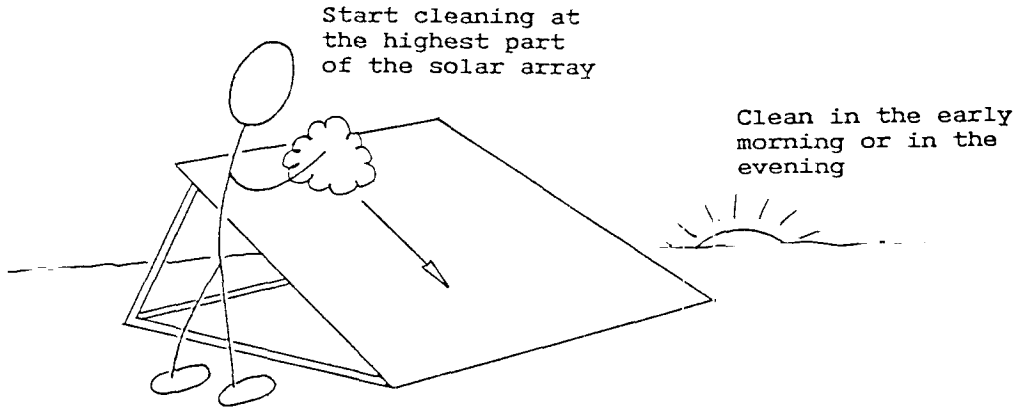
(b) If the solar array is on the roof you will need a ladder to reach it. Be very careful when working on the roof. Check that access to the array is secure and safe for the user. If not make it safe.

(c) Use a clean, soft cloth wetted with water.

(d) Wipe the surface of the solar array gently, starting at the highest point and working down to the lowest point. Make sure that all the rust is removed.

(e) Do not stand on the solar array, or lean heavily on it, as this may cause damage.

(f) Make sure that the person in charge of the refrigerator knows that he/she should clean the solar array every week.



CLEANING THE SOLAR ARRAY

C.3. Preventing Solar Array Shadowing

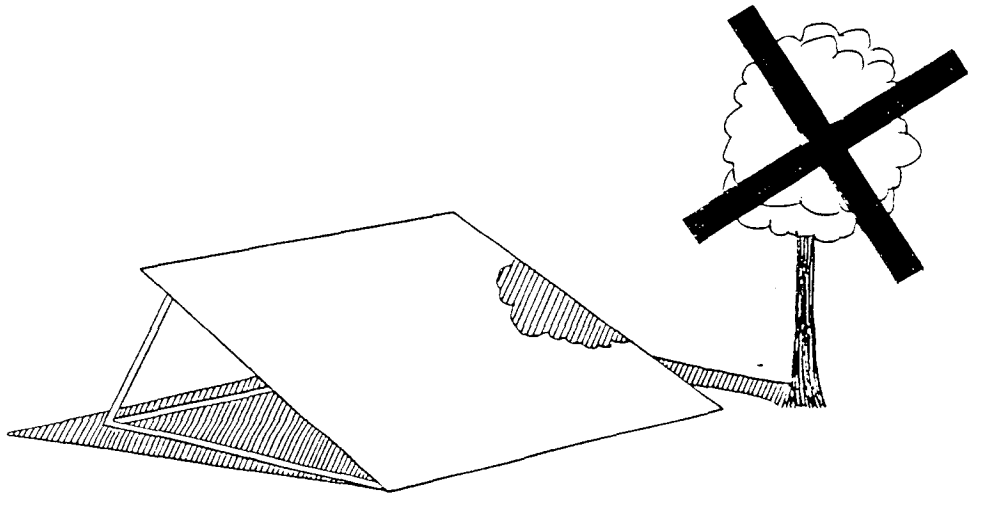
The solar array will not work properly if it is shaded during the day.

(a) Check that the solar array is not shaded on any part. This should be checked at approximately 8.00 a.m., 12.00 noon and 4.00 p.m. on the day that you visit the health centre.

(b) Cut back bushes and trees that may start to shade the solar array between 8.00 a.m. and 4.00 p.m. Trees and bushes which cause shading only before 8.00 a.m. or after 4.00 p.m. need not be cut down.

(c) Make sure that nobody has put anything in front of the solar array that may block the sunshine falling on it.

(d) If new buildings cause shadows to fall on the array it may be necessary to move the array. Consult the person in charge of the refrigerator as to where it may be moved and make arrangements to do this.



CUT BACK BUSHES AND TREES THAT MAY HAVE STARTED TO SHADE THE SOLAR ARRAY

C.4. Inspection of Electric Cables

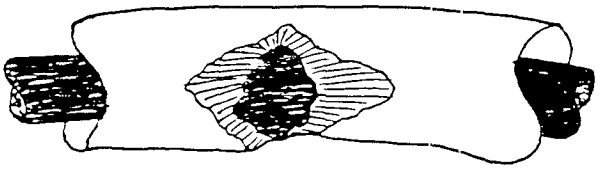
Electric cables run between the charge regulator and the solar array, the batteries, and the refrigerator. These cables should be inspected every time you visit an installation to make sure that they are in good condition.

(a) Check the connections on the cables which go to the battery terminals, the solar array terminals, the refrigerator terminals (on the compressor controller and on the refrigerator socket), and the charge regulator terminal strip. The connections should be clean and tight. If they are loose, tighten them. If they are dirty, take them off and clean them with a wire brush before connecting them tightly.

(b) Follow each cable to its end, wherever possible. Look for the following types of damage: the cable has been cut, the insulation is worn or the insulation has been eaten away leaving the metal inside showing.

(c) If the cable is damaged, it must be replaced. Follow the instructions on Page 72 to replace the cable.

(d) If there is evidence of animals eating the cables it may be necessary to use armoured cable.



REPLACE DAMAGED CABLES

C.5. Checking the Performance of the Solar Array

NOTE 1: It is only necessary to check the performance of the solar array if you believe there may be a problem with it. For example if the user reports or the daily record sheets indicate that the "Do Not Freeze Ice Packs" or "Refrigerator Disconnected" indicator lights are often lit.

NOTE 2: You should only check the solar array on a day when the sky is clear (no clouds) and at about midday.

NOTE 3: Before disconnecting any cables label them so you know where to reconnect them.

1. Clean the solar array (See page 30).

2. Check that the solar array is not shaded (See page 31).

3. Disconnect from the solar array, the array cable that leads to the charge regulator.

4. Measure the short circuit current of the solar array (See page 28).

5. Measure the open circuit voltage of the solar array (See page 27). It should be 17-20 volts for a 12 volt system.

6. Disconnect one module from the array and measure the short circuit current of the module (See page 28).

   For 12 volt systems the short circuit current in the solar array should approximately be equal to the current in a module multiplied by the number of modules (to within 15%). (For example if the short circuit of one module is 2.5 Amps and there are four modules in the array then the solar array short circuit should be approximately 2.5 x 4 = 10 Amps.

7. If the array current and voltage do appear correct reconnect the module and array cable.

8. If the solar array short circuit current or open current voltage does not appear correct then there may be a fault with a module or the way the modules are connected together. Refer to the fault finding task D7 on Page 58 to find out what action is required to repair the fault.

C.6. Battery Maintenance

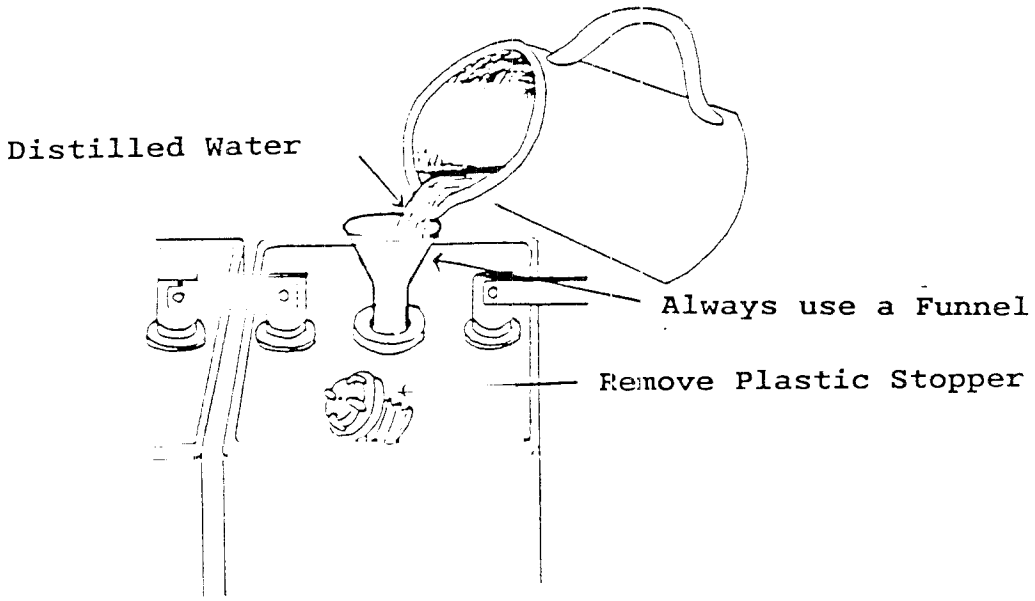
WARNING:
- KEEP NAKED FLAMES AWAY FROM BATTERIES AS EXPLOSIVE GASES MAY BE PRESENT.
- THE LIQUID IN BATTERIES IS CORROSIVE, KEEP OFF SKIN AND AWAY FROM EYES. AVOID CONTACT WITH CLOTHES.

(a) Switch the refrigerator OFF.

(b) Disconnect the battery cables at the battery labelling the cables clearly so you know where to reconnect them.

(c) Measure, and note in the log book, the voltage of each battery and the of the batteries combined.

(d) If the batteries are not sealed, they will have plastic stoppers in a row on the top. Remove each stopper one by one and see if the metal plates inside are covered by liquid. If the tops of the metal plates are above the liquid level, add distilled water until they are completely covered or to the level indicated in the battery. Replace the stopper. Do this for every compartment in each battery.



ADDING WATER TO THE BATTERIES

(e) If there are non-sealed batteries, measure and note in the log book the electrolyte specific gravities and temperatures and determine the state of charge of the batteries (see page 20).

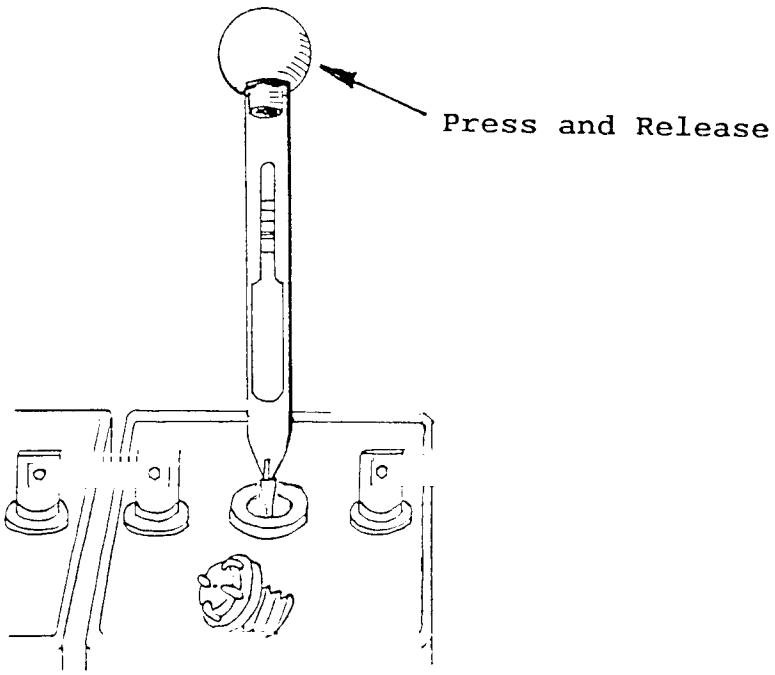
(f) Check the ages of the batteries from the log book or from marks on them. If they are more than 5 years old, order and fit a replacement as soon as possible.

(g) Check the wiring connections to the batteries. If the wiring connections are loose, tighten them. If the connections are very dirty or corroded, loosen them and clean them with a wire brush before tightening them again.

(h) Apply petroleum grease to the terminals.

(i) Reconnect the battery cables ensuring they are in the correct position.

(j) Switch ON the refrigerator.



CHECKING THE SPECIFIC GRAVITY

C.7. Defrosting the Refrigerator

If the ice in the freezer compartment of the refrigerator is more than 5mm (1/4 inch) thick, defrost the refrigerator.

(a) Move the vaccine into another refrigerator or store it in a cold box with ice-packs.

(b) Switch the refrigerator OFF.

(c) Open the lid or door of the refrigerator and freezer compartment.

(d) As soon as it is possible to remove ice with your fingers, do so. Do not remove ice with knives or other sharp objects.

(e) Wipe the freezer compartment dry after all the ice has been removed.

(f) Clean the refrigerator inside with soap and water, then dry it carefully. Never use scouring powder, steel wool or abrasive cleaners. Remember to clean the lid or door sealing gasket and put some talcum powder on it to prevent it sticking to the lid.

(g) Switch the refrigerator back ON.

(h) Wait until the inside temperature has fallen to between $0^{\circ}C$ and $+8^{\circ}C$.

(i) Put the vaccine back inside and remember to close the lid/door again.

(j) Defrosting must be carried out as quickly as possible to prevent damage to the vaccine.

(k) Tell the person in charge of the refrigerator to defrost it regularly. It should be defrosted when the ice in the freezer compartment becomes more than 5mm (1/4 inch) thick.

C.8. Cleaning the Refrigerator

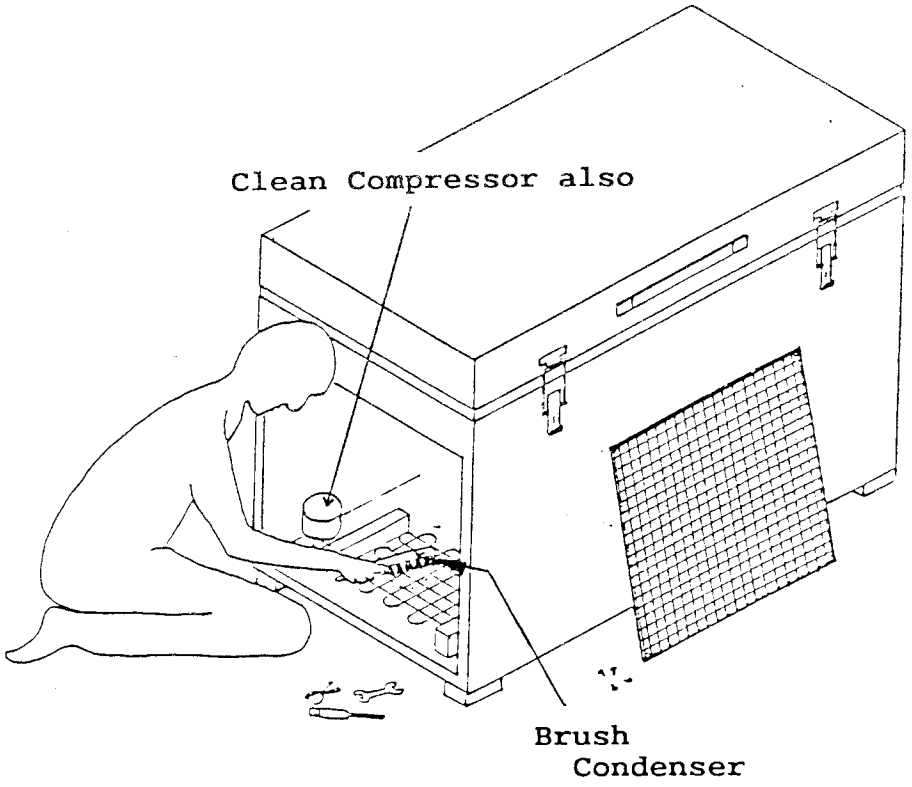
(a) Switch OFF the refrigerator.

(b) Clean the surfaces of the condenser and compressor using a soft brush. The condenser and compressor must be clean or the refrigerator will not work properly.

(c) If the condenser is fan-assisted make sure the fan rotates freely and brush dirt away from the fan and fan motor.

(d) Switch the refrigerator ON again.

(e) Wipe clean the outside of the refrigerator using soap and water.



CLEAN THE CONDENSER AND COMPRESSOR

PART 3: FAULT FINDING AND REPAIR

A.1. INTRODUCTION

(a) **Before starting the fault finding, make sure you are familiar with the location of the components of a solar refrigerator.**

A typical solar refrigerator layout is shown on Pages 6 and 7.

Annex 1 shows the location of components on the most commonly used solar refrigerators.

(b) Each installed solar refrigerator will have a USER who was trained by the installation technician on how to operate and care for the refrigerator. It is your responsibility when at a health centre to make sure that the user is operating and maintaining the refrigerator correctly.

(c) Each refrigerator you are responsible for should have a Daily Record Sheet, which is filled in by the user. **Look at the DAILY RECORD SHEET before starting fault finding. It may help you identify the source of problems.**

(d) Each solar refrigerator technician should keep a Maintenance Log Book. **It is important that you note in the MAINTENANCE LOG BOOK, visits to sites,** results of **checks made, observations made and repairs made** (together with a fully detailed **list of parts used,** and parts provided to the users).

CHECK DAILY RECORD SHEETS

NOTE IN MAINTENANCE LOG BOOK

B: HOW TO FIND THE FAULT

The instructions in this part of the handbook advise you on what to do if the refrigerator compartments are not maintaining the correct internal temperatures. The temperatures should be more than $0^{o}C$ and less than $8^{o}C$ in the refrigerator compartment, and less than $0^{o}C$ in the freezer compartment.

If the temperatures are not within these ranges you should follow this fault finding procedure. FOLLOW THIS PROCEDURE CAREFULLY. DO NOT TRY TO TAKE SHORT CUTS. DO NOT MISS OUT ANY TASKS IN THE PROCEDURE.

B.1. Determine the Symptoms

Identify the symptoms of the fault by finding out if:

(a) **The refrigerator is too warm** (above $8^{o}C$) **and the compressor is NOT running.** You may determine if the compressor is running by:

- listening for the motor noise from the compressor, (but make sure that it is not the noise of the fan, if fitted),
- touching the compressor to see if it is vibrating, and
- touching the compressor to see if it is hot.

(b) **The refrigerator is too warm** (above $8^{o}C$) **and the compressor is running** at times.

(c) **The refrigerator is too cold.**

B.2. Carry Out Preliminary Checks

These preliminary checks are to be done in order to verify that the user had performed all of the user checks and tasks.

IT IS IMPORTANT that:

(a) You be sure that you have correctly identified the symptoms of the fault.

(b) You always start with the first step listed under each symptom and proceed in order through all the steps.

(c) If, after doing ALL the CHECKS and ACTIONS, the refrigerator is still not working properly you move the vaccine into another refrigerator or cold box, and

(d) **PERFORM THE CHECKS AND ACTIONS (LISTED ON THE NEXT PAGE) UNDER THE SYMPTOM OF THE FAULT YOU HAVE IDENTIFIED.**

SYMPTOM - The refrigerator is too warm (above 8°C) and the compressor is NOT running:

(a) Check that it is switched ON. If not, then switch it ON.

(b) Do ALL the USER maintenance checks listed on pages 44 to 46.

(c) Check that the thermostat setting has NOT been changed by someone to a warmer setting. (Applies only if the thermostat can be adjusted). If it has, then reset it at the initial position.

(d) Check that the fuse has not blown. If it has, replace it. If the fuse blows for a second time proceed step by step through the Fault Finding Chart on Page 41.

SYMPTOM - The refrigerator is too warm (above 8°C) and the compressor is running at times:

(a) Do ALL the USER maintenance checks listed on pages 44 to 46.

(b) Check that the thermostat setting has not been changed by someone to a warmer setting. (Applies only if the thermostat can be adjusted). Reset it at the initial position.

(c) If the refrigerator compartment temperature is still more than 8°C, proceed step by step through the Fault Finding Chart on page 42.

SYMPTOM - The refrigerator is too cold:

REMEMBER VACCINE IS DESTROYED IF FROZEN.

(a) Some refrigerators have a movable separator between the freezer compartment and the refrigerator compartment. If it has been removed, incorrectly positioned, or is partly broken, replace it or repair it.

(b) Check that the thermostat setting has not been changed by someone to a colder setting. (Applies only if the thermostat fitted can be adjusted). Reset it at the initial position and wait for the temperature in the refrigerator compartment to warm up. (This may take some time).

(c) If the refrigerator compartment temperature is still less than 0°C. Proceed to the Fault Finding Chart on Page 43.

C: FAULT FINDING CHARTS

CHART No. 1

SYMPTOM - Refrigerator is TOO WARM and compressor is NOT running

Check out the following possible faults by first looking at the fault at the top of the chart. If this is found not to be the fault then move to the next fault in the direction of the arrows.

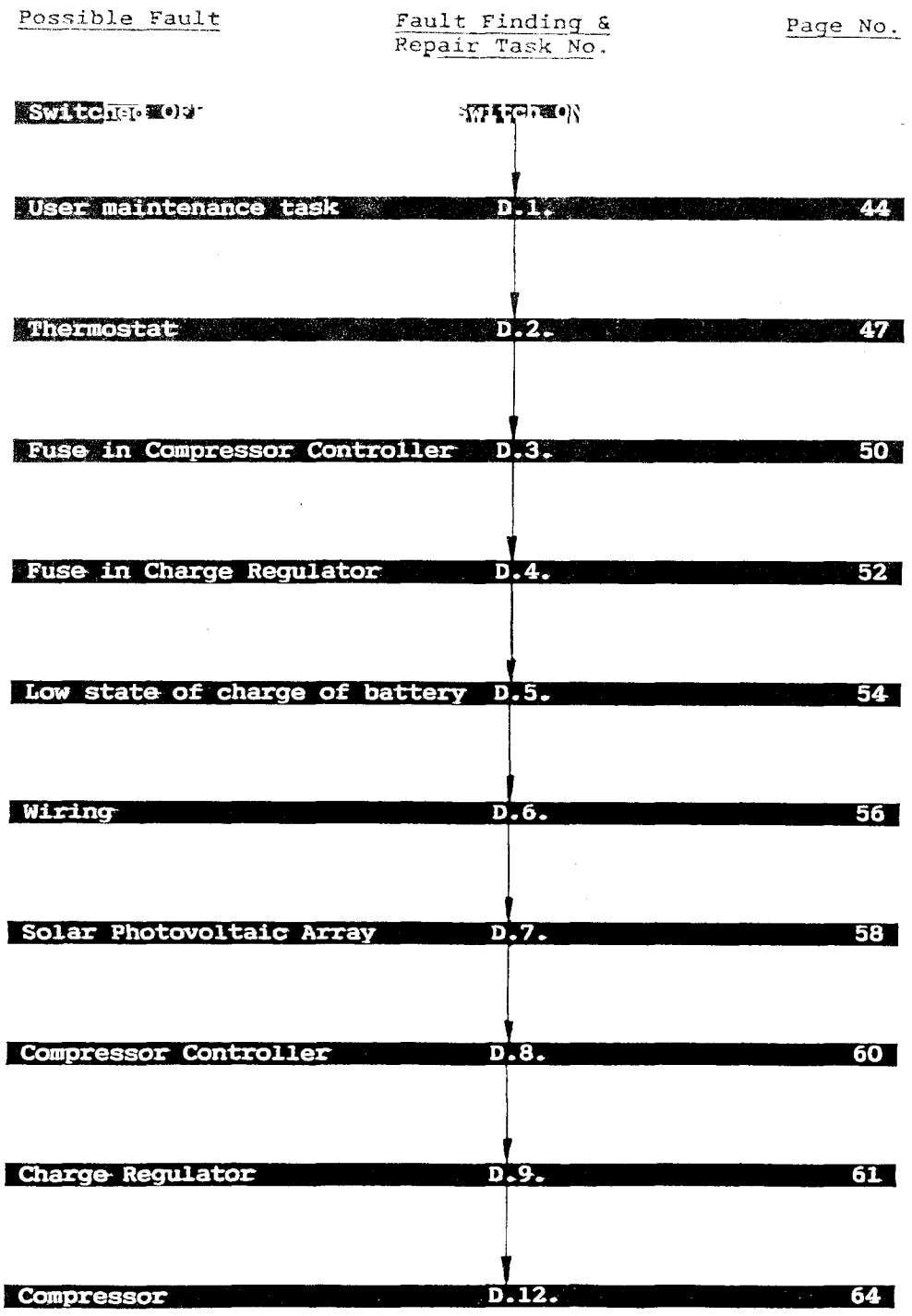


CHART No. 2

SYMPTOM - Refrigerator is TOO WARM (above 8°C) and the compressor is running at times.

Check out the following possible faults by first looking at the fault at the top of the chart. If this is found not to be the fault then move to the next fault in the direction of the arrows.

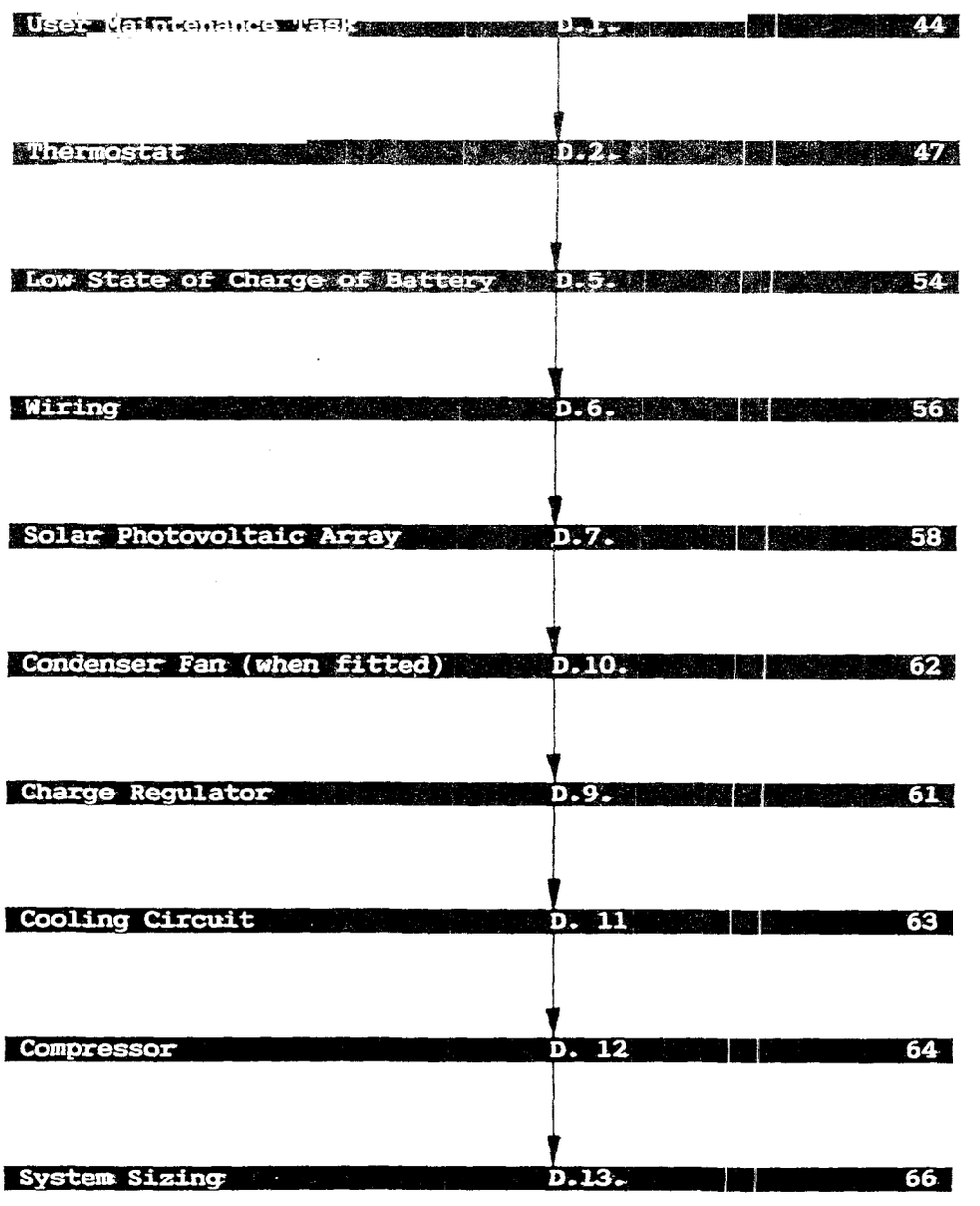


CHART No. 3

SYMPTOM - Refrigerator is TOO COLD

REMEMBER - VACCINE IS DESTROYED IF FROZEN

Check for the following possible faults by first looking at the top of the chart. If this is found not to be the fault then move to the next fault in the direction of the arrows.

Possible Fault	Fault Finding & Repair Task No.	Page No.
Movable Separator between refrigerator and freezer damaged, incorrectly positioned or removed. (Applies only to some types of refrigerator cabinets, e.g. Electrolux RCW 42)	replace or repair separator	
↓		
"Continuous running", "draw down" or "freezer" switch on. (Applies only to some types of refrigerator with these additional switches).	Switch the refrigerator back on to normal mode	
↓		
Thermostat faulty	D.2.1.	47

D. FAULT FINDING AND REPAIR TASKS DESCRIPTIONS

D.1. USER MAINTENANCE TASKS

The USER is responsible for undertaking routine maintenance tasks. If the refrigerator stops operating correctly, the user is also trained to do some simple checks before calling for the solar refrigerator technician.

IT IS YOUR RESPONSIBILITY TO:

- MAKE SURE THAT THE USER HAS DONE ALL OF HIS MAINTENANCE TASKS CORRECTLY, AND THE SIMPLE FAULT FINDING CHECKS BY RE-DOING THE SAME TASKS, AND
- TRAIN THE USER IF ALL TASKS ARE NOT DONE CORRECTLY.

Technician Action required

(a) Check that the DAILY RECORD SHEETS of the user are filed in correctly. Check:

- the refrigerator temperature record. The refrigerator should ALWAYS been operating above $0^{o}C$.
- if there is a record of warning indicator light being lit. The warning indicator lights are normally labelled as "Do Not Freeze Ice Packs" and "Low Battery State of Charge" or "Refrigerator Disconnected".

(b) Check that the refrigerator is switched ON, if not, turn it ON.

(c) Check that no obstacles are preventing free air circulation around the refrigerator.

(d) Check that the ice formation on the evaporator is less than 5 mm thick. If it is more, defrost the refrigerator.

(e) Find out from the User if defrosting is often necessary, if he says 'yes' then check the lid or door sealing gasket. If the seal is not making good contact, either:

- glue it back on,
- replace the seal, and/or
- adjust the door.

If it necessary to replace the seal or adjust the door, check afterwards that the contact between the lid/door and the refrigerator cabinet is good.

(f) Check that:

- the condenser and compressor are free from dust,
- that the fan (if fitted) turns freely, and
- that the outside of the refrigerator cabinet is clean.

If not, clean them thoroughly.

(g) Check that the solar array is clean, and that a clean cloth is available to clean the array.

(h) Check that the solar array is not shaded or even partly shaded from trees or other obstructions from at least 8.00 a.m. in the morning until 4.00 p.m. in the afternoon. If it is shaded, cut back the trees or remove the obstacle. If neither is possible it will be necessary for an installation technician to move the solar array to another place where it is not shaded.

(i) Check the condition of the batteries:

1. Check the level of electrolyte (acid and water mixture) in each battery cell if the battery is not a sealed type. The metal plates MUST be well covered.

2. Add clean distilled water to the batteries if the metal plates are not covered. Follow the procedure explained on Page 34.

3. Ask the user:

   - if he has added distilled water,
   - in which cells he added water
   - when was the last time he added water
   - how often he adds water, and to which cells.

- if the level of water in any cell has ever dropped below the top of the metal plates.

- where he obtains his distilled water, and how often.

- what the distilled water is stored in, and how is the container closed.

This information will help you determine if the batteries are in good condition. Since:

- if a cell in a battery needs water added more often than the other cells, then this cell is no longer operating correctly and the battery should be replaced.

- if a battery needs water often (more than once in six months) then it is either poorly ventilated, exposed to direct sunlight, or is being deeply discharged in which case its life will be considerably shortened.

- if the water added to a battery is not clean and distilled, the battery life will be shortened.

- if the plates of the battery are exposed to the air, then they are damaged and the battery should be replaced.

(j) If you have done ALL of the above User Maintenance Tasks and have not found anything which would cause the refrigerator not to operate correctly, then PROCEED TO THE NEXT STEP ON THE FAULT FINDING CHART.

D.2. FAULTY THERMOSTAT

2.1. REFRIGERATOR IS TOO COLD (colder than 0°C)

Symptoms of the Fault

1. The refrigerator compartment is too cold.
2. The compressor MAY run all the time.

How to confirm this fault

1. Check the evaporator is adequately defrosted.
2. Check the thermostat sensing element is firmly attached. (in some refrigerators it is attached to the evaporator)
3. Adjust the thermostat to its warmest position.
4. **If the refrigerator compressor continues to run**, the thermostat is faulty. See below for action required.
5. **If the compressor stops running**, adjust the thermostat until the temperature in the refrigerator compartment is above 0°C and below 8°C. See Page 71 for how to adjust the thermostat.

Action Required

1. Remove ALL vaccine to another refrigerator or coldbox with ice packs.
2. **If the compressor continues to run when the thermostat is adjusted to any position, CHANGE THE THERMOSTAT** in accordance with the manufacturer's instructions.
3. **Reload the refrigerator.**

2.2 REFRIGERATOR TOO WARM (Warmer than 8°C)

Symptoms of the fault

1. The refrigerator is too warm.

2. The compressor may not be running or running only very occasionally.

How to confirm this fault

1. Check the evaporator is adequately defrosted. If it is not this may be the problem. Defrost the refrigerator.

2. Check that the "Do Not Freeze Ice Packs" or "Refrigerator Disconnected" indicator lights are not lit. **If they are lit** the problem is not the thermostat, so proceed to the next step in the fault finding chart.

3. Check the thermostat wires are tightly connected to terminals T and C of the compressor controller. If tightening the connection causes the compressor to run the fault has been repaired.

4. Check the thermostat wires are tightly connected to the thermostat unit (Mechanical type only). If tightening the connection causes the compressor to run the fault has been repaired.

5. Check the wires from the thermostat unit to the compressor controller for signs of damage. If damage is apparent replace the wire.

6. Adjust the thermostat to its coldest position.

7. If the compressor now runs the thermostat setting was incorrect. Adjust the thermostat to obtain 2°C to 4°C in the bottom of the refrigerator compartment as explained on Page 71.

8. If the compressor still does not run connect a wire across the 2 terminals of the thermostat.

9. If the compressor runs when you connect the temporary wire, but does not run with this temporary wire then:

   - the thermostat is faulty or

   - the wires are incorrectly connected or

   - the wires are defective

Repair Action Required

1. Tighten, correct or change the wires.

2. **If the compressor still does not run CHANGE THE THERMOSTAT** in accordance with the manufacturer's instructions.

D.3. FUSE BLOWN IN COMPRESSOR CONTROLLER

Symptoms of the fault

1. The refrigerator is TOO warm and the compressor is NOT running.

2. REFRIGERATOR DISCONNECTED indicator light MAY be lit.

How to confirm this fault

1. Switch off the refrigerator.

2. Remove the fuse from the compressor controller. Check that the fuse holder is not corroded and that the fuse fits tightly in the fuse holder.

3. Check the electrical resistance of the fuse.

4. Thoroughly clean the fuse holder.

5. Replace the fuse with a spare fuse that has been checked to be good.

6. Switch the refrigerator on. (Some models also have a circuit breaker protecting the refrigerator, make sure that it is also switched on.) **If the compressor now runs, the fault is confirmed and has been repaired.**

7. **If the compressor does not run** check the fuse again. If it has blown again do the actions listed below.

Repair Action required

1. Check that your spare fuse is of the correct type and current rating.

2. Check that the batteries are of the correct voltage and are connected together correctly.

3. Check that the connections between the batteries and the compressor controller are correct and tight. (Positive wire connected to the positive terminal of the compressor controller and negative to the negative terminal).

4. Switch OFF the refrigerator.

5. Disconnect at the compressor controller the wires from the thermostat and fan (if fitted). Fit a temporary wire between terminals T and C of the compressor controller.

6. Replace the fuse with a good fuse of the correct type and switch on the refrigerator.

7. **If the refrigerator runs** there is a fault in the thermostat or fan which is causing the fuse to blow when they are connected. Connect each one separately to determine which is faulty - the thermostat or the fan.

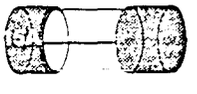
8. **If the fuse blows again**, switch OFF the refrigerator, **remove the electrical socket from the compressor.** (This disconnects the compressor controller from the compressor), fit a new fuse, and switch on the refrigerator.

9. **If the fuse does not blow** with the compressor socket disconnected, the fault is probably in the compressor. **Proceed with the next steps in the Fault Finding Chart** to make sure of your diagnosis before replacing the compressor.

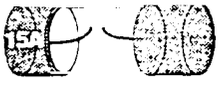
10. **If the fuse blows each time you replace it** and switch on the fridge with and without the compressor socket disconnected, then change the compressor controller. (See Page 75)

11. Fit a new fuse and switch ON the refrigerator again. If with the new compressor controller the fuse does not blow the fault was the compressor controller. If the fuse continues to blow, **PROCEED TO THE NEXT STEP ON FAULT FINDING CHART No. 1.**

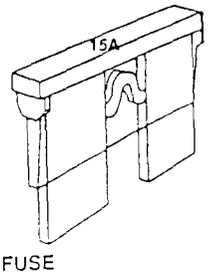
DO NOT FORGET TO REPLACE THE FUSE LATER WHEN THE FAULT IS FOUND.



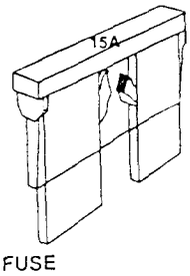
FUSE
GOOD



FUSE
FAILED



FUSE
GOOD



FUSE
FAILED

D4: FUSE BLOWN IN CHARGE REGULATOR

Symptoms of the Fault

The refrigerator is TOO WARM and the compressor is not running.

How to confirm this fault

SOME TYPES OF CHARGE REGULATOR DO NOT HAVE FUSES in the charge regulator, if this is the case then proceed to the next step on FAULT FINDING CHART No. 1.

If the charge regulator is fitted with a fuse then:

1. Switch off the refrigerator.

2. Remove the fuse from the charge regulator. Check that the fuse holder is not corroded and that the fuse fits tightly in the fuse holder.

3. Check the electrical resistance of the fuse.

   If the fuse has blown take the actions detailed below . **If the fuse has not blown replace the fuse and proceed with the next step on the FAULT FINDING CHART No. 1.**

Repair action required

1. Check that you have the correct fuse.

2. Check that the positive and negative connections from the photovoltaic array to the charge regulator are correct, tight and the terminals are not corroded. If there is a poor or wrong on connection this may be the fault. Make good the connections.

3. Examine the cable from the photovoltaic array to the charge regulator to make sure that it is not damaged. If there is some damage this may be the fault. Repair or replace the cable.

4. Check that the batteries are connected with the correct polarity to the charge regulator, and that any other connections are correct, tight and not corroded.

5. Fit a fuse tested to be good and of the correct size.

6. Switch on the refrigerator. (Some models also have circuit breaker protecting the refrigerator, make sure that it is also switched on.)

7. Turn off the refrigerator, take out the fuse and check it. **If the fuse is:**

   - **blown** then **PROCEED TO THE NEXT STEP ON THE FAULT FINDING CHART** to find out why the fuse is blowing.

     DO NOT FORGET TO REPLACE THE FUSE LATER.

   - **not blown**, also **PROCEED TO THE NEXT STEP ON THE FAULT FINDING CHART.** This is because the original fuse must have blown for a reason, and you have to find the reason.

D5: LOW STATE OF CHARGE OF BATTERIES

THE BATTERIES MAY BE FAULTY OR MAY ONLY HAVE A LOW STATE OF CHARGE as a result of a long period of cloudy weather.

Symptoms of the fault

1. The refrigerator is too warm.
2. The voltmeter (not fitted to all models) shows battery voltage to be less than 11.5 V.
3. The REFRIGERATOR DISCONNECTED indicator light is lit or has been lit recently.

How to confirm fault

1. Cover the solar array so that NO sunlight falls on it.
2. Check that the refrigerator is switched on.
3. Measure the voltage of the batteries at the + and - terminals of the compressor controller.
   - The voltage should be greater than 11.5 volts for 12 volt systems (22.6 volts for 24 volt systems) if the compressor IS NOT running.
   - The voltage should be greater than 10.5 volts for 12 volt systems (21.3 volts for 24 volt systems) if the compressor IS running.
4. If the voltage at the compressor controller terminals is not greater than the values shown above, the batteries have a low state of charge.

Repair action required

1. Switch off the refrigerator.
2. If you have a fully charged replacement battery available, (2 batteries for 24 volt system) remove the batteries from the refrigerator and connect the fully charged battery.

3. With the solar array still covered, switch on the refrigerator. THE REFRIGERATOR COMPRESSOR SHOULD NOW RUN.

4. **If the COMPRESSOR DOES NOT RUN;** PROCEED TO THE NEXT STEP ON THE FAULT FINDING CHART.

5. **If the COMPRESSOR DOES RUN:**

   (a) Check the level of distilled water in each cell of each battery, and top up the water if necessary (See Page 34)

   (b) Recharge each battery (unless the battery manufacturer or supplier states this is not to be done for your batteries).

6. Recharge the batteries by switching OFF the refrigerator and:

   (a) Allowing five days for the batteries to be recharged by the solar array, **OR**

   (b) By removing the batteries from the refrigerator and charging with a battery charger.

   (c) When fully charged by either method, disconnect each battery and leave each battery for 2 hours.

   (d) Connect one battery (2 batteries for 24 volt systems) to the refrigerator, switch in the refrigerator and measure the voltage between the + and - terminals of the compressor controller.

   (e) If the voltage of the battery with the compressor running is LESS THAN 12.5 volts (or 25 volts for 24 volt systems), the battery is not holding the charge and should be replaced. (See Page 78)

   (f) Repeat step (d) for each of the batteries you have charged.

   (g) Reconnect the correct number of batteries required for the solar refrigerator.

   (h) If NO batteries need replacing, **PROCEED TO THE NEXT step on the FAULT FINDING CHART** which corresponds with the symptom you have diagnosed. This will enable you to find out if the low state of charge of your batteries is the result of some other fault in your system.

D6. WIRING

Symptoms of the fault

1. The refrigerator is too warm and the compressor is not running.

2. The refrigerator operates normally sometimes but at other times the refrigerator is too warm and the compressor is not running.

How to confirm this fault

1. Check the voltage at:

   (a) The terminals of the charge regulator WHICH ARE CONNECTED TO THE SOLAR ARRAY CABLE. In sunlight this voltage should be 13.5 to 19 volts. (27 to 38 volts for 24 volt systems)

   (b) the + and - terminals of the compressor controller. The voltage should be 11.5 to 13 volts if the batteries are adequately charged. (23 to 26 volts for 24 volt system)

2. If the voltages at the charge regulator and the compressor controller do not correspond with the above values, then there maybe a wiring fault. See below for what action you should take.

Repair action required

1. Switch OFF the refrigerator.

2. **Label wires** before disconnecting them so that you know where to reconnect them.

3. Inspect all the electrical cables and connections. Repair or replace any which are visibly defective.

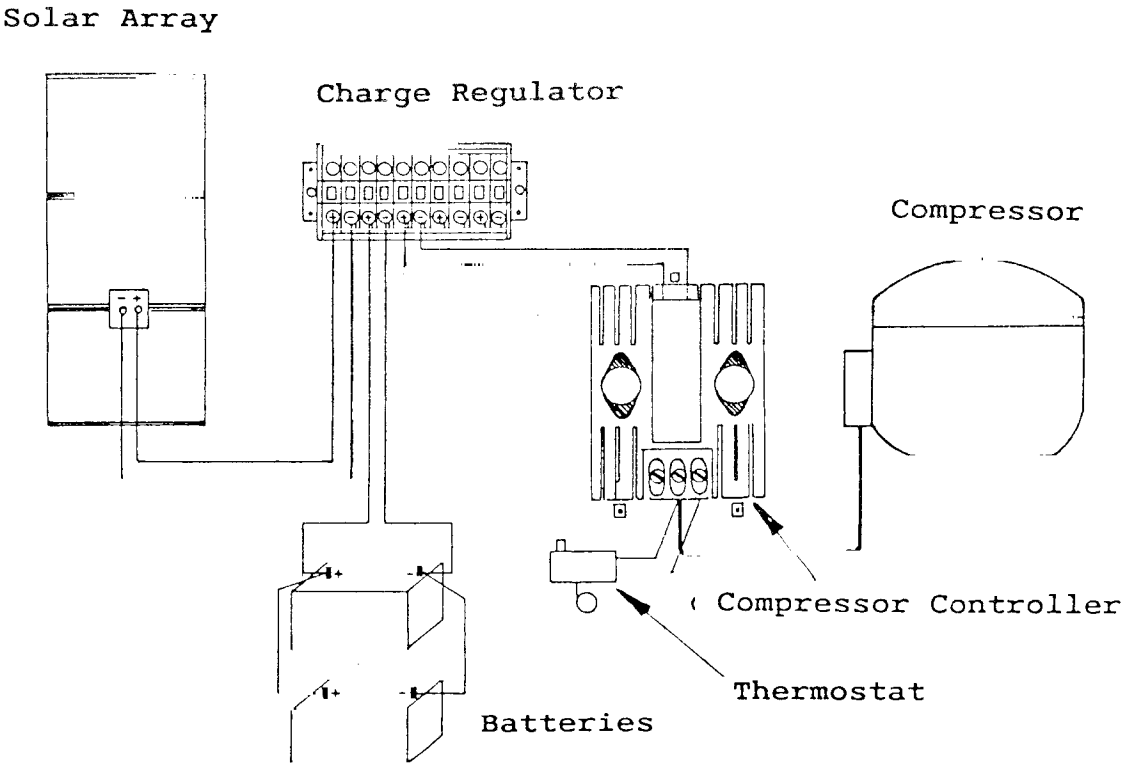
4. Disconnect the solar array wires from the charge regulator.

5. Clean all terminals of the charge regulator and solar array junction box.

7. Check the voltages at the charge regulator and compressor controller again as detailed above under "How to confirm this fault".

   If the voltages are now correct the fault has been repaired.

   If the voltages are still not correct PROCEED WITH THE NEXT CHECK ON THE FAULT FINDING CHART.



TYPICAL WIRING DIAGRAM FOR A SOLAR REFRIGERATOR
(Source: FNMA 75)

D.7. PHOTOVOLTAIC ARRAY

Symptoms of the fault

1. The refrigerator is too warm and the compressor is not running or is running only very occasionally.
2. The batteries become discharged periodically.
3. The indicator lights for normal operations my not be lit or the "Refrigerator Disconnected" and "Do Not Freeze Ice Packs" lights are often lit.

How to confirm this fault

ON A DAY WHEN THE SKY IS CLEAR (NO CLOUDS) AND AT ABOUT MIDDAY;

1. Clean the solar array (See Page 30)
2. Check that the solar array is not shaded (See Page 31)
3. Disconnect from the solar array, the array cable that leads to the charge regulator.
4. Measure and write down the short circuit current of the solar array (See Page 28)
5. Measure and write down the open circuit voltage of the solar array. It should be 17-20 volts for a 12 volt system.
6. Disconnect one module from the array and measure and write down the short circuit current of the module (See Page 28)

   For 12 volt systems the short circuit current in the solar array should be approximately (within 15%) equal to the current in a module multiplied by the number of modules. (For example if the short circuit of one module is 2.5 Amps and there are four modules in the array then the solar array short circuit should be 2.5 x 4 = 10 Amps).
7. **If the array current and voltage do appear correct** reconnect the module and array cable. **PROCEED TO THE NEXT CHECK IN THE FAULT FINDING CHART.**

8. **If the solar array short circuit current or open current voltage does not appear correct** then there may be a fault with a module or the way the modules are connected together.

9. Measure the open circuit voltage and short circuit current in each module with each module disconnected from the other modules.

10. If the voltage and current measured on one module is not similar, to other modules (more than 15% different) the module is probably faulty and should be replaced.

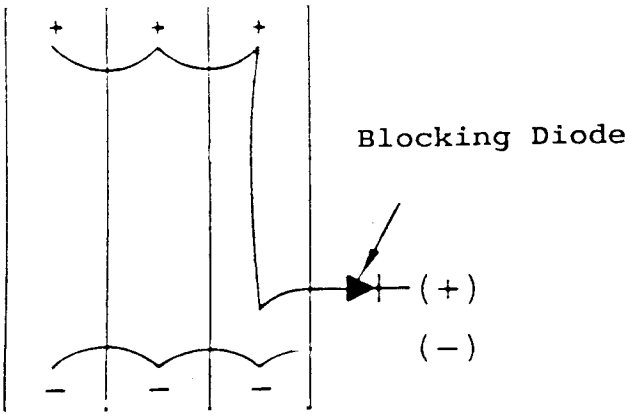
11. If the voltage and current of all the modules are similar then there was probably a poor connection on one module or a faulty wire.

Repair action required

1. If a module is faulty (replace it as described on Page 69)

2. If a wiring fault or connection fault between modules is suspected check the electrical continuity of each wire and clean all the wire terminals.

3. Reconnect all the modules to the array and check all connections are correct. Typical wiring for a 12 volt system is shown below.



4. Check the output of the solar array again to confirm that the correct array current is approximately equal to the current of one module times the number of modules and hence is correctly connected.

D.8. COMPRESSOR CONTROLLER

Symptoms of this fault

The refrigerator is too warm and the compressor does not run.

How to confirm this fault

Measure the voltage at the input terminals of the compressor controller. If the voltage is more than 11.5 volts (12 volt system) or more than 22.5. volts (24 volts system) the compressor should run. If the compressor does not run, proceed as follows.

Repair action required

1. Remove the thermostat and compressor fan wires (if fitted) from terminals T,C, and F of the compressor controller. Fit a temporary wire between terminals T and C. The compressor should then run.

2. If the compressor does not run, CHECK THE FUSE in the compressor controller again as explained on Page 50.

3. If the compressor still does not run, change the compressor controller with another of the same model (or compressor controller specified by the system supplier). (See Page 75)

4. If the compressor still does not run, the compressor controller is NOT faulty. **PROCEED TO THE NEXT STEP ON THE FAULT FINDING CHART No. 1.**

D.9. CHARGE REGULATOR FAULTY

Symptoms of this fault

1. The refrigerator is too warm and the compressor is not running or running only occasionally.

2. The batteries become discharged periodically.

How to confirm this fault

1. If all previous steps in the fault finding procedures have not indicated a fault then change the Charge Regulator (see Page 73) and see if the refrigerator operates normally for at least one month.

Repair action required

1. If after replacing the charge regulator the solar refrigerator works correctly for one month the fault was probably the Charge Regulator.

D.10. CONDENSER FAN (If fitted)

Symptom of the fault

The refrigerator is too warm and the compressor runs very frequently.

How to confirm this fault

When the compressor is running look to see if the condenser fan is rotating.

If it is rotating this is not the problem. Proceed to the next check in the fault finding chart.

If it is not rotating a fault if indicated. See below for the action you should take.

Repair action required

1. Switch off the refrigerator.
2. Disconnect the fan wires from the compressor controller. Check the continuity of each wire. If a break in a wire is detected replace the wire.
3. Clean the connections and reconnect the fan wires to the compressor controller.
4. Check to see if the fan can freely rotate. If it is jammed remove the item that is stopping it from rotating.
5. Switch ON the refrigerator.
6. **If the fan now rotates** when the compressor is running the fault has been repaired.
7. **If the fan still does not rotate** replace the fan as described on Page 77.

D.11. COOLING CIRCUIT FAULT

Symptom of the fault

The refrigerator is too warm and the compressor runs continuously or very frequently.

How to confirm this fault

1. If the compressor runs and the evaporator plate does not get cold all over then:

   (a) the cooling circuit may be undercharged with refrigerant, or

   (b) the capillary tube blocked, or

   (c) there may be moisture in the system

2. If the refrigerator is correctly charged with refrigerant, there must be liquid in the pipe coming out of the condenser. To check this, do the following:

   (a) adjust the thermostat to its coldest setting and run the compressor for at least five minutes.

   (b) with the compressor running, hold a lighted match under the condenser outlet pipe until the match is finished.

   (c) as soon as the match has gone out put your finger on the pipe where the match heated it.

   (d) the pipe should be warm only. If there is liquid inside the pipe the heat from the match will be absorbed by the liquid in the pipe. If the pipe is too hot for you to keep your fingers on it, then there is no liquid in the pipe. This means that the refrigerator is not adequately charged with refrigerant.

Repair action required

IF YOU ARE SURE that the symptoms indicate that there is insufficient refrigerant in the refrigerator or there may be a problem with moisture or a blockage, then REFER TO THE **TECHNICIAN'S HANDBOOK FOR COMPRESSION REFRIGERATORS, PART B,** FAULTS AND FAULT FINDING. PAGE 7 gives a fault finding chart and procedure to find and repair the fault.

D.12. COMPRESSOR

Symptoms of the fault

The refrigerator is too warm.

How to confirm this fault

1. Measure the voltage at the input terminals of the compressor controller. If the voltage is more than 11.5 volts (12 volt system) or more than 22.5 volts (24 volts system), the compressor should run.

2. If the compressor runs continuously and the refrigerator temperature does not decrease to less than 8°C after 4 hours, a cooling circuit problem is evident go to Page 62.

3. **If the compressor does not run**, proceed as follows.

4. Switch OFF the refrigerator and disconnect the electrical socket from the compressor.

5. Measure the electrical RESISTANCE between the following connections on the compressor plug with your OHMMETER: (See Diagram of Pins on next page)

   - Pins No. 1 and 3.
   - Pins No. 4 and 3.
   - Pins No. 2 and 3.

   The electrical RESISTANCE should be VERY LOW between these connections.

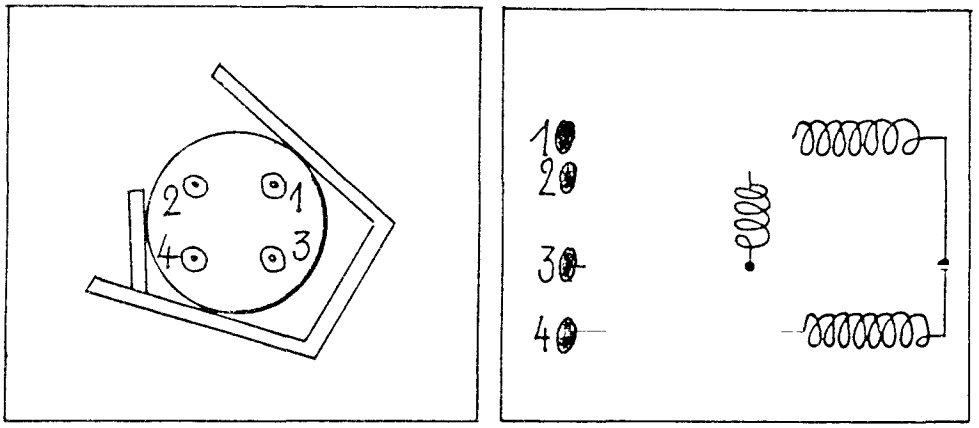
6. Measure the electrical RESISTANCE between Pin No. 3 and the metal body of the compressor. Make sure that you have good electrical contact between your OHMMETER lead and the compressor metal body. The electrical RESISTANCE should be VERY HIGH.

7. If the electrical RESISTANCE between the compressor pins (See Para. 5. above) is not VERY LOW and the electrical RESISTANCE between Pin No. 3 and the compressor body is not VERY HIGH, then the compressor is faulty.

Repair action required

1. ONLY CHANGE THE COMPRESSOR **WHEN YOU ARE SURE** THAT ALL PREVIOUS STEPS IN THE FAULT FINDING CHART HAVE BEEN CAREFULLY CHECKED.

2. Replace the compressor in accordance with the manufacturer's instructions. Refer also to the procedure described in the WHO handbook for COMPRESSION refrigerator repairs. (Refer to the inside of the front cover of this handbook for details).



D.13. SYSTEM SIZING

Symptoms of the fault

1. Refrigerator operates correctly during certain seasons, but the batteries become discharged at times in the year when it is not very sunny or the ambient temperature is high.

2. The indicator light "Do Not Freeze Icepacks" and possibly "Refrigerator Disconnected" are lit early in the morning especially at the times in the year when it is not very sunny or the ambient temperature is high.

How to confirm the fault

1. If you are sure that each of the checks you have made in FAULT FINDING CHART No. 2 has been correctly performed and that no fault was found, when you performed these checks, then the system sizing may not be correct. (The system sizing is incorrect if the number of solar modules and/or the number of batteries are insufficient).

2. Check the DAILY RECORD SHEETS to see if large quantities of vaccine and/or medical supplies are frequently loaded into the refrigereator.

3. Check the DAILY RECORD SHEETS to see that the quantities of icepacks frozen do not exceed the amounts recommended in the User Handbook for Photovoltaic Refrigerators, Table 1, and that the amount of icepacks shown in Table 1 is not more than the quantity specified for this type of refrigerator system.

4. Check with the person who is responsible for the refrigerator to make sure that food and drinks and other non-medical supplies are not being kept in the refrigerator and that items other than icepacks are not being frozen in the freezer compartment.

5. If the above checks indicate that the refrigerator is being correctly operated and that no parts of the system are defective, then closely observe the operation of the refrigerator during several days and note when the indicator lights show "Do Not Freeze Icepacks", and possibly "Refrigerator Disconnected".

6. If the problem continues a part of the system may be undersized.

Repair action required

1. Write down your findings on the DAILY RECORD SHEETS kept by the User;

2. Prepare a note with a full explanation of checks performed and your conclusions that there may be a problem with sizing.

3. Send or preferably hand-deliver your note to:

   (a) the chief of the solar refrigerator installation team,

   (b) the person responsible for solar refrigerators in the organisation responsible for the EPI program in your country;

   (c) ask your head of department to send a copy of your note to the Cold Chain Unit, Expanded Programme on Immunisation at the World Health Organization, 1211 Geneva - 27, Switzerland.

4. Advise the user that he or she should refrigerate only vaccine and other essential items and should try to minimize the number of unfrozen ice packs placed in the freezer at one time.

REMEMBER: VACCINE AND ESSENTIAL MEDICAL ITEMS ONLY SHOULD BE IN THE REFRIGERATOR

E. REPAIR TECHNIQUES

E.1. INTRODUCTION

Some of the repair tasks that you may have to carry out on the cooling system of a solar powered refrigerator are similar to those for a normal compression refrigerator. These have been fully described in the **Technician's Handbook for Compression Refrigerators Parts A, B and C**, produced by WHO Expanded Programme on Immunization. You should have a copy of each of these three booklets in order to carry out the repair tasks listed below:

(a) Replacing a thermostat (see Part C)
(b) Replacing a compressor (see Part C)
(c) Mending a refrigerant leak (see Part A and Part C)
(d) Recharging the refrigerant loop when the system is undercharged (see Part A and Part B)
(e) Recharging the refrigerant loop when the system is overcharged (see Part B)
(f) Replacing the evaporator (see Part C)
(g) Replacing a capillary tube (see Part C)
(h) Replacing a filter/drier (see Part C)
(i) Replacing the lid/door sealing gasket
(j) Adjusting the lid/door sealing
(k) Adjusting dropped or twisted doors

Other repair tasks that you may have to carry out on a solar powered refrigerator are described in the following pages.

You should also always refer to the maintenance and repair handbooks of the solar refrigerator manufacturer, if these are available, as their instructions should be more specific.

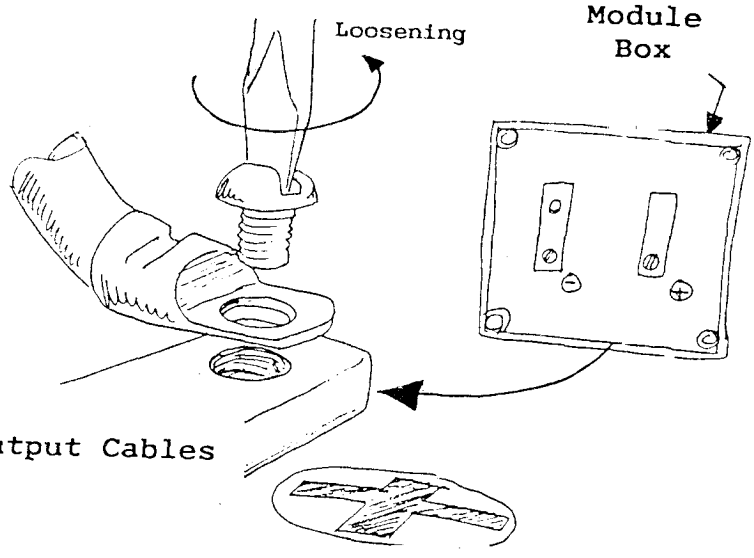
E.2. REPLACING A MODULE OF THE SOLAR ARRAY

(a) Work on the solar array early in the morning or in the evening. Completely cover the front of the solar array with thick cloth or a sheet. The solar array must not be in bright sunshine when you work on it except when you are checking performance.

(b) Disconnect the wires from the solar array at the charge regulator terminal strip. Use insulated tools and be careful not to touch the terminals with your hands as you could get an electric shock.

(c) Remove the lid of the junction box at the back of the faulty module.

(d) Mark the positive wire and the negative wire. Then disconnect the module output cables from the positive and negative terminals in the terminal box.



(e) Loosen the mounting bolts from the module and remove the module from the solar array frame.

(f) Place the new module (which has been checked to be of the correct type and good performance) in the solar array frame and tighten the mounting bolts.

(g) Connect the module cables to the correct terminals in the module terminal box.

(h) Replace the lid of the module terminal box. Do not over tighten the lid screws.

(i) Reconnect the solar array back to the charge regulator at the charge regulator terminal strip. Be careful not to touch the terminals with your hands.

(j) Remove the cover or sheet from the solar array.

(k) Check the performance of the solar array. (See Page 33)

E.3. ADJUSTING THE THERMOSTAT

(a) Set the thermostat in its middle position. (Halfway between its maximum and minimum settings). Allow 4 hours for the temperature to stabilise.

(b) Read the thermometer in the bottom of the refrigerator compartment after 4 hours. The temperature should be between 2°C and 4°C.

(c) If it is not, adjust the thermostat to a warmer or colder setting as appropriate. Allow another 4 hours before checking the temperature.

(d) Continue adjusting and checking in the same way until the temperature in the bottom of the refrigerator compartment is between 2°C and 4°C.

REMEMBER: WAIT 4 HOURS BETWEEN ADJUSTING THE THERMOSTAT AND CHECKING THE TEMPERATURE

E.4. REPLACING POWER CABLES

(a) The power cables are the electrical wires running from the charge regulator to the solar array, the batteries, and the refrigerator.

(b) If one of these cables is damaged it must be replaced because it might cause a short-circuit. Do not mend the damaged cable, except as a temporary measure.

(c) Turn the refrigerator off.

(d) Cover the solar array with a thick cloth or sheet.

(e) Disconnect the damaged cable from its terminals. If the cable is between the battery and the charge regulator, disconnect the battery terminals first. If the cable is between the solar array and the charge regulator, disconnect the solar array terminal first. If the cable is between the refrigerator and the charge regulator, disconnect the charge regulator first. Use insulated tools and do not touch the terminals with your hands to avoid any risk of electric shock.

(f) Replace the damaged cable with a new one.

(g) Remove the cover placed over the solar array.

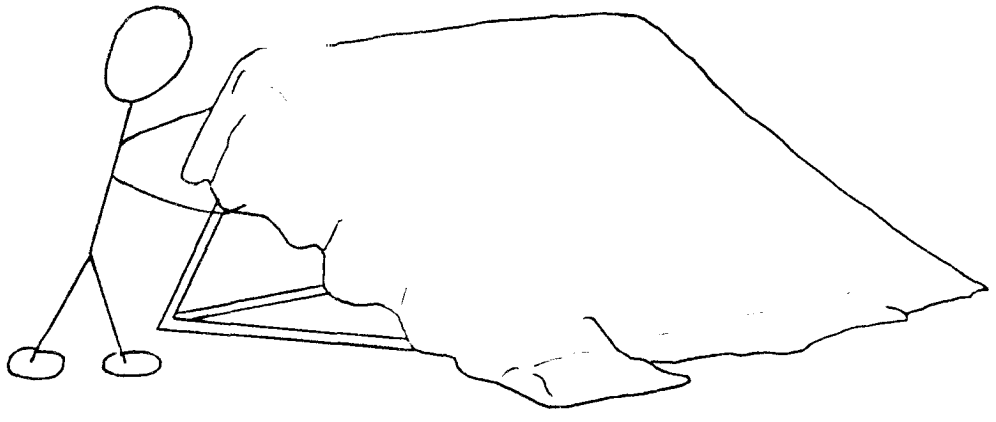
(h) Turn the refrigerator back on.

(i) After replacing the damaged cable consider what may have cause it to be damaged. If there is a nearby sharp edge causing "fretting" smooth it off. If rodents or termites are the problem take the necessary action to be rid of them. If the problem persists consider armoured cable.

E.5. REPLACING THE CHARGE REGULATOR

(a) Switch the refrigerator OFF. If the charge regulator has an ON/OFF switch, switch the charge regulator OFF too.

(b) Cover the solar array with a thick cloth or a sheet. Make sure that the array is completely covered, and be careful not to scratch its surface.



COVER THE SOLAR ARRAY BEFORE REPLACING THE REGULATOR

(c) If you cannot cover the solar array, replace the voltage regulator early in the morning or in the evening when the sun is low in the sky.

(d) LABEL ALL WIRES that you are about to disconnect so that you can reconnect them to the correct points.

(e) Disconnect all the wires from the charge regulator. The wires should be disconnected in the following order:

1. Load positive
2. Load negative
3. Solar array positive
4. Solar array negative
5. Battery positive
6. Battery negative

(f) Remove the old charge regulator from its mounting and replace it with the new one. Make sure that it is the same type of regulator as the old one.

(g) Reconnect all of the wires to the new charge regulator in the following order:

1. Battery negative
2. Battery positive
3. Solar array positive
4. Solar array negative
5. Load negative
6. Load positive

(h) Reconnect the wires from the new charge regulator to the battery terminals.

(i) Uncover the solar array.

(j) Switch the refrigerator back ON again.

E.6. REPLACING THE COMPRESSOR CONTROLLER

The compressor controller is fitted to the electrical circuit to reduce the possibility of damage to the compressor motor. If it is faulty, it should be replaced as follows:

(a) Switch the refrigerator OFF.

(b) Disconnect the wires from the battery terminals.

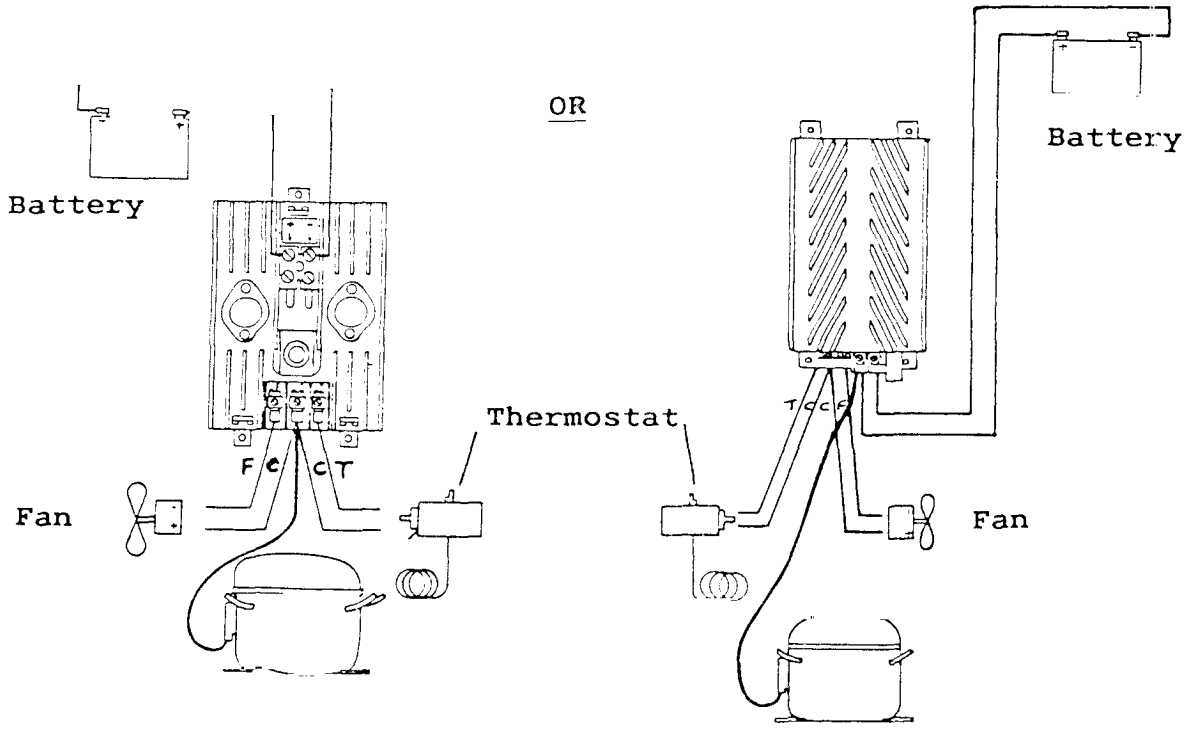
(c) Label all the wires you are about to disconnect.

(d) Disconnect the wires from the faulty compressor controller in the following order:

1. to charge regulator
2. to compressor
3. to fan
4. to thermostat

(e) Unscrew the faulty compressor controller from its mountings.

(f) Screw a replacement compressor controller to the mounting. If the compressor is made by DANFOSS, it must be installed vertically with the connection terminals downwards, as shown below.



(g) Reconnect all wiring to the compressor controller (ensuring correct polarity) in the reverse order they were disconnected.

(h) Reconnect the wires to the battery terminals.

(i) Switch the refrigerator ON again.

E.7. REPLACING THE CONDENSER FAN (If fitted)

The refrigerator may have a small fan that blows air onto the condenser tubing too help keep it cool. If there is a condenser fan and it is broken, replace it according to the following instructions:

(a) Switch the refrigerator OFF.

(b) Disconnect the battery (or batteries).

(c) Mark which wire is connected to the positive terminal and which wire is connected to the negative terminal. Disconnect the wires from the fan terminals.

(d) Unscrew the broken fan from its mounting.

(e) Screw the new fan into place. The new fan must have the same voltage and power ratings as the old one.

(f) Reconnect the wires to the fan terminals making sure that the positive wire is connected to the positive terminal and the negative wire is connected to the negative terminal.

(g) Reconnect the battery.

(h) Switch the refrigerator back ON.

E.8. REPLACING A BATTERY

(a) Switch the refrigerator OFF.

(b) Mark which wire goes to the positive terminal and which wire goes to the negative terminal.

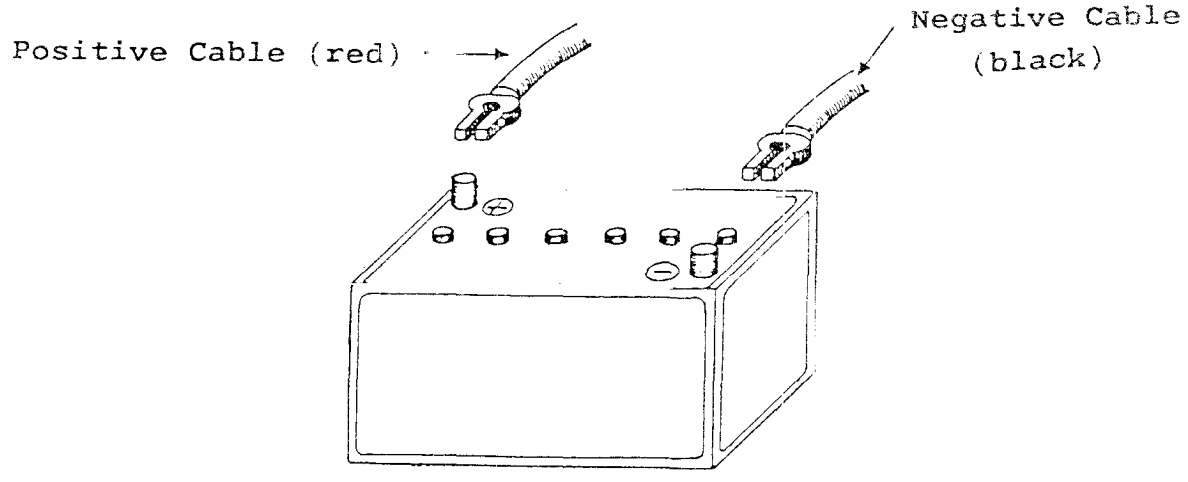
(c) Disconnect the wires of the faulty battery at the battery terminals.

(d) Remove the faulty battery and replace it with a new one. The battery must be of the same type as the old one.

(e) Reconnect the wires to the terminals of the new battery. Make sure that the positive wire is connected to the positive battery terminal and that the negative wire is connected to the negative battery terminal. If the battery terminals of the wire connections are dirty or greasy, clean them with a wire brush or steel wool before connecting them

(f) If more than one battery is used in the solar refrigerator ensure the connections are correct as indicated below.

(g) Switch the refrigerator back ON again.



ENSURE CORRECT POLARITY OF CONNECTIONS

PART 4: RECORD KEEPING

1. INTRODUCTION

Record keeping is a very important activity because:

- it provides the repair technician with important information needed for repair work;
- it provides cold chain management with statistics which assist in project evaluation and future project planning;
- it permits better care of vaccine and reduces waste;
- it increases the effectiveness of the immunisation program.

Records are kept by the user of the refrigerator system and by the repair technician. It is the responsibility of the repair technician to make sure that the user fills in the DAILY RECORD SHEETS correctly and EVERY day.

The **DAILY RECORD SHEET** which is shown on the next page is completed twice a day by the person responsible for using the refrigerator.

A **MAINTENANCE RECORD SHEET** is completed by the repair technician each time he visits a refrigerator installation and performs checks or does repairs. This MAINTENANCE RECORD SHEET is kept by the repair technician. It provides a record of repair tasks.

Each time the technician visits a site to perform repairs then he should take with him to the site:

(a) Completed MAINTENANCE RECORD SHEETS for that site, this will help him to see if there has been any change in the performance of any parts of the system and to find out if there is a history of a fault which will assist in diagnosing any new problems.

(b) New MAINTENANCE RECORD SHEETS.

A sample of a MAINTENANCE RECORD SHEET is provided on Pages 81 and 82.

DAILY RECORD SHEET

WEEK FROM _____ TO _____

	TIME	TEMPERATURE IN REFRIGERATOR COMPARTMENT	AMBIENT TEMPERATURE	QUANTITIES LOADED		INDICATORS ON	SIGNATURE
				ICEPACKS	VACCINES		
MONDAY MORNING							
MONDAY AFTERNOON							
TUESDAY MORNING							
TUESDAY AFTERNOON							
WEDNESDAY MORNING							
WEDNESDAY AFTERNOON							
THURSDAY MORNING							
THURSDAY AFTERNOON							
FRIDAY MORNING							
FRIDAY AFTERNOON							
SATURDAY MORNING							
SATURDAY AFTERNOON							
SUNDAY MORNING							
SUNDAY AFTERNOON							

MAINTENANCE RECORD SHEET SIDE 1

NAME OF SITE:
MAKE AND MODEL OF REFRIGERATOR:
QUANTITY AND TYPE OF BATTERIES:
QUANTITY AND TYPE OF PV MODULES:

POSSIBLE FAULT	RESULT OF FAULT FINDING CHECK

MAINTENANCE RECORD SHEET

SIDE 2

DESCRIPTION OF REPAIR MADE

PARTS USED		
NAME OF PART	QUANTITY	PART NUMBER

CHECKS PERFORMED AFTER THE REPAIR	
NAME OF PART CHECKED	RESULTS OF CHECK

DATE OF REPAIR:
NAME OF REPAIR TECHNICIAN:
SIGNATURE OF REPAIR TECHNICIAN:
SIGNATURE OF RESPONSIBLE PERSON AT SITE:

2. Completing the Maintenance Record Sheet

The procedure to fill in a MAINTENANCE RECORD SHEET is very easy. The steps are as follows:

At the top of the first page:

1. **Write the name of the site in the space provided.**

2. **Write the make and model of refrigerator in the space provided.** If you do not know you can find this information in Table 2 - SITE DATA SHEET, which is in the USER HANDBOOK. This handbook was provided with the refrigerator. Ask the user for this handbook.

3. **Write the quantity and type of batteries in the space provided.** You can also find this information in Table 2 - SITE DATA SHEET of the USER HANDBOOK.

In the table on the front page:

4. Write the name of the possible fault you are checking in the first space of the left-hand column. This should be the first item shown on the list of possible faults shown in CHART No. 1, CHART No. 2, or CHART No.3 in (See pages 41 to 43).

5. When you have followed the procedure for the first fault finding and repair task description write the result of your work in the space provided alongside the possible fault.

6. Proceed to the next fault in the chart which corresponds to your symptom and enter the name of the possible fault in the second space on the left hand side of the table.

7. Follow the fault finding procedure which corresponds to this fault and enter the result alongside the possible fault.

8. Continue in order through each step on the fault finding chart until you diagnose the fault. Write down the results of each step before proceeding to the next step.

9. When you reach the step where the fault is diagnosed proceed to the second side of the MAINTENANCE RECORD SHEET.

10. In the space provided under ACTION, describe the repair and give a complete lists of the parts used, including part numbers where possible.

11. Following the repair, check that the component that you have replaced is operating correctly by repeating the "How to Confirm a Fault" for the step where the repair was performed. When this procedure is followed, no fault should now be evident. The results of the checks performed should be entered in the last block of the MAINTENANCE RECORD SHEET.

12. Enter the date of the repair in the space provided at the bottom of the second side of the MAINTENANCE RECORD SHEET.

13. Write your name clearly underneath the date.

14. Sign the MAINTENANCE RECORD SHEET to verify that the work described on the sheet has been performed.

15. Ask the person at the site who is responsible for the refrigerator to sign the MAINTENANCE RECORD SHEET.

PART 5. USER TRAINING

User training is initially done by the installation technician when the refrigeration system is installed. The installation technician explains the activities described in the **USER HANDBOOK** FOR PHOTOVOLTAIC REFRIGERATORS.

As the repair technician you are responsible for continuing the training of the user of the photovoltaic refrigerator system. This training is commonly called on-the-job training.

The responsibilities of the repair technician in providing on-the-job training to the user may be divided into the following 4 parts:

A: ACTIONS ON HANDOVER

The user should fully understand all of the actions on handover which are described in detail in **PART 1 - ACTIONS ON HANDOVER** of the **USER HANDBOOK** FOR PHOTOVOLTAIC REFRIGERATORS.

Actions on handover include:

(a) Identifying to the user the basic parts of the solar refrigerator power supply and the basic parts of the refrigerator cabinet.

(b) Completing Tables 1 to 5 in the User Handbook.

If the person responsible for the photovoltaic refrigerator has recently changed you will need to repeat the training on identifying the basic parts of the solar refrigerator when you visit the site.

B: HOW TO OPERATE THE SYSTEM

The user should fully understand how to operate the system. This is described in detail in **PART 2 - HOW TO OPERATE YOUR SYSTEM** of the **USER HANDBOOK** FOR PHOTOVOLTAIC REFRIGERATORS. Check that the user understands:

1. How to switch the refrigerator ON.

2. Opening and closing of the refrigerator cabinet.

3. Locking the refrigerator cabinet.

4. When to switch the refrigerator OFF.

5. Correct storage temperatures and conditions for vaccine.

6. Loading the refrigerator.

7. Filling in the DAILY RECORD SHEET.

C: USER MAINTENANCE

The user should fully understands how to do simple maintenance, which is described in detail in **PART 3 - USER MAINTENANCE** of the **USER HANDBOOK** FOR PHOTOVOLTAIC REFRIGERATORS.

Part 3 of the User Manual is extremely important. These are the tasks which the user must do on a regular basis if the refrigerator is to operate correctly. These tasks are grouped into daily, weekly, monthly and six monthly tasks.

As the repair technician you must check that these tasks have been performed. In doing these checks, you should always be accompanied by the user who should assist you in carrying out these tasks. By doing this you can make sure that the user knows how to do each one of them correctly.

This is the most effective type of on-the-job training for the user.

The tasks you should check the user can do are as follows:

Group 1 (tasks normally done daily by the user)

1. Fill in the DAILY RECORD SHEET.

2. Check the indicator lights and any other meters.

3. Check that there is free air circulation all around and underneath the refrigerator cabinet.

4. Check that the refrigerator cabinet is not overloaded and that only vaccines and medical supplies are kept in the refrigerator.

Group 2 (tasks normally done weekly by the user)

5. Check the amount of ice forming around the freezer compartment. Defrost if necessary.

6. Clean the photovoltaic array.

7. Check for shadowing of the photovoltaic array. Cut back trees or bushes or remove any obstacles.

Group 3 (task normally done monthly by the user)

8. Clean the parts of the refrigerator (including the condenser).

Group 4 (tasks normally done every six months by the user)

9. Check the level of the acid in every battery cell (except sealed batteries). Top up with distilled water if necessary.

10. Check that all parts of the system are firmly and safely mounted, and that nothing is visibly damaged. Repair if possible.

11. Check the lid/door seal. Replace if necessary.

D: WHAT TO DO IF A FAULT OCCURS

The user should know what to do if a fault occurs. This is described in detail in "Part 4 - What to do if a Fault Occurs" of THE **USER HANDBOOK** FOR PHOTOVOLTAIC POWERED REFRIGERATORS.

Part 4 defines a procedure which the user should follow if a fault occurs, it is important that this procedure be fully understood. As the repair technician you should talk to and work with the user to make sure that the user can correctly identify the symptoms of a fault.

Symptoms divide into three basic areas:

1. The refrigerator is too warm (above $8^{o}C$) and the compressor is not running.

2. The refrigerator is too warm (above $8^{o}C$) and the compressor is running.

3. The refrigerator is too cold.

After you are sure the user can identify the symptoms of a fault check that he or she knows which checks and actions correspond with the symptoms of the fault. (These are described as Page 23 of the **USER HANDBOOK**).

GLOSSARY OF TECHNICAL TERMS

BATTERIES:	store the electricity to supply the **SOLAR PHOTOVOLTAIC REFRIGERATOR** at night and in cloudy weather when there is no sunshine.
CHARGE REGULATOR:	An electronic unit that regulates the amount of electricity being put into the **BATTERIES.** It prevents over charging and damage to the **BATTERIES.**
COMPRESSOR:	pumps the **REFRIGERANT** around the **COOLING CIRCUIT.** There is an electric motor inside the **COMPRESSOR** which makes a humming noise when it is running. The **COMPRESSOR** will get warm when it is running. This is normal.
CONDENSER:	the coil of metal tubing at the back or underneath of the **REFRIGERATOR.** It transfers the heat removed from the refrigerator to the outside air.
COOLING CIRCUIT:	The piping and components in which the **REFRIGERANT** travels. It includes the **EVAPORATOR, CONDENSER** and **COMPRESSOR.**
COMPRESSOR CONTROLLER :	the electronic unit that converts the electricity stored in the **BATTERIES** to the correct requirements of the **COMPRESSOR** motor.
DOOR/LID SEALING GASKET:	the strip of rubber or plastic that goes around the inside edge of the lid/door of the **REFRIGERATOR.** The **SEALING GASKET** stops cold air from getting out of the **REFRIGERATOR** and warm air from getting in.

FREEZER COMPARTMENT: the coldest compartment of the **REFRIGERATOR**, usually with its own separate door inside the main door. **ICEPACKS** are frozen inside the **FREEZER COMPARTMENT.**

FUSE: a small strip of metal (in a holder) that melts when there is too much electricity consumed. A **FUSE** protects electrical components from damage.

INSTALLATION TECHNICIAN: the person who brings the **SOLAR PHOTOVOLTAIC POWERED REFRIGERATOR** to the health centre and who puts it together and installs it so that it is ready for use.

MAIN COMPARTMENT: the largest space in the **REFRIGERATOR** where the temperature is kept at between $0^{\circ}C$ and $+8^{\circ}C$. This is where vaccines and medicines are stored and is often called the **VACCINE COMPARTMENT.**

PHOTOVOLTAIC: the name for the way in which a **SOLAR ARRAY** converts sunlight to electricity. "PV" is a short way of saying **PHOTOVOLTAIC.**

PV REFRIGERATOR: See **SOLAR PHOTOVOLTAIC REFRIGERATOR.**

REFRIGERANT: the fluid that is pumped through the **COOLING CIRCUIT** by the **COMPRESSOR.** The **REFRIGERANT** carries heat out of the **REFRIGERATOR.**

REFRIGERATOR: an insulated cabinet that can keep vaccine and medicine cold. The **REFRIGERATOR** may be front loading and have a door, or it may be top loading and have a lid. It may also have a **FREEZER COMPARTMENT** to freeze **ICEPACKS.**

SERVICE AND REPAIR TECHNICIAN: the person who visits the health post to carry out regular preventative maintenance on the **SOLAR PHOTOVOLTAIC REFRIGERATOR** and any repairs that are necessary.

SOLAR ARRAY: produces electricity when sunlight falls on it. Often referred to as the **PV ARRAY.**

SOLAR PHOTOVOLTAIC REFRIGERATOR: a **REFRIGERATOR** supplied with electricity from a **SOLAR ARRAY.** Also known as a **SOLAR REFRIGERATOR** or **PV REFRIGERATOR.**

THERMOSTAT: the device that controls the temperature inside the **MAIN COMPARTMENT** of the **REFRIGERATOR.**

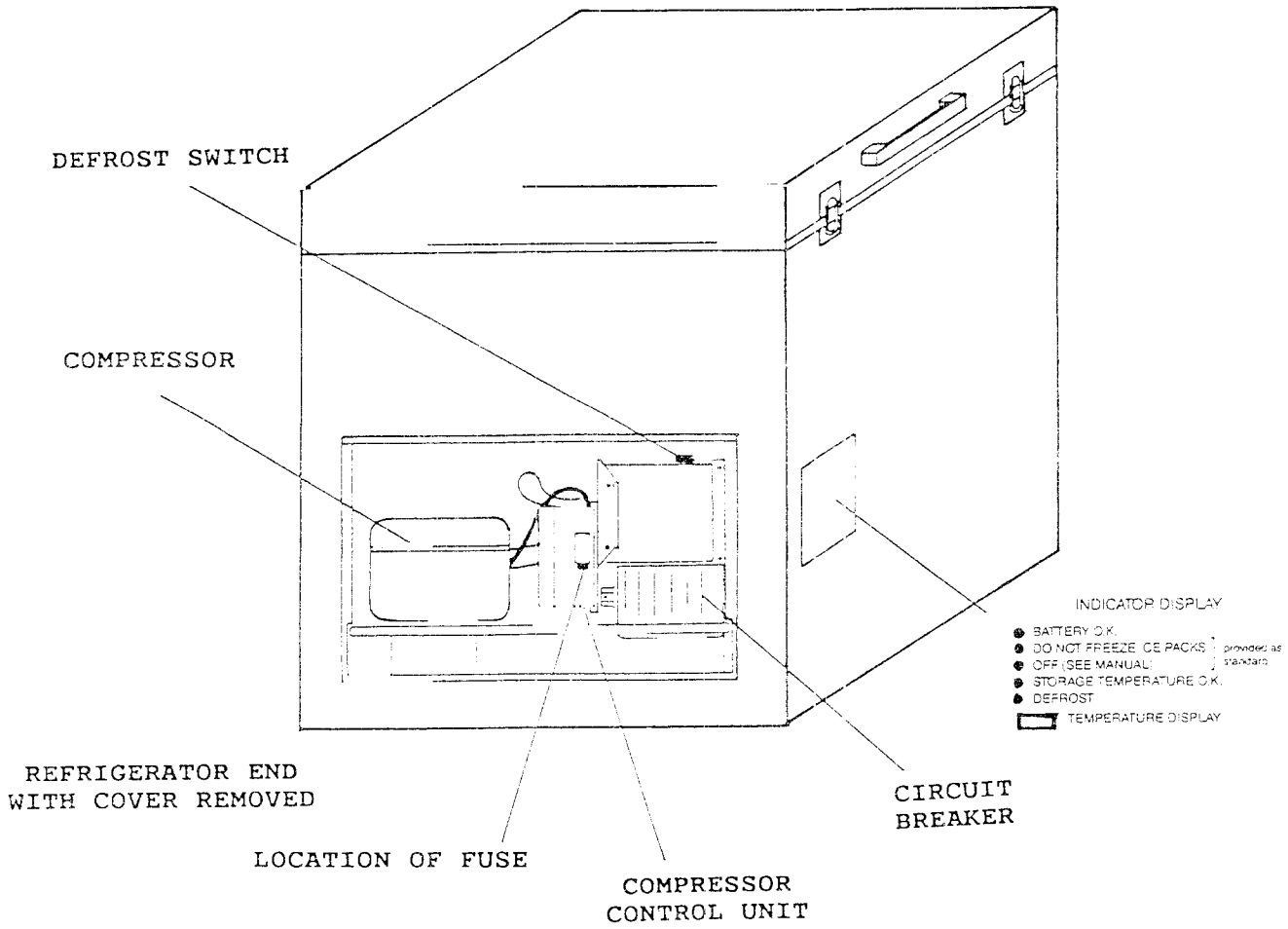
TILT ANGLE: the angle that the **SOLAR ARRAY** makes with the horizontal ground.

VACCINE COMPARTMENT: the **MAIN COMPARTMENT** of the **REFRIGERATOR** where the temperature is kept at between $0^{\circ}C$ to $8^{\circ}C$ for the storage of vaccine.

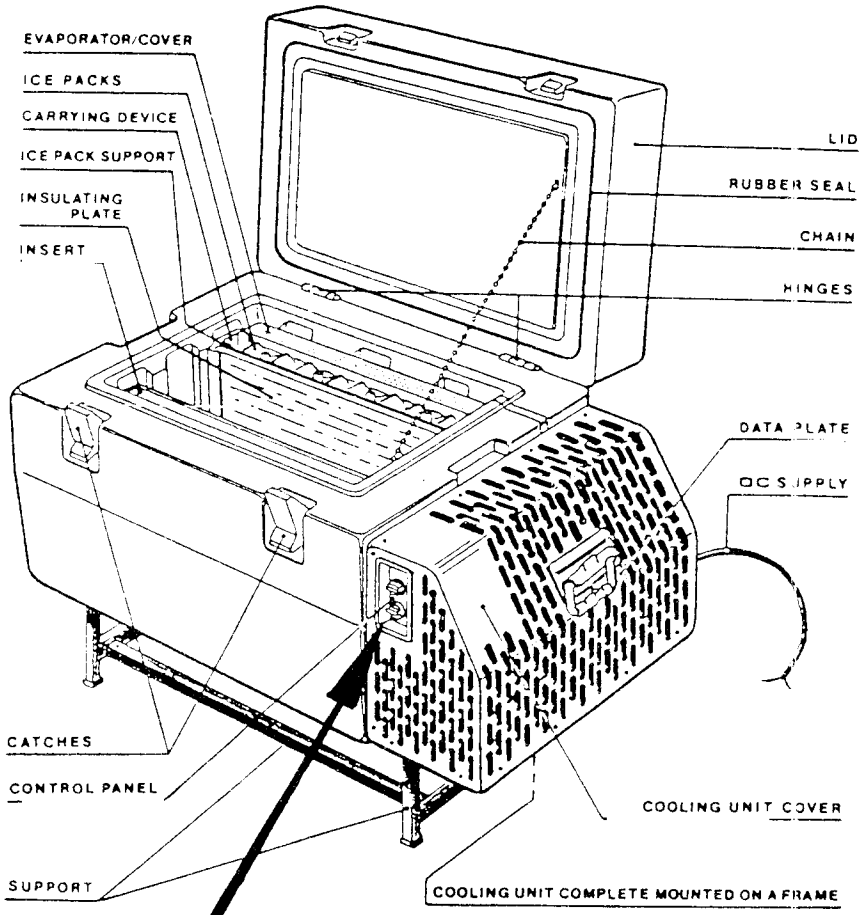
VENTILATION GRILLE: an opening in the side of the **SOLAR POWERED REFRIGERATOR** that allows air to circulate around the **CONDENSER** and **COMPRESSOR.**

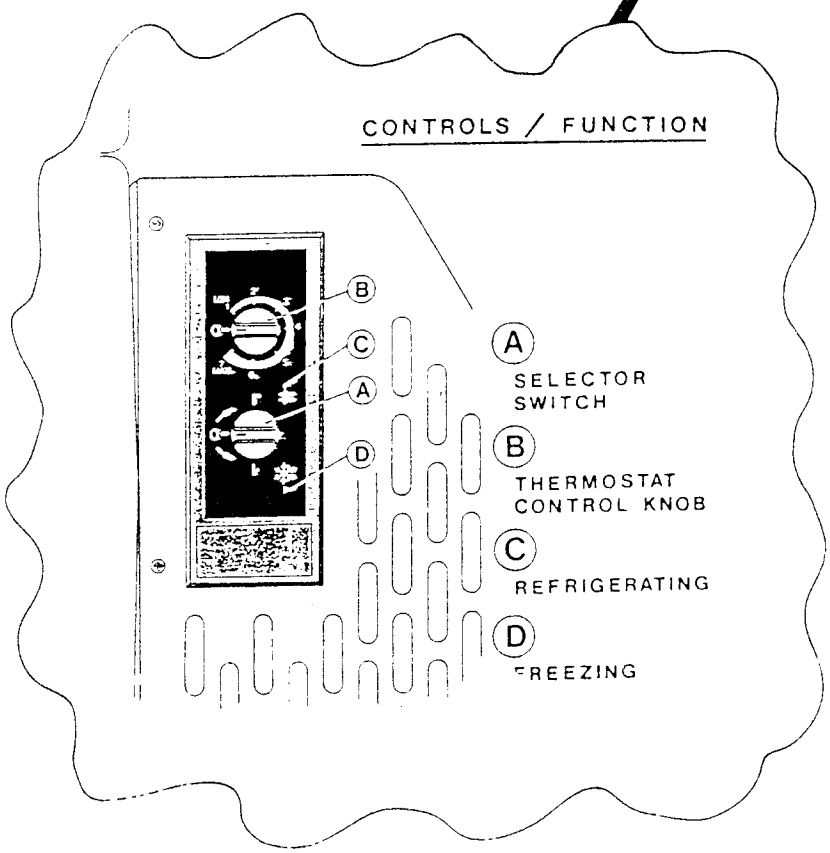
ANNEX 1

COMPONENT LAYOUTS OF SOME COMMONLY USED SOLAR REFRIGERATORS

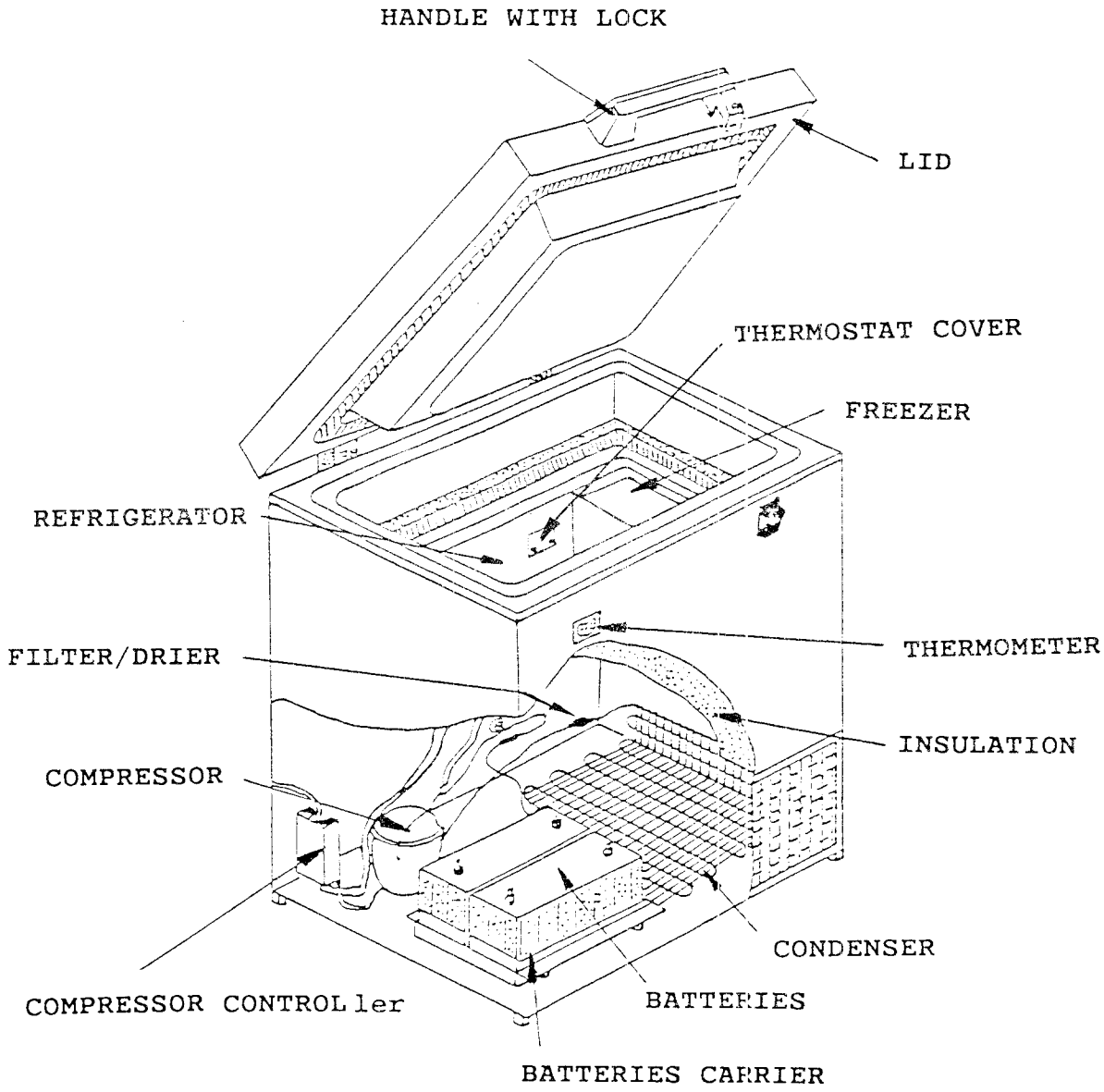


BP SOLAR VR50

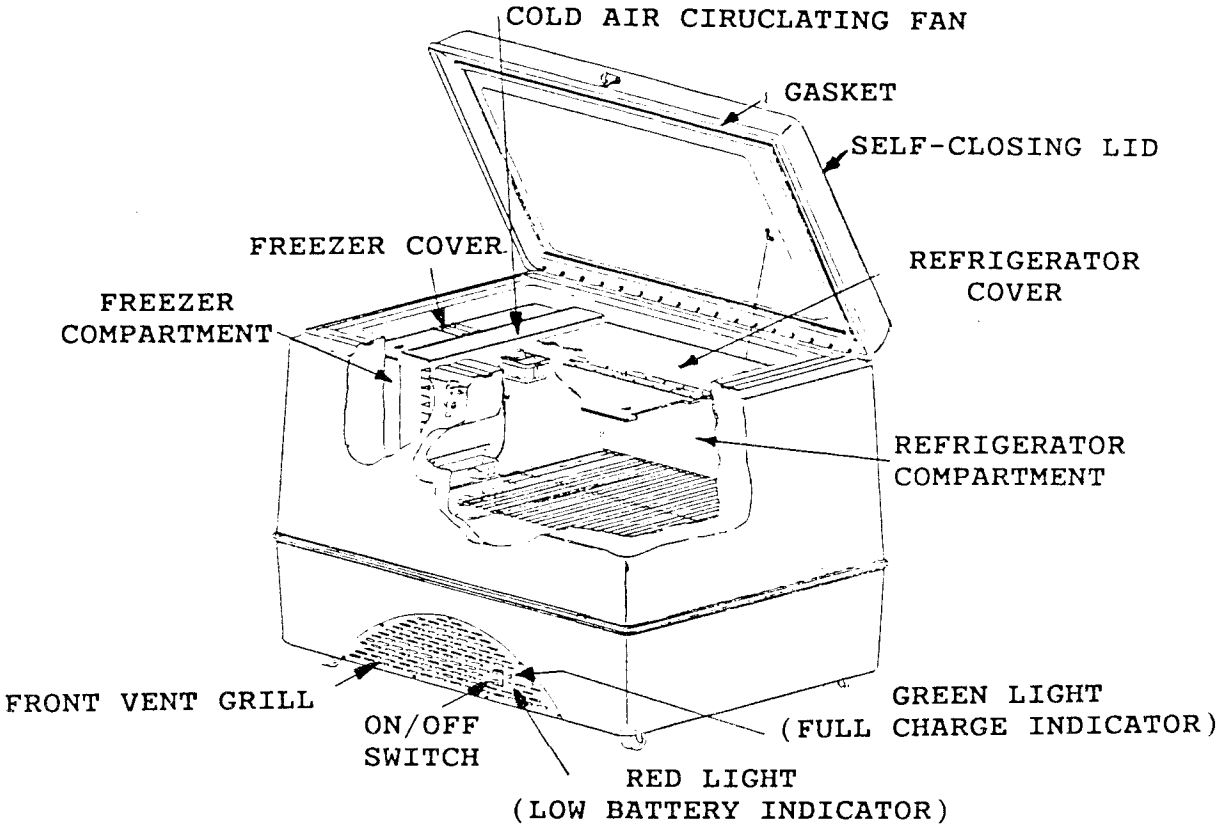


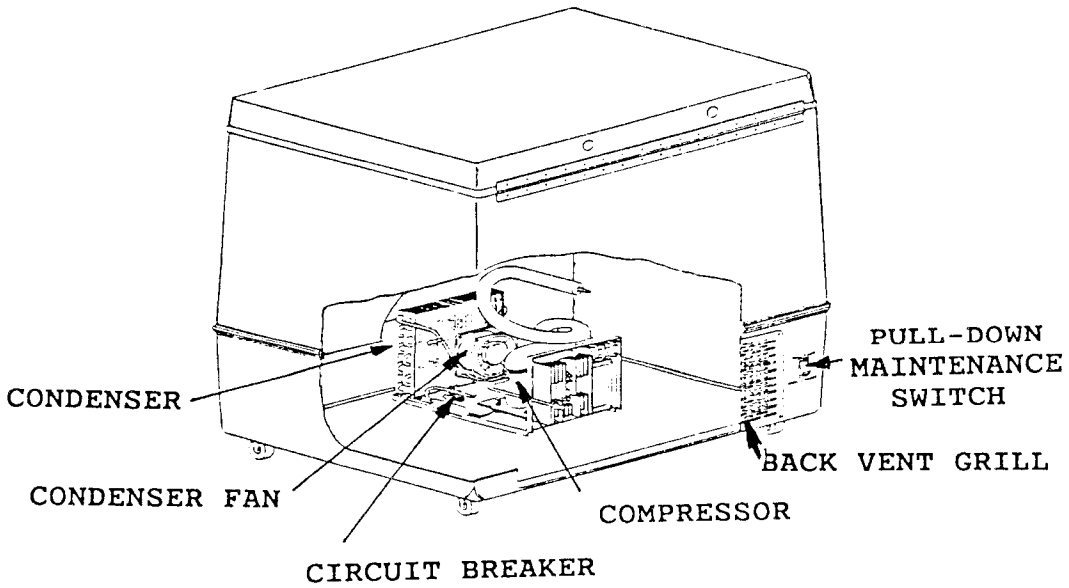


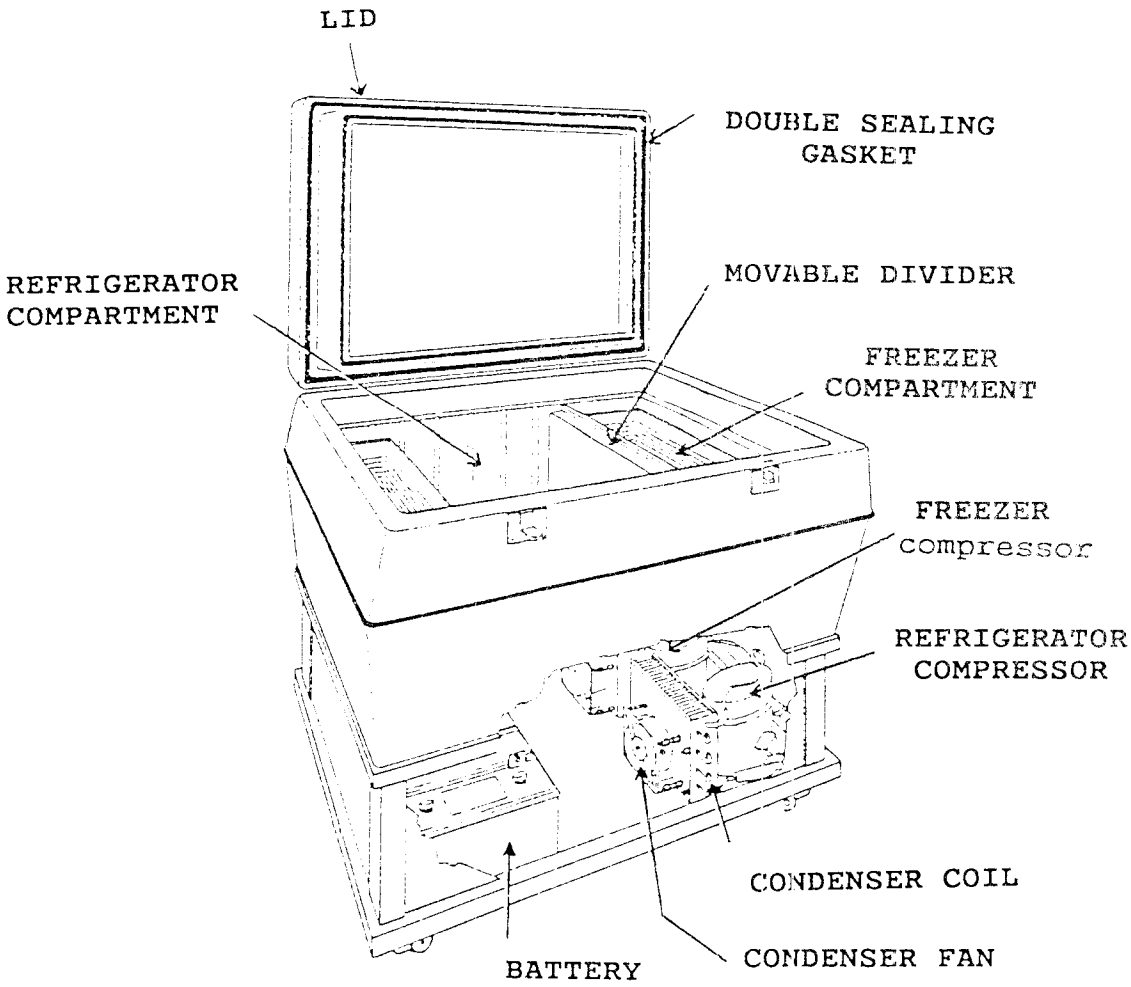
ELECTROLUX RCW42


HANDLE WITH LOCK
LID
THERMOSTAT COVER
FREEZER
REFRIGERATOR
THERMOMETER
FILTER/DRIER
INSULATION
COMPRESSOR
CONDENSER
COMPRESSOR CONTROL ler
BATTERIES
BATTERIES CARRIER

FNMA 75


COLD AIR CIRUCLATING FAN
GASKET
SELF-CLOSING LID
FREEZER COVER
REFRIGERATOR COVER
FREEZER COMPARTMENT
REFRIGERATOR COMPARTMENT
FRONT VENT GRILL
ON/OFF SWITCH
GREEN LIGHT (FULL CHARGE INDICATOR)
RED LIGHT (LOW BATTERY INDICATOR)


PULL-DOWN MAINTENANCE SWITCH
CONDENSER
BACK VENT GRILL
CONDENSER FAN
COMPRESSOR
CIRCUIT BREAKER



POLAR PRODUCTS

ANNEX II

ADDITIONAL EPI TOOL KIT NEEDED FOR PHOTOVOLTAIC REFRIGERATOR REPAIR

ADDITIONAL TOOLS REQUIRED TO THE STANDARD UNIPAC/EPI TOOL KIT

- Multimeter (digital)
  - 10 Amp
  - 10 mV accuracy
  - Ohm
- 2 shunts
  - 0-200 mV at 0-20 Amps
- 1 hydrometer, break proof
- 1 compass
- 1 pair of plastic gloves
- 1 spirit level
- 1 latitude template (to manufacture on site)
- 1 mercury in glass thermometer - range 10-60^{o}C
- 1 protective sheath for thermometer
- 1 bimetal thermometer

= = =

(continued from front inside cover)

(b) REFRIGERATOR USE, MAINTENANCE AND REPAIR SERIES

This series, which is grouped into 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 refrigerators

- 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.)

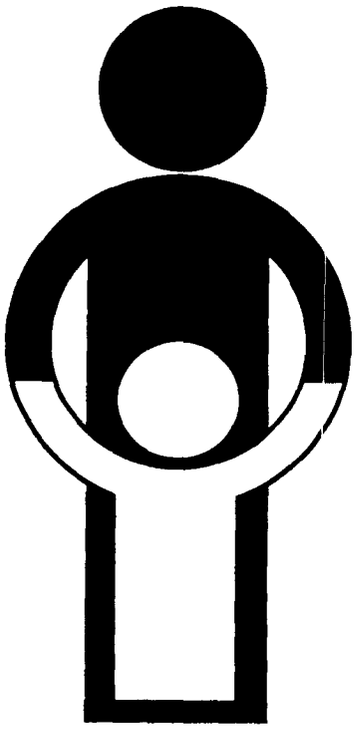
14. How to look after a compression refrigerator
15. User's handbook for compression refrigerators

16. How to look after a kerosene refrigerator
17A. User's handbook for kerosene refrigerators (Electrolux RAK 1302)
17B. User's handbook for kerosene refrigerators (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 ORGANISATION MONDIALE DE LA SANTE

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