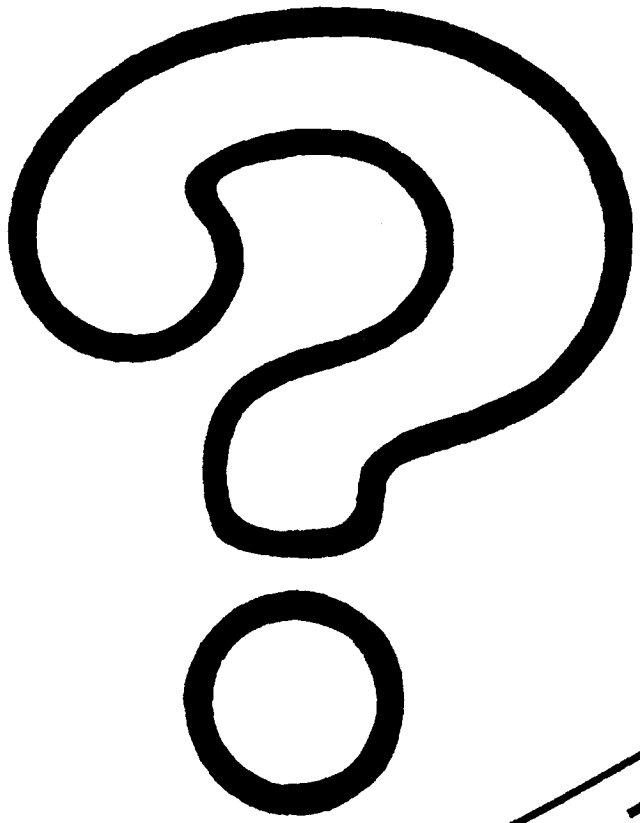
TECHNICIAN'S HANDBOOK FOR
COMPRESSION REFRIGERATORS

PART E

TASK SHEETS
AND
PROGRESS TESTS



Addendum

TASK SHEETS ON PHOTOVOLTAIC REFRIGERATORS

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

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

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

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

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

(continued on back inside cover)

(continued from front inside cover)

(b) REFRIGERATOR USE, MAINTENANCE AND REPAIR SERIES

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

- Repair Technicians Handbooks

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

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

- User and Maintenance Handbooks

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

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

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

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

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

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

WORLD HEALTH ORGANIZATION

EXPANDED PROGRAMME ON IMMUNIZATION

TECHNICIANS HANDBOOK FOR

COMPRESSION REFRIGERATORS

PART E

ADDENDUM

TASK SHEETS

ON

PHOTOVOLTAIC REFRIGERATORS

TECHNICIAN'S HANDBOOKS FOR COMPRESSION REFRIGERATORS

PART E

TASK SHEETS ON PHOTOVOLTAIC REFRIGERATORS

CONTENTS

A: HOW A SOLAR PHOTOVOLTAIC REFRIGERATOR WORKS

Task Number 1: **Identify the parts of the refrigerator**

Equipment required: None

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 2 and 7.

Introduction:

The cooling system of a solar photovoltaic refrigerator is almost the same as a normal compression refrigerator. The main difference is that a solar powered refrigerator runs on 12V or 24V DC electricity.

A normal compression refrigerator runs on 110V, 220V or 240V AC electricity.

Action:

Look closely at your solar photovoltaic refrigerator. Find the following parts of the cooling system and point them out to your instructor.

(a) Compressor
(b) Condenser
(c) Evaporator
(d) Filter-drier
(e) Thermostat
(f) Capillary tube
(g) Refrigerator Compartment
(h) Freezer Compartment
(i) Door/lid seal
(j) Compressor Controller
(k) Temperature Indicators

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

Equipment required: None

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 2, 6 and 7.

Action:

1. Find the following parts of the solar electricity supply system for the photovoltaic refrigerator and point them out to your instructor. Answer the questions listed below.

   (a) The solar array
   (b) A solar module
       How many modules are there?
   (c) Charge regulator
   (d) Battery bank
       How many batteries are there?
   (e) The Electrical cables

2. Explain to your instructor how a refrigerator works.

B: SAFETY CONSIDERATIONS

Task Number 3: Batteries

Equipment required: Battery acid
Small piece of glass

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 3 and 4.

Action:

1. Explain why batteries are dangerous.

2. What should you do if acid from a battery gets on your skin or on your clothes. What will happen?

3. What should you do if acid from a battery gets in your eye?

4. Why should batteries be kept upright? What do you do if acid is spilled?

5. Is it dangerous to have flames and cigarettes close to batteries? Why?

6. What should you do before you disconnect a battery from a refrigerator? Why?

7. A battery has one positive and one negative terminal, which terminal do you connect first when you are replacing a battery in a refrigerator. Do you do the same when you are disconnecting a battery?

8. Your instructor will pour a few drops of acid on to the following materials:

   - a piece of glass
   - a piece of wood
   - a concrete or tiled floor

   What happens? How would you clean up the acid after a spill?

Task Number 4: **Photovoltaic Array**

Equipment required: Ladder, crawling boards, large cloth.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 4.

Action:

1. Is a photovoltaic array dangerous? Why?
2. Before you connect or disconnect the wires of a photovoltaic array what must you do?
3. Why are photovoltaic arrays often mounted on the roof, or in a protective fence?
4. How should you transport a photovoltaic array or modules?
5. If a photovoltaic array is mounted on a roof what must you do to have safe access?
6. Check that the access to the photovoltaic array is safe. Recommend changes to the instructor which would make access easier and safer.
7. Prepare a photovoltaic array so that it is safe to start work on.

Task Number 5: **First Aid Measures**

Equipment required: First Aid Kit

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 4.

Action:

1. What is the difference between acid and electrolyte?
2. What do you do if battery acid splashes in your eye?
3. What must you do if acid or electrolyte falls on your skin?
4. If someone falls from the roof or a high place, what should you do?
5. If someone receives and electrical shock, what should you do?
6. Do you have a first aid kit? What does it contain? What is the purpose of each item in it?
7. Demonstrate to your instructor how you would use the items in your First Aid Kit.

C: HOW TO MEASURE

Task Number 6: **Temperature**

Equipment required: Operating refrigerator system, Technician Repair Kit

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 8 to 10.

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.

Action:

1. How would you check the accuracy of a bi-metal thermometer?

2. Thermometers used in the compartments of refrigerators frequently have red and/or green ranges marked on the scale. Look at the ranges on the thermometers and explain to the instructor the correct temperature at which the refrigerator compartments should be operating.

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 0-80^{o}C; why? The thermometer should be encased in a metal shell to protect it from breakage.

Action:

1. Place the bulb of the thermometer in the electrolyte, it should be held carefully for about 30 seconds before you read it. You must be careful not to press the thermometer bulb against the metal plates in the battery because they are delicate and easily damaged. Read the temperature.

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

Task Number 7: **Identify positive and negative terminals**

Equipment required: Operating Photovoltaic Refrigerator

Handbook reference: None

Action:

1. Positive terminals should be marked with a + sign. Negative terminals are marked with a - sign.

2. Find the following positive (+) and (-) terminals and point them out to your instructor.

   (a) Solar array output terminals
   (b) Output terminals (in the module junction box) on a solar module
   (c) Charge regulator terminal strip: terminals for solar array, batteries and refrigerator
   (d) Battery terminals
   (e) Compressor Controller terminals
   (f) Thermostat terminals

3. The terminals may have other marks on them, depending on the type of refrigerator. Ask your instructor what these marks mean.

Task Number 8: **Measure voltage**

Equipment required: Voltmeter or Multimeter, crocodile clips

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 13.

Action:

1. Adjust thermometer so that it is set to measure DC voltage, in the range 0 to 30V DC.

2. Without disconnecting any wires, measure the voltage across the terminals listed below. Make sure that you connect the positive (+) terminal to the positive (red +) wire from the multimeter and the negative (-) terminal to the negative (black -) wire from the multimeter.

3. Measure the following voltages and write them below:

   (a) Charge regulator output to the refrigerator
   (b) Input voltage at the Compressor Controller
   (c) Battery voltage
   (d) Solar array output voltage

4. Discuss the readings with your instructor. Ask him/her to check the voltages. Are the values what you would expect?

RESULTS:

Charge regulator output voltage .....
Input voltage to the Compressor Controller .....
Battery voltage .....
Solar array output voltage .....

Task Number 9: **Measure current**

Equipment required: Multimeter, screwdriver, crocodile clips

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 15 to 18.

Action:

1. Adjust the meter so that it is set to measure current in the range 0 to 10A DC.
2. Make sure that the refrigerator is turned OFF.
3. Disconnect the positive (+) wire from the refrigerator terminal on the charge regulator terminal strip.
4. Connect the positive (+) wire of the meter to the positive (+) refrigerator terminal on the charge regulator terminal strip.
5. Connect the negative (-) wire of the meter to the positive (+) wire of the refrigerator that you have just disconnected.
6. Ask your instructor to check that you have connected the multimeter properly.
7. Turn the refrigerator ON and measure the current on the meter and write it down below.
8. Turn the refrigerator OFF and discuss the current that you have measured with your instructor.
9. Disconnect the meter and insert a current shunt to measure the same refrigerator current.
10. Set your multimeter to read millivolts, switch ON the refrigerator and measure the current flowing through the shunt. Explain to your instructor how you converted your multimeter millivolt reading into a current measurement.
11. Switch the refrigerator OFF, disconnect the shunt and reconnect the refrigerator wire. Switch ON the refrigerator again and check it works normally.

RESULTS:

Current measured directly .....
Current measured with a shunt .....

Task Number 10: **Measuring Resistance**

Equipment required: Operating refrigerator system, Technician Repair Kit

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 19 and 64.

Action:

1. Switch OFF the refrigerator.
2. Disconnect the wires from the positive terminal of the battery.
3. Disconnect the electrical socket from the compressor.
4. Set the multimeter to measure resistance.
5. Set the range on the multimeter to 100,000 ohms or the largest range of resistance on your multimeter.
6. Measure the resistance between Pin No. 3 of the compressor and the metal body of the compressor.
7. Write down below the resistance you have measured.

   Resistance: .....

Task Number 11: **Measuring state of charge of batteries**

Equipment required: Operating refrigerator system, Hydrometer, Thermometer

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 20-22.

Introduction

In batteries used for photovoltaic refrigerators the amount of energy stored in a battery at any time is called the "State of Charge". This can be approximately estimated by measuring the voltages across the battery terminals when the battery is being discharged under known conditions of current and temperature. This 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 measured approximately by measuring the density of the electrolyte (that is the name of 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.

Action:

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

2. Leave the battery for 1 hour to allow the acid and water to mix.

3. Measure the specific gravity of the electrolyte as described on Page 21 of the Technicians Handbook and write the measurement down below.

4. Measure the temperature of the battery electrolyte and determine the correction factor to apply to the specific gravity measurement is described on Page 21 of the Technicians Handbook. Write down your measurement.

5. Determine the corrected specific gravity and the state of charge of the battery (Page 22 of Technicians Handbook).

6. Determine the state of charge of several other batteries indicated by your instructor.

Specific Gravity Reading ....

Electrolyte Temperature ....

Correction to Specific Gravity ....

Corrected Specific Gravity ... .

State of Charge of Battery ... .

Task 12: **Measuring the Tilt and Direction of the Photovoltaic Array**

Equipment required: Operating refrigerator system, Technician Repair Kit

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 24.

Action:

Tilt

1. If you do not already know, find out the approximate latitude of the place where the refrigerator is installed. This is the angle the array should be tilted at. Write down the angle below.

2. Cut out a triangle from cardboard (DO NOT MAKE IT FROM METAL) The triangle should have:

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

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 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.

5. If the spirit level is not level adjust the tilt of the array so that the bubble on the level indicator shows that it is level.

6. If the latitude is less than 5^{o} what tilt should the photovoltaic array have? Explain the reason for your answer to the instructor.

   Latitude: .....

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 triangle (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 will point along the line of the edge of the template if the array slopes towards the equator as it should;

   - 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. If the array is not pointing in the correct direction, adjust it and recheck the direction with the compass and template.

Task Number 13: **Measuring Open Circuit Voltage**

Equipment required: Photovoltaic Array, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 13, 14 and 27.

Action:

1. To test the photovoltaic array or one of the modules in the array, you need to be able to measure the open-circuit voltage (V_{oc}).

2. Measure V_{oc} at around 12 noon on a very sunny day.

3. V_{oc} is the voltage across the two output terminals when no electrical current is flowing. Measure V_{oc} for the array by disconnecting one solar array output wire from the terminal box.

4. Measure the voltage across the solar array and write down your answer below.

5. Now make the necessary disconnections to measure the V_{oc} of one module and explain to your instructor what you are doing and why. Take the measurement and write it down below.

6. Ask your instructor for the manufacturers data and compare the readings.

   Array V_{oc}: .....

   Module V_{oc}: .....

Task Number 14: **Measuring Short Circuit Current**

Equipment required: Photovoltaic Array, Technicians Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 15 and 28.

Action:

1. To test the solar array or one of the modules you need to be able to measure the short-circuit current (I_{sc}).
2. Measure I_{sc} at round 12 noon on a very sunny day and during a long period of uninterrupted sunshine (no clouds).
3. I_{sc} 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.
4. Measure I_{sc} of the solar array by disconnecting a solar array output wire from the junction box. Take a measurement and write it down below.
5. Measure I_{sc} of one of the solar modules by disconnecting the module from the solar array at the module junction box. Take a measurement and write it down below.
6. Reconnect the output wires to the correct terminals after you have finished.

Array I_{sc}: .....

Module I_{sc}: .....

D: MAINTENANCE AND SERVICE TASKS

Task Number 15: Checking the Daily Records

Equipment required: Completed Record Sheets

Handbook reference: A User Handbook for Photovoltaic Refrigerators. Table 1 Page 5.

Action:

1. Who normally fills in the DAILY RECORD SHEETS?
2. Who looks at the DAILY RECORD SHEETS and why?
3. If some of the readings in the column TEMPERATURE IN REFRIGERATOR COMPARTMENT show that the temperature is $-2^{o}C$ then what should you do.
4. If the readings in the column TEMPERATURE IN REFRIGERATOR are all between $0^{o}C$ and $8^{o}C$ but the Column INDICATORS ON shows that the DO NOT FREEZE ICEPACKS or FRIDGE DISCONNECTED indicators have been lit sometimes; What should you do?
5. What is the largest amount of icepacks which have been loaded into the freezer compartment in one day. Is this more or less than the maximum number specified in Table 1 of the USERS HANDBOOK.
6. If any of the readings in the INDICATORS ON column show that the DO NOT FREEZE ICEPACKS or FRIDGE DISCONNECTED indicators have been lit, are these occasions when vaccine or icepacks were loaded? Is this normal?
7. How many times has the refrigerator not been operating correctly according to the DAILY RECORD SHEET.
8. Discuss with your instructor the actions you would take to find any faults which are apparent from the DAILY RECORD SHEETS.
9. What other information should be contained on the DAILY RECORD SHEETS. Why?

Task Number 16: **Checking temperatures, lights and any other indicators.**

Equipment required: Operating refrigerator system, equipped with thermometers and indicators.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 8 and 9.

Action:

1. Identify the indicator lights and meters fitted to the refrigerator system.

2. Explain the purpose of each indicator.

3. What are the positions or status of each indicator when the refrigerator is operating normally?

4. If any of the indicator lights or meter shows that the refrigerator is not operating normally, what is the FIRST thing that the USER should do?

5. If any of the indicator lights or meters show that the refrigerator is not operating normally, what is the FIRST thing that the REPAIR TECHNICIAN should do?

6. How do you know that the thermometers are working correctly? Explain to the instructor how you would check this.

7. How do you know that the indicator lights are operating? Explain to the instructor how you would check this.

8. If the DO NOT FREEZE ICEPACKS indicator is lit and the refrigerator compartment temperature reads $7^{O}C$ on the thermometer, what does this mean?

Task Number 17: **Checking free air circulation**

Equipment required: Operating refrigerator system, equipped with thermometers and indicators.

Handbook reference: A User Handbook for Photovoltaic Refrigerators. Page 9.

Action:

1. Why is it necessary to have free air circulation around the refrigerator?

2. Which parts of the refrigerator need to have air circulated around them?

3. Should the refrigerator cabinet be raised off the ground? Why?

4. If the refrigerator is installed so that direct sunlight falls on it during some of the day, is this important? What should you do about it?

5. Should the refrigerator be installed in a small room which is completely closed? If so, why?

6. How much free space should be left around the refrigerator?

7. What will the thermometers or indicators show if there is not enough free air circulation around the refrigerator.

8. Should the USER know that free air circulation around the refrigerator is important?

Task Number 18: **Is the Refrigerator loaded correctly**

Equipment required: Operating refrigerator system, fully loaded and equipped with thermometers and indicators.

Handbook reference: A Users Handbook for Photovoltaic Refrigerators. Pages 5 and 12.

Action:

1. How much vaccine can be stored in the refrigerator?
2. How many icepacks can be put into the freezer compartment in any 24 hour period?
3. If the DO NOT FREEZE ICEPACKS indicator comes on, what must the USER DO?
4. How much space should be left between vaccine packs?
5. Should the refrigerator be switched ON or OFF when you are loading it?
6. Unload the refrigerator completely. Where must you put the vaccine?
7. Load the vaccine in the refrigerator compartment correctly and show the instructor. Record the quantity of vaccine loaded on the DAILY RECORD SHEET.
8. When can you keep food and drinks in the refrigerator?
9. What should you do if the indicator light FRIDGE DISCONNECTED is lit?

Task Number 19: **Check the ice forming around the freezer compartment. Defrosting**

Equipment required: Operating refrigerator system, User Service Kit.

Handbook reference: A Users Handbook for Photovoltaic Refrigerators. Page 15.

Action:

1. Check the amount of ice forming around the freezer compartment. What thickness of ice can you allow before you need to defrost the refrigerator?

2. What should you do with the vaccine when defrosting a refrigerator?

3. Described to your instructor what you should do after all the ice has melted.

Task Number 20: **Checking the lid/door seal**

Equipment required: Operating refrigerator system, User Service Kit.

Handbook reference: Users Handbook for Photovoltaic Refrigerator Page 21.

Introduction:

The lid/door seal prevents the cold inside the refrigerator and freezer compartments from escaping into the room when the door/lid is closed.

Action:

1. Open the refrigerator and place a thin paper strip over the place where the seal of the refrigerator cabinet comes into contact with the lid/door.

2. Close the lid/door.

3. Pull the paper strip. If it moves easily the door/lid needs adjustment or the seal needs replacing.

4. Try the paper strip all around the lid/door in this way, paying special attention to the corners.

5. Check all the way around the lid/door in this way, paying particular attention to the corners.

6. If the seal is not making good contact show your instructor and tell him what you would do to make good the seal.

Task Number 21: **Clean the Photovoltaic Array**

Equipment required: Photovoltaic Array

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 30.

Introduction:

Dust and dirt on the photovoltaic array reduces its capacity to produce electricity. It should always be kept clean.

Action:

1. CLEAN THE ARRAY as described on Page 30 of the Technicians Handbook. Remember - do not stand on the solar array, or lean heavily on it, as this may break it.

2. At what time of day should you clean the array? Why?

3. Who is normally responsible for cleaning the solar array?

4. What safety precautions do you taken when cleaning the solar array?

Task Number 22: **Checking for shadowing of the array**

Equipment required: Operating refrigerator system, User Service Kit, Compass

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 31.

Introduction:

Shading of the array, even partly, will reduce the amount of electricity produced for the refrigerator.

Action:

1. When you are standing by the photovoltaic array, identify any trees or buildings within 50 meters.

2. Use your compass to determine the direction of these trees or buildings.

3. If your compass shows that these trees or buildings are towards the South (if you are North of the equator) or to the North (if South of the equator) then they may shade the array.

4. To check this more carefully, look at the array at 8.00 a.m., at 12.00 noon and at 4.00 p.m. to see if the array is shaded because of these trees or buildings.

5. If the array is shaded what can you do?

6. If the array is close to being shaded, is this likely to cause a problem during another season of the year? Explain this to your instructor.

7. You will need to cut back bushes and trees that have started to shade the solar array between 8.00 a.m. and 4.00 p.m. Trees and bushes which only cause shading in early morning (before 8.00 a.m.) or late afternoon (after 4.00 p.m.) do not need to be cut. What should you do before cutting down any trees or bushes?

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

9. What do you need to do if a new building causes shadows to fall on the array?

Task Number 23: **Cleaning the parts of the refrigerator cabinet**

Equipment required: Operating refrigerator system, User Service Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 37.

Introduction:

To operate correctly and reliably, the refrigerator cabinet and the parts inside it must remain clean.

Action:

1. CLEAN THE PARTS OF THE REFRIGERATOR CABINET as follows:

   (i) Switch OFF the refrigerator.

   (ii) Remove or open the cover which provides access to the compressor, condenser and fan (if fitted) of the refrigerator cabinet.

   (iii) Use the soft brush provided with your refrigerator to remove any dust and dirt from the condenser and compressor.

   (iv) If the condenser is fitted with a fan, make sure that the fan rotates freely, and brush dirt and dust away from the fan and fanmotor.

   (v) Switch the refrigerator ON again.

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

Task Number 24: **Checking the level of acid in the batteries**

Equipment required: Operating refrigerator system, User Service Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 34 and 35.

Action:

WARNINGS:
- o KEEP NAKED LIGHTS, SPARKS AND HEAT AWAY FROM BATTERIES AS EXPLOSIVE GASES MAY BE PRESENT.
- o LIQUID (ELECTROLYTE) IN BATTERIES IS CORROSIVE. KEEP OFF SKIN AND AWAY FROM EYES. AVOID CONTACT WITH CLOTHES.

1. If the batteries are sealed they will NEVER need topping up.
2. If the batteries are not of the sealed type, then they will have plastic stoppers or a plastic lid on the top. Remove each stopper or each lid one by one and see if the metal plates inside are covered by liquid.
3. Show your instructor to which level the batteries should be topped up with distilled water.
4. Add DISTILLED WATER, if necessary to each cell until it is filled up to the correct level indicated or until the metal plates are well covered. Use the plastic bottle with a spout or a clean funnel to put in the water.
5. Replace each stopper or lid.
6. It is important that ONLY DISTILLED WATER is used. Why?
7. Explain to your instructor why it is necessary to ask the user questions about how he or she maintains the batteries. What questions should you ask and what are you able to conclude from the replies.

Task Number 25: **Checking that the refrigerator system is safe and secure**

Equipment required: Operating refrigerator system, User Service Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 29.

Action:

1. Check that:

   (a) the array is firmly mounted,

   (b) all cables or electrical wiring connecting the different parts of the system together are firmly attached to the wall or floor if they are not inside the refrigerator cabinet,

   (c) there is safe access to the photovoltaic array and all parts of the array are secure,

   (d) the batteries are secure and cannot be reached by children,

   (e) no parts of the refrigerator cabinet are loose or dangerous to the people who use the refrigerator system.

2. Report any defects to your instructor and explain what must be done to correct the problem.

E: FAULT FINDING AND REPAIR TASKS

Task Number 26: **Determine the Symptoms**

Equipment required: Photovoltaic Refrigerator, thermometer

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 39.

Action:

1. How do you know if the refrigerator is operating correctly? What are the things to do to find out?
2. What are the temperatures inside the refrigerator compartment? What should they be?
3. What are the temperatures inside the freezer compartment? What should they be?
4. Is the compressor running?
5. If there is a noise like a motor running how can you tell whether it is the compressor running or the condenser fan.
6. What are the ways to check if the compressor is running.
7. If the refrigerator temperature is too cold, should the compressor be running?
8. If you have decided that the refrigerator is not operating correctly, there are three possible symptoms. What are they?
9. When you have determined the symptom of the fault, what do you do next?

Task Number 27: **Preliminary Checks and Actions**

Equipment required: User service kit and photovoltaic system.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 39 and 40.

Action:

1. If a refrigerator is too warm (above $8^{o}C$) and the compressor is not running, what checks and actions would you do?

2. In what order would you do these checks and actions?

3. If you do these checks and actions twice and are still sure that your choice of symptom is correct, then what do you do?

4. The refrigerator compartment is warmer than $8^{o}C$ and the compressor is running at times or always. What checks and actions are necessary?

5. If the temperature of the refrigerator compartment is lower than $0^{o}C$, what is the first thing that you must do?

6. Does the refrigerator have a removable separator between the refrigerator and freezer compartments? Is it correctly positioned? If not what will happen?

7. After you have conducted the checks and actions which correspond with any of the 3 symptoms and still think that the refrigerator is not operating correctly, what do you do before proceeding step by step through the fault finding charts?

8. What tools are supplied in the user service kit? Make a complete list for your instructor, and suggest any additional tools that you think the user is likely to need.

Task Number 28: **The Fault Finding Charts**

Equipment required: None

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 41 and 43.

Action:

1. What is the difference between CHART No. 1, CHART No. 2 and CHART No. 3?

2. How do you know which CHART to use?

3. What must you do with any vaccine before checking out the faults in the charts?

4. What is the first rule to follow when using any one of the charts?

5. Can you name the checks which are normally the responsibility of the user?

6. If you have carefully checked each fault on the chart which corresponds to the symptom of the fault and the refrigerator system still does not work. What should you do?

Task Number 29: **Thermostat**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 47 to 49 and 71.

Action:

1. Measure the temperature of the refrigerator in the vaccine compartment. Is it too warm or too cold?

2. Show your instructor in which direction you need to adjust the thermostat.

3. **If the refrigerator compartment is too cold:**

   (a) Adjust the thermostat to its warmest position

   (b) If the compressor was running what should now happen?

   (c) If the compressor stops running adjust the thermostat (Page 71 of Technicians Handbook) until the correct temperature is achieved.

   (d) If the compressor does not stop running change the thermostat.

4. **If the refrigerator is too warm:**

   (a) Adjust the thermostat to its coldest position.

   (b) If the compressor was not running what should now happen?

   (c) If the compressor started running adjust the thermostat until the correct temperature is achieved. (Page 71 of Technicians Handbook).

   (d) If the compressor does not start running what should you do next?

Continued .....

(e) If the compressor is not running, temporarily connect a wire across the 2 terminals of the thermostat.

The compressor should run.

If the compressor runs when you connect a wire, but does not run with the thermostat connected what faults are likely?

(f) If the compressor does not run:

- o tighten, correct or change the wires, or
- o change the thermostat in accordance with the manufacturer's instructions.

Task Number 30: **Fuses**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 50 to 53.

Action:

1. Point out to your instructor where fuses are located on the photovoltaic refrigerator.

2. Switch off the refrigerator.

3. 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.

4. Check the electrical resistance of the fuse. What resistance would you expect to read if the fuse has blown?

5. Take a spare fuse and measure the resistance of the new fuse so that you know it is good. Thoroughly clean the fuse holder and put in the spare fuse.

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

7. If the compressor is still not running, turn off the refrigerator take out the fuse and check it. If the fuse is blown what should you check for?

8. Carry out the checks after you have told your instructor what the checks should be.

9. Do not forget to replace the fuse and switch on the refrigerator after you carried out these checks and the fault has been repaired.

Continued .....

10. Does the charge regulator have a fuse? If yes

    (a) Switch off the refrigerator?

    (b) Check the electrical resistance of the fuse

    (c) If the fuse has blown what checks should you make?

    (d) Carry out these checks after you have told your instructor what the checks should be.

    (e) Do not forget to replace the fuse and switch on the refrigerator after you have carried out these checks and the fault has been repaired.

Task Number 31: **Batteries**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 54, 55 and 78.

Introduction:

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

Action:

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.
5. Switch off the refrigerator.
6. 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.
7. If the refrigerator does not run with fully charged batteries explain to your instructor what you would do next.
8. Explain to your instructor how you would charge up batteries with a low state of charge.

Task Number 32: **Wiring**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 32,56 and 72.

Action:

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 a 11.5 to 13 volts if the batteries are adequately charged. (23 to 26 volts for 24 volt systems).

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.

3. Switch OFF the refrigerator.

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

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

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

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

8. Check the continuity of all wires using the multimeter. Replace any wire that has a break.

9. Reconnect all wires. Check the voltages at the solar array and compressor controller again to confirm the fault has been repaired.

10. Switch ON the refrigerator.

Task Number 33: **Photovoltaic Array**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 58 and 69.

Action:

1. Measure the open circuit voltage at the terminals of the solar array which are normally connected to the charge regulator and at the terminals of each module. In sunlight this voltage should be 17 to 20 volts for most modules intended for use on 12 volt refrigerators. (33 - 39 volts for 24 volt systems).

2. Measure the short circuit current which flows between the terminals of the solar array.

3. Measure the short circuit current between the terminals of each module.

4. Do you think these values are correct. Check with your instructor. What simple relationships between module and array measurements should apply to the voltage and current measurements?

5. If your measurements do not appear correct check the open circuit voltage and short circuit current of each module. If the voltages and current of all modules are similar what could be the problem?

6. If one module appears faulty replace it as described on Page 69 of the Technicians Handbook.

7. Reconnect all wiring and recheck the performance of the array.

Task Number 34: **Compressor Controller**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 60 and 75.

Action:

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

2. 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.

3. If the compressor does not run, CHECK THE FUSE in the compressor controller again as explained on Page 50 of the Technicians Handbook.

4. If the compressor still does not run, change the compressor controller with another of the same model (See Page 75 of the Technicians Handbook).

5. If the compressor does not run with a new compressor controller the compressor controller is NOT faulty.

Task Number 35: **Charge Regulator**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 61 and 73.

Introduction:

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

Action:

1. Switch the refrigerator OFF. If the charge regulator has an ON/OFF switch or circuit breaker switch this off too.

2. Cover the solar array with a thick cloth or sheet.

3. Replace the charge regulator as described on Page 73 of the Technicians Handbook. Remember to label all wires so you know where to reconnect them.

4. Uncover the array and turn the refrigerator ON again.

5. Check the refrigerator is working correctly.

Task Number 36: **Condenser Fan**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 62 and 77.

Action:

1. When the compressor is running look to see if the condenser fan is rotating.
2. If it is not rotating a fault if indicated.
3. Switch off the refrigerator.
4. 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.
5. Clean the connections and reconnect the fan wires to the compressor controller.
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 of the Technicians Handbook.

Task Number 37: **Cooling Circuit**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 63.

Action:

1. If the compressor runs and the evaporator plate does not get cold all over what is likely to be the fault?

2. To check if the refrigerator is correctly charged with refrigerant, 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.

3. If you are not familiar with how to add refrigerant to a compression refrigerator tell your instructor. He or she will give you an additional task to do.

Task Number 38: **Compressor**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 19 and 64.

Action:

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 volt system), the compressor should run.

2. If the compressor does not run, proceed as follows.

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

4. Measure the electrical RESISTANCE between connections on the compressor plug with your OHMMETER or multimeter as described on Page 64 of the Technicians Handbook. Note down below your measurements

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

5. Measure the electrical RESISTANCE between Pin No. 3 and the metal body of the compressor. What reading would you expect?

6. If the electrical RESISTANCE between the compressor pins is not VERY LOW or the electrical RESISTANCE between Pin No. 3 and the compressor body is not VERY HIGH, then the compressor is faulty.

7. REMEMBER: ONLY CHANGE THE COMPRESSOR **WHEN YOU ARE SURE** THAT ALL STEPS IN THE FAULT FINDING CHART HAVE BEEN CAREFULLY CHECKED AND YOU ARE SURE THE COMPRESSOR IS FAULTY.

Task Number 39: **Fault Finding**

Equipment required: Operating refrigerator system, Technician Repair Kit.

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook.

Action:

READ TASK 40 ON THE NEXT PAGE. DO THIS TASK AT THE SAME TIME AS TASK 40.

1. Your instructor has introduced a fault into the solar refrigerator.

2. Commence fault finding assuming that the refrigerator is too warm. Use the fault finding charts in Part 3 of the Technicians Handbook.

3. Report to your instructor when you find a fault or if you are uncertain what to do next.

4. When your instructor confirms that you have found the fault correctly, describe the proper steps for making a repair.

5. If your instructor agrees with your plan carry out the repair.

6. Check that the refrigerator works properly after you have completed the work.

7. If you did not find any faulty component but the user reported that the "Do Not Freeze Ice Packs" and "Refrigerator Disconnected" lights are often lit, finallywhat do you think may be the problem?

8. What would you advise the user in this case?

9. What action would you take?

F: MAINTENANCE RECORD KEEPING

Task Number 40: **Maintenance Record Keeping**

Equipment required: Operating refrigerator system, Technician Repair Kit. Maintenance Record Sheets

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Page 79.

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 planning;
- it permits better care of vaccine and reduces waste and increases the effectiveness of the immunisation program.

Action:

DO THIS TASK AT THE SAME TIME AS TASK 39

Fill in a MAINTENANCE RECORD SHEET as you are carrying out the fault finding by following the steps below:

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.
3. Write the quantity and type of batteries in the space provided.

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 on the fault finding chart.

5. When you have followed the "Action" required for the first fault finding and repair task description write the result of your work in the space provided alongside the possible fault before continuing to the next step in the chart.

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

7. When you reach the step where the fault is diagnosed and the "Repair Action Required" is followed to make the repair, proceed to the second side of the MAINTENANCE RECORD SHEET. In the space provided under ACTION, describe the repair.

8. In the block below, give a complete list of the parts used, including part numbers where possible.

9. 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.

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

11. Write your name clearly underneath the date.

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

13. Ask the person at the site who is responsible for the refrigerator to sign the MAINTENANCE RECORD SHEET. In this case this will be your course instructor.

G: USER TRAINING

Task Number 41: **User Training**

Equipment required: Operating refrigerator system, Technician Repair Kit. Maintenance Record Sheets

Handbook reference: Fault Finding and Repair of Photovoltaic Refrigerators: A Technicians Handbook. Pages 85 to 88.

Introduction:

User training is done by the installation technician when the refrigeration system is installed. User training is also done by you the repair technician when servicing or when repairs are performed.

You are also responsible for training the user of the photovoltaic refrigerator system. This training is commonly called on-the-job training.

Action:

1. Consider that your instructor is the USER. Train him or her on:

   (a) Actions on handover

   (b) How to operate the system

   (c) User maintenance

   (d) What to do if a fault occurs

REMEMBER: What may be obvious to you may not be obvious to a user especially one who has only recently been made responsible for a photovoltaic refrigerator. Take your time in explaining and ask the "user" questions to see if he or she understands what you are explaining.

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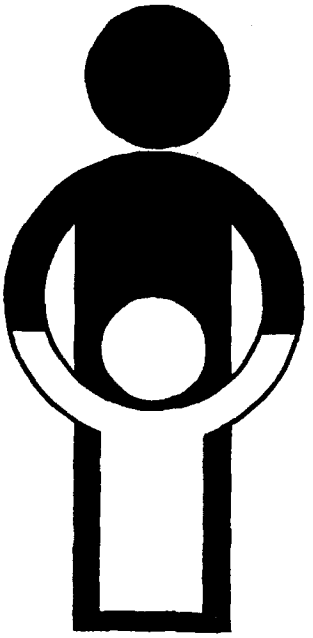

WORLD HEALTH ORGANIZATION ORGANISATION MONDIALE DE LA SANTE

1211 GENEVA 27-SWITZERLAND Telegr.: UNISANTE-GENEVA Telex: 27821 OMS 1211 GENEVE 27-SUISSE Télégr.: UNISANTE-GENEVE