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User's handbook for vaccine cold rooms and freezer rooms

Vaccines and Biologicals

World Health Organization

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Contents

Abbreviations ..... *iv*

Glossary ..... *v*

Revision history ..... *vi*

1. Introduction 1

1.1 Purpose of this handbook 1
1.2 Target readership and limitations 2
1.3 Layout of handbook 2

2. Personal safety 3

2.1 Actions for personal safety 3
2.2 Checklist for personal safety 4

3. Vaccine safety 5

3.1 Action for vaccine safety 5
3.2 Checklist for vaccine safety 6

4. Routine and emergency maintenance 9

4.1 General points 9
4.2 Daily checks 10
4.3 Weekly checks 10
4.4 Monthly checks 12
4.5 Monitor routine and emergency maintenance 12
4.6 Monitor the spare parts inventory 13

5. The room enclosure 14

5.1 The room enclosure 14
5.2 Checklist of room enclosure problems 15

6. Cooling equipment and controls 16

6.1 How the cooling equipment works 16
6.2 Safety during maintenance 21
6.3 Troubleshooting the cooling equipment 21

7. Contingency planning 29

7.1 Safe storage rules 29
7.2 Review contingency options 29
7.3 Prepare and maintain the contingency plan 29

Abbreviations

°C	degrees centigrade
BCG	bacille Calmette-Guérin (tuberculosis vaccine)
CFC	chlorofluorocarbon
cm	centimetres
DT	diphtheria and tetanus toxoid (vaccine)
DTP	diphtheria–tetanus–pertussis (vaccine)
EEFO	earliest-expiry-first-out
EPI	Expanded Programme on Immunization
HepB	hepatitis B vaccine
HFC	hydrofluorocarbon
Hib	*Haemophilus influenzae* type b (vaccine)
IPV	inactivated polio vaccine
mm	millimetres
MMR	mumps–measles–rubella (vaccine)
MR	measles–rubella (vaccine)
OPV	oral polio vaccine
PPM	planned preventive maintenance
Td	tetanus toxoid and diphtheria (reduced component) (vaccine)
TT	tetanus toxoid
UNICEF	United Nations Children's Fund
WHO	World Health Organization
YF	yellow fever (vaccine)

Glossary

Cold room	a purpose made insulated enclosure fitted with refrigeration equipment which maintains a set temperature above 0°C.
Cold store	a facility where the cold room/freezer room or other refrigeration equipment are located, including a packaging area.
Freezer room	a purpose made insulated enclosure fitted with refrigeration equipment which maintains a set temperature below 0°C.

Revision history

Originally issued as *Logistics and cold chain for primary health care: User's handbook for vaccine cold rooms or freezer rooms.* EPI/LOG/84/22.

Revised November 1986.

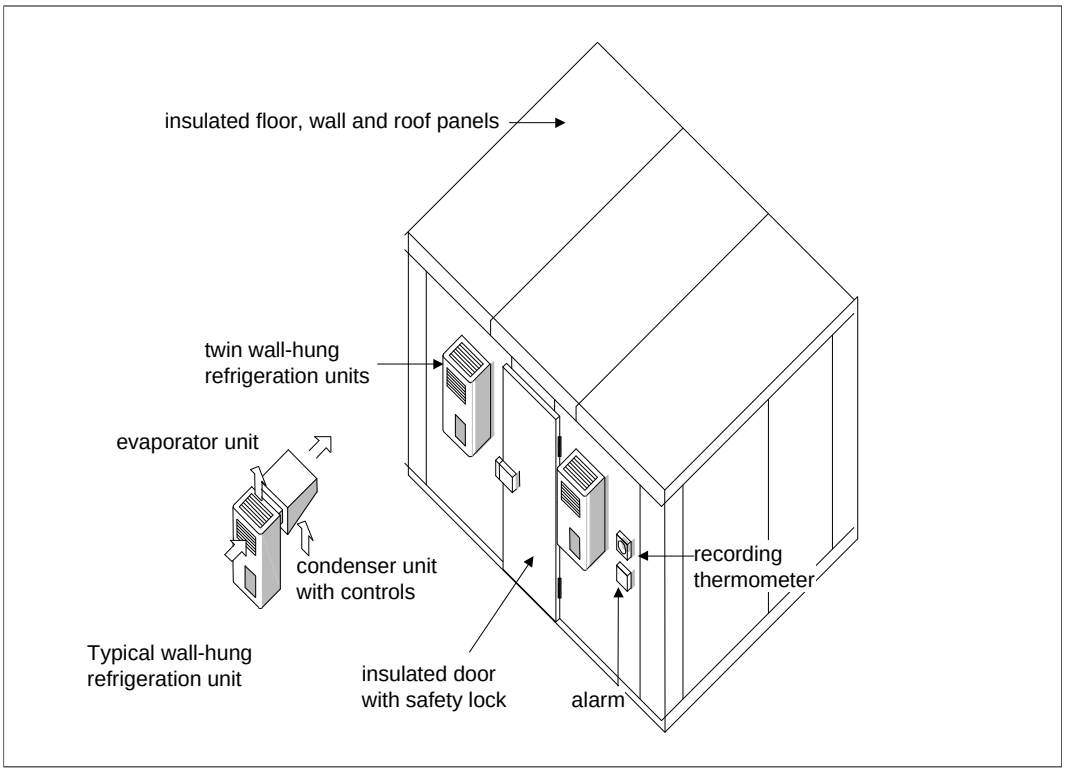
Rewritten and renamed November 2002.

1. Introduction

1.1 Purpose of this handbook

This document teaches you how to look after a modern cold room or freezer room of the type illustrated in Fig. 1. It does not teach you in detail how to service and repair the equipment.

Fig. 1. A modern sectional cold room or freezer room



The document assumes either that

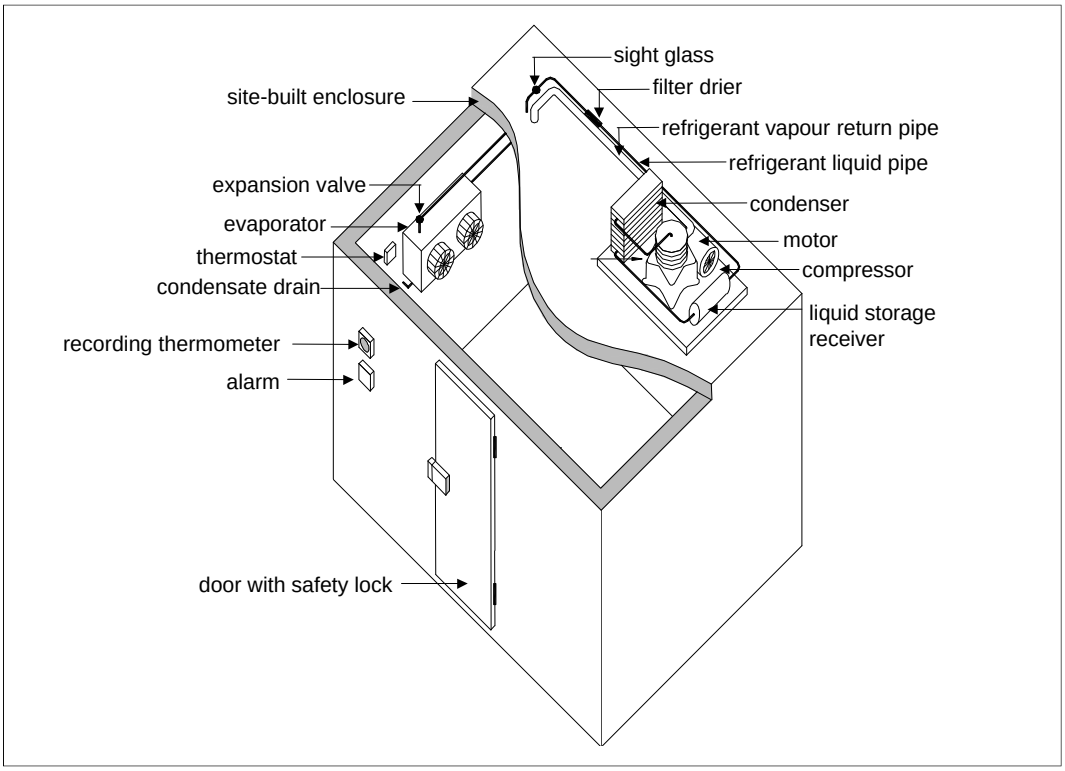
- there is a maintenance agreement with the cold room supplier whereby routine servicing and repairs are carried out by a qualified maintenance technician who is familiar with the equipment;

or that

- the cold room supplier has taught you or one of your colleagues how to service and repair the equipment.

If you have an old-fashioned site-built cold room or freezer room of the type illustrated in Fig. 2 you should also read the November 1986 edition of the *User's handbook for vaccine cold stores* (EPI/LOG/84/22/Rev. 1).

Fig. 2. A site-built cold room or freezer room



1.2 Target readership and limitations

The handbook is intended for persons responsible for managing vaccine stores and their principal assistants. It gives general guidance and advice only. Wherever possible, cold room or freezer room installers should be made responsible for training staff in the use of the equipment installed. The handbook may also be used as a training tool in conjunction with its companion volume: *How to look after a cold room or freezer room: self-assessment tool.* (WHO/V&B/02.30).

1.3 Layout of handbook

The handbook is arranged as follows.

Section 2 tells you how to work safely in cold rooms and freezer rooms.

Section 3 tells you how to store vaccine safely.

Section 4 tells you about routine maintenance and good housekeeping.

Section 5 tells you about the room enclosure and some of the faults that may arise.

Section 6 tells you about the cooling equipment and controls and provides you with a series of fault-finding flowcharts.

Section 7 tells you how to prepare contingency plans for dealing with a major equipment failure.

2. Personal safety

2.1 Actions for personal safety

Working in cold rooms and freezer rooms can be dangerous. This is particularly the case in hot climates where people wear thin clothes and may have no experience of intense cold. In all climates it is important to take the following eight precautions.

1. **Tell a colleague what you are doing.** Do not enter a cold room or freezer room on your own without informing a colleague first. If you become trapped in the room you may suffer from hypothermia and die.
2. **Check the lock.** Before you enter, check that you have the key and that the door was locked by the last user. Keep the key with you so that you cannot be locked in the room by mistake.
3. **Check the door.** Before anyone enters a cold room or freezer room, check that the door can be opened from the inside.
4. **Cold rooms.** Do not work for any length of time in a cold room unless you are wearing warm clothing. Never remain inside on your own for more than a few minutes, otherwise your body will become chilled and your reactions will become slow.
5. **Freezer rooms.** Never enter a freezer room without wearing protective clothing, including gloves. Never remain inside on your own for more than a few minutes, otherwise your body will become chilled and your reactions will become slow.
6. **Dry ice.** Internationally shipped vaccines may be packed in dry ice. Dry ice changes into carbon dioxide gas when it evaporates (sublimes). If carbon dioxide accumulates in a confined space it can cause suffocation. If you receive large quantities of vaccine in international shipping containers, do not place the containers in a small cold room or freezer room until the dry ice has been removed.
7. **Check the people.** When you enter a cold store with more than two or three colleagues, count the people before they go in and count them again when they come out. Make sure no one is left behind.
8. **Lock the door when you leave.** Lock the door and put the key in a safe place.

2.2 Checklist for personal safety

Carry out the following checks at least once a month.

2.2.1 Check the lock

Check that the door lock is working properly and that all keys are accounted for.

2.2.2 Check the door

Go inside the room and ask a colleague to close the door from outside.

- Test the action of the internal safety release handle. Does it work properly? If not, call the maintenance technician.
- A freezer room should have an electrically heated door seal. If the door seal heater is not working the door may freeze shut. If the door is difficult to open and there is ice around the door seal, the heater may not be working. Call the maintenance technician
- A freezer room should be fitted with a pressure release vent. Every time you enter the room you let in a certain amount of warm air. When this cools it contracts and negative pressure begins to build up inside the room. The pressure release vent then opens and allows enough outside air to enter and rebalance the pressure. However, if the pressure release vent is blocked, the negative pressure remains, and the door becomes very difficult to open. If the door is difficult to open, check the release vent to see if it is iced up. Remove the ice if you can. If you cannot do this, call the maintenance technician.

2.2.3 Check clothing

Check what special clothing is available for the people who work in the store.

- Are there warm jackets? Are there warm trousers? Are there warm gloves? Are there enough sets for the people who work in the store? Do they fit the people who work in the store? If the answer to any of these questions is "No", obtain more clothing.
- Are the clothes kept in a safe place where they are not likely to be lost, stolen or damaged? If they are not kept in such a place, arrange for the provision of a suitable safe storage place.

3. Vaccine safety

3.1 Action for vaccine safety

Your primary task when looking after a cold room or freezer room is to protect the vaccines from damage. All vaccines are eventually damaged if they are exposed to excessively high temperatures. Some vaccines are quickly destroyed if they are frozen. Damaged vaccines lose their potency and children who are immunized with such vaccines are not protected against disease.

1. **Know the correct storage temperature for every vaccine.** Learn the correct storage temperature for each vaccine. Keep a storage temperature checklist in the vaccine store so that you can check if you are in doubt. Refer to Fig. 3.
2. **Keep the door closed.** Avoid opening the cold room or freezer room door unless it is absolutely necessary to do so. If the room is not fitted with an internal plastic strip curtain, always close the door when you are working inside.
3. **Lock the door.** Keep the cold room or freezer room locked and make one person responsible for the key. Make sure that a spare key is kept in a safe place.
4. **Turn off the interior light.** Switch off the interior light as soon as you have finished working inside. The light bulb gives off heat and this makes the refrigeration plant run longer than necessary.
5. **Monitor the storage temperature.** Monitor the temperature of every cold room and freezer room at least twice a day.
6. **Stack the vaccine correctly.** Make sure there is sufficient space to allow good air circulation around the vaccine. Leave a gap of 5 cm between the vaccine cartons and the wall of the room. Stock the room as recommended by the installer. Do not allow the room to become overloaded.
7. **Organize storage for earliest-expiry-first-out (EEFO) handling.** Make sure that vaccine is stacked on the shelves systematically so as to encourage EEFO stock management. Necessary adjustments should be made in accordance to the VVM status.
8. **Avoid frozen vaccine (cold rooms only).** Vaccine can freeze inside a cold room for any of the following reasons:
    - *Vaccine stored too close to evaporator.* The air coming from the evaporator may be below 0°C until it has mixed properly with the air in the room. The danger zone typically extends for 50 cm in front of the evaporator. Vaccine must not be stored within this zone.

- *Thermostat set incorrectly.* This may reduce the temperature throughout the room to below 0°C.
- *In cold climates where the cold room is located in an unheated space.* If the temperature outside the cold room is close to or below 0°C the vaccine inside the room may freeze. A cold room in a cold climate should be built in a space that is permanently heated. Alternatively, it should be fitted with a thermostatically controlled heater circuit that maintains the inside temperature between +2°C and +8°C, even if the outside temperature is below 0°C.

9. Know the contingency plan. Make sure you know what to do if the cold room or freezer room breaks down. See Section 7.

3.2 Checklist for vaccine safety

Carry out the following checks whenever a batch of vaccine is received or issued.

3.2.1 Store vaccine at the correct temperature

- Is the vaccine being stored at the correct temperature? Follow the recommendations in Table 1.

Table 1. Recommended temperatures and storage times

<table>
<tr><th></th><th>Primary</th><th colspan="2">Intermediate</th><th>Health centre</th><th>Health post</th></tr>
<tr><th></th><th></th><th>Region</th><th>District</th><th></th><th></th></tr>
<tr><th></th><th>6 months[a]</th><th>3 months</th><th>1 month</th><th>1 month</th><th>Daily use</th></tr>
<tr><td>OPV</td><td colspan="2">-15°C to -25°C</td><td rowspan="15" colspan="3">+2°C to +8°C</td></tr>
<tr><td>BCG</td><td colspan="2" rowspan="7">WHO no longer recommends that freeze-dried vaccines be stored at -20°C. Storing them at -20°C is not harmful but is unnecessary. Instead, these vaccines should be kept in refrigeration and transported at +2°C to +8°C.</td></tr>
<tr><td>Measles</td></tr>
<tr><td>MMR</td></tr>
<tr><td>MR</td></tr>
<tr><td>YF</td></tr>
<tr><td>Hib freeze-dried</td></tr>
<tr><td>DT</td></tr>
<tr><td>DTP</td><td colspan="2" rowspan="8"></td></tr>
<tr><td>DTP–HepB</td></tr>
<tr><td>HepB</td></tr>
<tr><td>Hib liquid</td></tr>
<tr><td>Td</td></tr>
<tr><td>TT</td></tr>
<tr><td colspan="6">Diluent vials must NEVER be frozen. When the manufacturer supplies a freeze-dried vaccine packed together with its diluent, ALWAYS store the product between +2°C and +8°C. Where space permits, diluents supplied separately from the vaccine may be stored safely in the cold chain between +2°C and +8°C.

[a] Six months is the maximum recommended storage time at primary level. This includes the period required to obtain clearance from the national regulatory authority.</td></tr>
</table>

- If you are in any doubt about the correct temperature for a particular vaccine, store it in the cold room rather than the freezer room. Do this, for example, if you are uncertain whether a freeze-dried vaccine has been packed with its diluent. Diluent must *never* be frozen.
- Vaccine that can be damaged by freezing is very quickly destroyed if placed inside a freezer room.
- OPV should always be kept in a freezer room but is not damaged immediately if stored at +2°C to +8°C. Other vaccines that are best kept frozen are not damaged at +2°C to +8°C.

3.2.2 Check cold room stacking

- Check that the vaccine is stacked correctly on the shelves and clear of the walls to allow good airflow.
- Check that all vaccine is kept in its inner cardboard box. There should be no loose vials in the store.
- Check that no vaccine is stored within the danger zone close to the evaporator.
- Check that all vaccine is stacked on shelves, not on the floor.
- Check that the room is not overloaded and that it is not being used to store unauthorized substances.

3.2.3 Check store organization

- Check that the vaccine is stored systematically and that the contents of each batch are kept together.
- Check that the vaccine is being issued in EEFO order and according to the VVM status.

3.2.4 Check storage and management of diluents

- If diluents are packed with the vaccine, check that none are being kept in the freezer room.
- If diluents are packed separately, check that the correct batch of diluent is issued with the vaccine.

3.2.5 Check storage temperatures

Monitor temperatures twice daily. At each inspection read the temperature record for the entire period since the last reading.

Cold rooms and vaccine refrigerators

- *Temperature between +2°C and +8°C*. Situation normal, no action necessary.
- *Temperature at or below 0°C*. VACCINE AT RISK. Take immediate action to correct the low temperature and ensure that the problem does not arise again. Inspect the freeze-sensitive vaccines and/or carry out a shake test to establish if any has been frozen. Frozen vaccine has to be either destroyed or tested in order to establish whether it is still potent. Make a report.

- *Temperature between +8°C and +10°C*. If there has been a temporary power failure, no further action is necessary. Check that the refrigeration unit is working, monitor the situation closely and take appropriate action if the temperature is not within the normal range at the time of the next inspection.
- *Temperature above +10°C*. VACCINE AT RISK. Take immediate action to implement the agreed contingency plan, and make a report.

Freezer rooms and chest freezers

- *Temperature between -25°C and -15°C*. Situation normal, no action necessary.
- *Temperature below -25°C*. Adjust thermostat. Check that the temperature is within the normal range at the time of the next inspection.
- *Temperature above -15°C*. If there has been a temporary power failure, no further action is necessary. A temporary rise to +10°C is permissible following an extended power cut. Check that the refrigeration unit is working, monitor the situation closely and take appropriate action if conditions are not normal at the time of the next inspection.
- *Temperature above +10°C*. VACCINE AT RISK. Take immediate action to implement the agreed contingency plan, and make a report.

4. Routine and emergency maintenance

4.1 General points

1. **Keep the space outside the room cool.** Keep the space outside the cold room or freezer room as cool as possible. Condenser units give off a considerable amount of hot air. If this hot air is not removed the efficiency of the cooling units is reduced. Trees or screens help to shade the building that houses the cold store. Good ventilation removes the hot air. Alternatively, air conditioning may have to be used to keep the space cool.
2. **Keep the condenser unit well ventilated.** Do not allow rubbish and packaging to accumulate in the vaccine storage area. It is essential to maintain free air movement around the condensing units.
3. **Carry out minor maintenance.** Inspect the inside and outside of the room. Carry out minor maintenance, e.g. paint over scratches, adjust door hinges, and oil locks. Report any severe damage to the maintenance technician.
4. **Maintain the standby generator.** If you have a standby electrical generator, make sure you know how to use it *before* the main power supply fails. Keep the starter battery charged and in good condition and ensure that the tank is full and that you have a good supply of fuel. Keep the starting handle in a safe place near the generator. Run the generator every week to ensure that it is working.
5. **Know where switches and fuses are.** Find out where the main switch and electrical fuses are. Make sure that you have spare fuses and know how to fit them.
6. **Know how to contact the service agency or maintenance technician.** Find out the name and telephone number of the service agency and/or the telephone number of the maintenance technician. Have the numbers ready for use in case of emergency.
7. **Listen to the cooling equipment.** Learn how the cooling equipment sounds when it is working correctly. This helps you to identify faults before they become too serious. Cooling equipment runs more often during the hot season than during cooler periods. In cold weather it may run very infrequently. The running time of the cooling equipment increases if the door is opened frequently. Learn about the working of the automatic changeover system. Generally this is set up so that one cooling unit runs for 24 hours and another takes over for the following 24 hours. This is known as duty-sharing and ensures that both units get the same amount of use.

4.2 Daily checks

1. **Temperature.** Check the temperature of the room *twice each day* as described in Section 3.2.5. Cold rooms must be kept between +2°C and +8°C. Freezer rooms must be kept between -15°C and -25°C.

2. **Temperature record.** Look at the chart recorder or look at the output from the electronic recorder. The temperature should have remained within the correct limits at all times.

3. **Listen to the cooling equipment.** If you notice any unusual noise, or if the unit seems to be running for longer than normal, you must find the reason. See Section 6.

4. **Check inside the room.**

   - Is the airflow from the evaporator normal?
   - Is the evaporator fan running quietly?
   - Is there water on the floor? If there is, the evaporator drainpipe may be blocked.

   Refer to Section 6 for advice on these problems.

5. **Check outside the room.**

   - Remove any rubbish.
   - Check for signs of vermin such as cockroaches, mice, rats and bats.
   - Clean the floor *twice a week*.

6. **At the end of the day.** Make sure that:

   - all lights in the room are switched off;
   - there is nobody inside the room;
   - the door to the room is closed and locked.

4.3 Weekly checks

1. **Change the temperature chart.** If you have a chart recorder with a paper disc, change the disc at the end of each week. Write the start date on the new chart. Write the finish date on the old chart and keep it safely in a file for at least 12 months. If the recorder is operated by clockwork, wind up the mechanism. Refill the ink containers or check the pens. Fig. 3 shows an extreme example of what happens when the paper disc is not changed.

Fig. 3. How NOT to look after a temperature chart recorder

If you have an electronic recorder, print out a copy of the weekly chart and keep it safely in a file for at least 12 months. Show the file to the maintenance technician at each routine service visit.

2. **Check the liquid sight glasses.** If the cooling units have accessible sight glasses, check that both are filled with liquid and show "dry" conditions. If you see bubbles, there may be a leak of refrigerant (refer to Section 6). If the moisture indicator shows "wet", the filter-drier probably needs changing. Ask the service agency or maintenance technician to check and replace it if necessary.

3. **Check ice build-up on the evaporator.** Check the ice formation on the evaporators. Look at the pipes and fins. Most modern cooling units have an automatic defrosting system. If they are coated with ice more than 6 mm thick the evaporator needs defrosting and there could be a defect in the defrosting system. Ask the service agency or maintenance technician to check.

4. **Check the duty-sharing system.** Check that the automatic duty-sharing system is working. You can tell if this is the case by making sure that each cooling unit operates on alternate days.[1]

5. **Check the alarm system.** Press the test button. The alarm should sound. If it does not the alarm may be faulty. Ask the service agency or maintenance technician to check it immediately.

6. **Check the store.** In addition to the daily checks:

   - Is the vaccine correctly stacked? See Section 3.2.2.
   - Are the vaccines and diluents correctly organized? See Sections 3.2.3 and 3.2.4.
   - In freezer rooms, make sure there is no build-up of ice on the floor, walls or shelves.
   - Clean the floor as recommended by the installer.

[1] Check the changeover timer. Some systems may change over less frequently than once every 24 hours.

7. **Run the standby generator.** Check the oil and fuel levels and fill up if necessary. Check the battery electrolyte level if the battery is of the open type. Run the generator until it has warmed up and make sure that it is operating correctly.

4.4 Monthly checks

1. **Check the room enclosure.** Carry out the checks described in Section 5.1.
2. **Check the vaccine stock. Count each type of vaccine and diluent in the store** and ensure that the actual amounts are the same as the amounts shown in your stock register. Follow the EEFO principle and VVM status to issue vaccines from the stock. Make sure that all vaccines are in their proper place in the store. Make sure that the correct diluent is being issued with each batch of vaccine.
3. **Check the standby generator fuel supply.** Check that the fuel supply for the generator is adequate.

4.5 Monitor routine and emergency maintenance

Ensure that the service agency or maintenance technician carries out all routine servicing as recommended by the manufacturer(s) of the room enclosure and the cooling and monitoring equipment. Ensure that you receive a copy of the service checklist as evidence that the work has been correctly done. Some of the necessary routine checks are:

- oil and refrigerant leak check;
- drive belt tension check;
- routine cleaning of compressor components, including the condenser coil and fins;
- door seal check;
- temperature control check, using the temperature charts as evidence;
- replacement of components before failure occurs as part of a planned preventive maintenance (PPM) regime.

4.5.1 If there is a maintenance agreement with an outside agency

If there is a maintenance agreement with the room supplier, check that it is being carried out. Is routine maintenance being performed correctly at the intervals stated in the agreement? When emergencies occur, does the maintenance technician arrive within the maximum time stipulated in the agreement? Does the maintenance technician bring the parts required to rectify faults? Are the faults repaired satisfactorily? Is the safety of vaccines compromised by a failure to respond adequately to emergencies?

If service standards are inadequate, make sure that a senior colleague immediately takes the matter up with the service agency.

4.5.2 If maintenance is performed in-house

Monitor the performance of the maintenance technician. Make sure that a record of routine and emergency maintenance is maintained. If emergency call-outs are frequent the technician may not be doing her or his job properly. Ensure that the technician is properly trained to maintain all the equipment for which he or she is responsible.

4.6 Monitor the spare parts inventory

Where spare parts are held by the EPI programme, maintain an inventory of them. Ensure that the stock register is completed whenever parts are used and whenever new parts are obtained. At least once a year, check with the maintenance technician that the stock of spare parts is adequate. If it is not adequate, make sure that it is replenished.

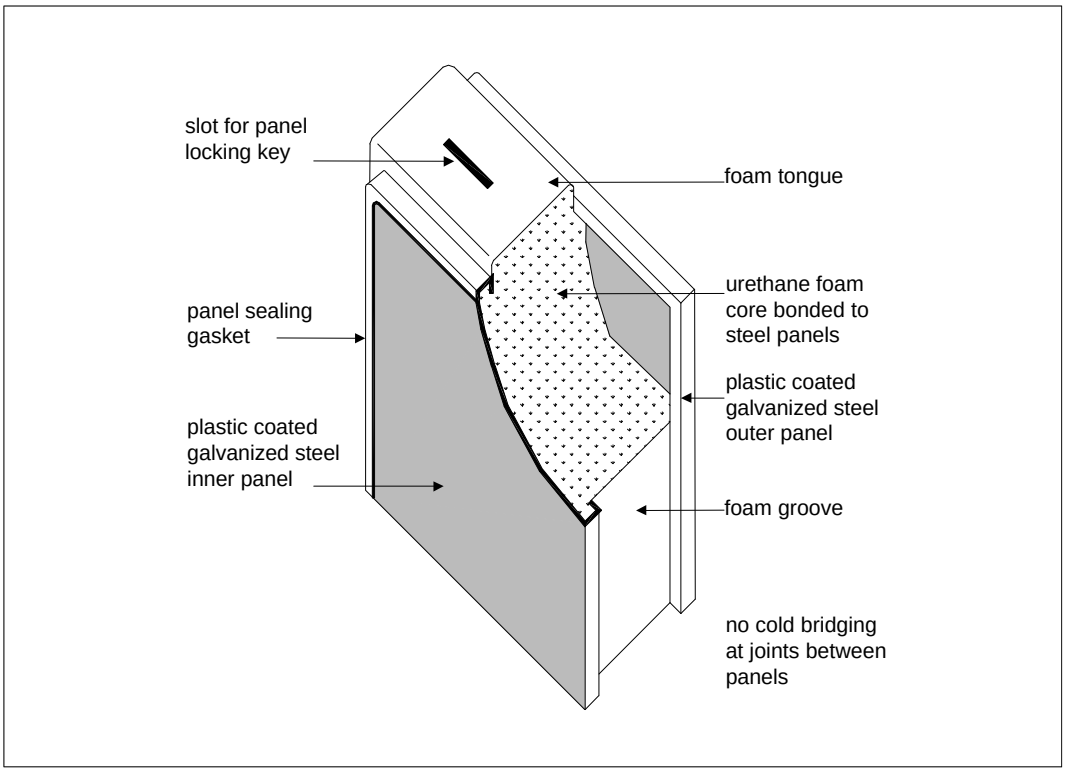
5. The room enclosure

5.1 The room enclosure

Modern cold rooms are constructed from prefabricated insulated panels. These consist of plastic-coated steel with plastic foam insulation (Fig. 4). The floor panels generally have an additional plywood layer covered with a patterned non-slip finish. The doors are insulated and fitted with airtight seals.

Most manufacturers are able to supply a full range of compatible components. These include shelving units, interior light fittings and flexible transparent plastic strip curtains to reduce cold air loss when the door is opened.

Fig. 4. Detail of a typical insulated panel



5.2 Checklist of room enclosure problems

Check the room enclosure every month to make sure there are no major problems.

5.2.1 Check the panels

- Check the bottoms of the panels to see if there are any signs of rust. Rust may occur if the panel coating is damaged and if water left after the floor has been washed collects under the floor panels.
- Inspect the panel joints internally and externally. There should be no evidence of movement along the joint lines and no sign of condensation or ice build-up. If the joints are not tight and well sealed the panels may absorb moisture. This reduces the efficiency of insulation. Furthermore, moisture may freeze inside the joints and force the panels apart.
- Inspect the area around the evaporator. This is usually the coldest part of the room. If there is ice or condensation on the panels, one or both of the following factors could be responsible.

Defective panel joints. As described above.

Condenser mounted close to door. In this position, humid air from outside the room comes into direct contact with the condenser. For this reason, where space permits, ceiling-mounted refrigeration units are preferable. However, where wall-mounted units are used, siting them beside the door often allows the most efficient possible use of the available space. If you see any of the defects described above, tell the maintenance technician.

5.2.2 Check the door

- Follow the safety checks described in section 2.2.2.

5.2.3 Check the strip curtain

- An internal plastic curtain reduces the amount of humid air that enters the room when the door is opened. If one is fitted, check to ensure that it is undamaged. If it is damaged, instruct the maintenance technician to replace it.

5.2.4 Check the pressure relief vent

- Inspect the pressure relief vent. It should not be iced up or otherwise blocked. A blocked vent causes negative pressure to build up in the room after the door is closed. If the panel joints are defective, humid air is drawn through the joints, where it can freeze and damage the panels. If the vent is blocked, try to clear it. If you cannot clear it, call the maintenance technician. *Never* block up the vent deliberately.

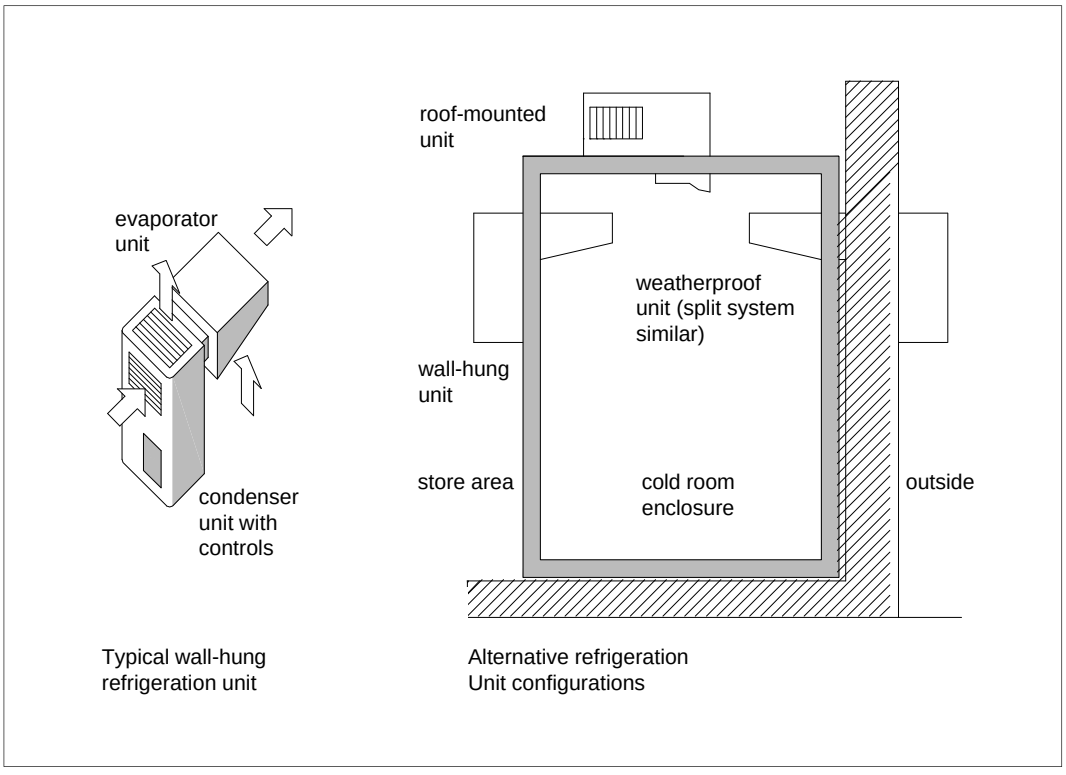
6. Cooling equipment and controls

6.1 How the cooling equipment works

You will be able to look after a cold room or freezer room very much better if you understand how the cooling equipment works and how to identify faults. However, you *must not* carry out any maintenance work on the cooling equipment unless you have been trained to do so.

A well-designed vaccine cold room or freezer room should have two independent cooling units. Fig. 5 illustrates the ways in which these can be sited.

Fig. 5. Alternative arrangements for refrigeration units



Each unit contains the following main parts.

6.1.1 The evaporator unit

The evaporator unit is located inside the cold room or freezer room. It contains the following main components.

1. **Expansion valve.** As liquid refrigerant enters the evaporator unit it passes through the expansion valve, where the pressure is reduced and the liquid vaporizes. During this expansion process the vapour cools. In a cold room it cools to just below 0°C. In a freezer room it cools to around -25°C. The expansion valve must control the fluid flow very accurately. If the flow is too slow, insufficient vapour enters the evaporator coil and the cooling effect is inadequate. If the flow is too fast, liquid refrigerant enters the evaporator coil. This liquid is drawn into the compressor, which is eventually damaged.
2. **Evaporator coil.** The evaporator coil is fixed on the inside wall or ceiling of the room. The coil consists of an array of tightly folded metal pipes with thin metal fins attached to them. These fins are delicate and easily damaged. The cold refrigerant vapour leaving the expansion valve passes through these pipes and cools the metal fins. The fins transfer this cooling effect to the air inside the room.
3. **Air circulation fan.** The evaporator unit incorporates an electric fan that is designed to circulate air over the evaporator fins and to distribute it evenly around the room.
4. **Automatic defrosting.** Most modern cooling units have an automatic defrosting system operated by a timer. The system can either be an electrical heater or a hot gas system.
5. **Condensate drip tray and drainpipe.** A tray located below the evaporator coil connects to a drainpipe running through the room wall. The tray collects condensation that drips off the coil and also collects melt water when the automatic defrosting system cuts in. In freezer rooms the drainpipe is electrically heated to ensure that the condensate drains away.

6.1.2 The condensing unit

This may be fitted on the external wall of the room, on the roof or away from the evaporator in the open air. This last arrangement is known as a split system. The condensing unit is connected to the evaporator by a pair of metal tubes that carry the refrigerant. The unit contains the following main components.

1. **Compressor.** This is a pump driven by an electric motor. It removes the vapour from the evaporator, compresses it and thus raises its pressure. As this happens its temperature also increases, in much the same way as the air in a bicycle pump heats up when the plunger is pushed down rapidly.
2. **Condenser.** This consists of a series of finned metal tubes, very similar to those in the evaporator coil. As the hot compressed vapour passes through the tubes it is cooled by an electric fan blowing air over the pipes. This causes the refrigerant vapour to condense back into a liquid, which passes into the liquid storage receiver.

3. **Liquid storage receiver.** This provides a reservoir of liquid that can be pumped back into the evaporator. In addition, when repairs are carried out, all the liquid in the system is transferred into the receiver and stored there in order to prevent loss.

4. **Filter-drier.** This is fitted to the pipe that carries liquid refrigerant from the storage receiver to the expansion valve. The filter removes any small pieces of dirt that might restrict the flow of refrigerant or block the system. The drier absorbs any water in the refrigerant. If there is water in the system it can freeze in the expansion valve and cause corrosion.

5. **Liquid sight glass.** This is fitted to the pipe immediately after the filter-drier. It allows the maintenance technician to check whether there is a leak in the system. The sight glass should be completely full of liquid. Bubbles in the liquid are evidence of a leak or a blockage. The sight glass usually contains an indicator that changes colour if water is present. A green colour is normally used to indicate dry conditions. If the colour changes to yellow there is water in the refrigerant and the filter-drier is no longer absorbing moisture and should be changed.

6.1.3 Temperature monitoring and warning devices

Not all units are fitted with every one of the controls described. Some have additional controls that are not covered here.

1. **Thermostat.** The thermostat maintains the temperature in the room at the correct level. When the room becomes too warm, the thermostat starts the compressor and this cools the room. As soon as the temperature has fallen sufficiently the thermostat stops the compressor.

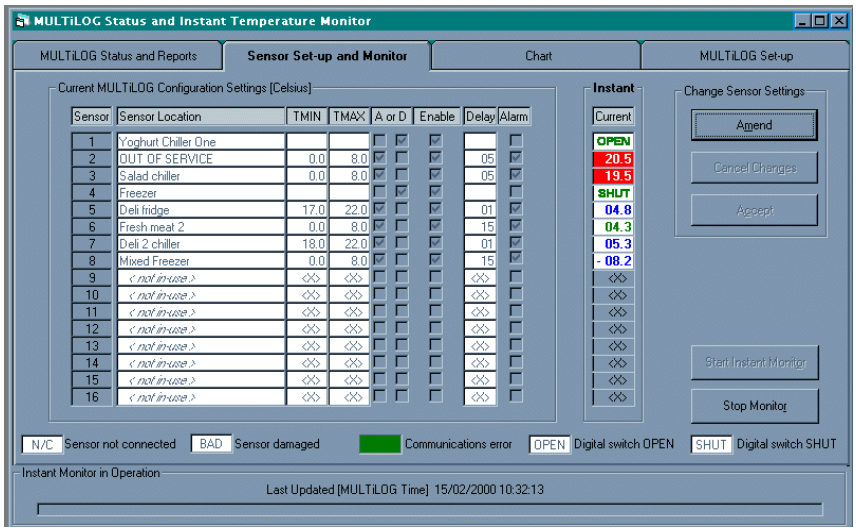
2. **Recording thermometer.** This provides a continuous record of the temperature inside the room. Usually, a circular paper chart rotates inside a case with a glass front and a pen records the temperature (Fig. 6). Some devices with more than one channel record temperatures at more than one place in the room and record events such as the opening of the room door. Sophisticated electronic recorders are also available which may send data to a personal computer (Fig. 7).

3. **Alarm.** An alarm emits a loud sound whenever the temperature in the room goes outside the designed range. It should also do so if the electricity supply fails.

Fig. 7. Typical recording thermometer

Source: Jules Richard Instruments.

Fig. 7. Screen image from an electronic temperature recording system



Source: Remonsys Ltd.

6.1.4 Safety controls

Most rooms are fitted with a number of safety devices to protect the equipment and the user if faults develop. These devices may include the following.

1. **High pressure cut-out:** prevents the pressure in the refrigeration system from becoming too high.
2. **Low pressure cut-out:** switches off the compressor if the pressure in the system becomes too low.
3. **Oil differential cut-out:** ensures that oil lubrication to the compressor is maintained.
4. **Motor overload protectors:** protect the electric motors against damage caused by excessive load or temperature.
5. **Duty-sharing timer switch:** automatically switches over from one refrigeration unit to the standby unit at the interval set by the manufacturer, commonly 24 hours.
6. **Voltage stabilizer:** corrects voltage fluctuations in places where the mains voltage fluctuates; if the voltage fluctuates outside the limits that the stabilizer is able to correct the device automatically turns off the power supply for a short period.
7. **Electrical fuses:** protect the entire system in the event of an electrical surge or an earthing failure.

6.1.5 Refrigerants

In order to avoid contamination the correct refrigerant must always be used to refill the cooling system. Observe the following rules to ensure that no contamination occurs.

1. **Label the equipment.** Fix a permanent label on the front of every appliance, indicating the type of refrigerant it contains.
2. **Label salvaged components.** Label every reusable component salvaged from old refrigeration circuits. The label must indicate the refrigerant used in the equipment from which the component was obtained. Salvaged components must only be used in equipment that uses the same refrigerant.
3. **Provide the correct tools and spare parts.** Provide the service technician with the correct tools and spare parts for the equipment for which he or she is responsible.

Until recently the chlorofluorocarbon (CFC) gas R12 was widely used as a refrigerant. However, CFC gases cause severe damage to the earth's ozone layer and contribute significantly to global warming. They are now being phased out.

Cold room manufacturers select refrigerants to suit the specified operating temperature. R134a, a hydrofluorocarbon (HFC) gas, is now often used for cold rooms. It is not suitable for use in freezer rooms. A variety of alternative gases are available for this purpose.

6.1.6 Low temperature protection heater

Cold rooms (not freezer rooms) installed in cold climates are sometimes fitted with a heater circuit to prevent the temperature inside the room from falling below +2°C when the air temperature outside the room is close to or below 0°C.

6.1.7 Heater mat

Over a period of time the low temperature inside a freezer room can cause the ground underneath to freeze. Frozen ground expands and may crack the concrete slab on which the freezer room is built. For this reason it is good practice to lay an electrical resistance heater mat below the insulated cold room floor. This keeps the temperature of the slab above 0°C, thus preventing the ground from freezing.

When a cold room or freezer room is located on an upper floor a heater mat is often installed to prevent condensation forming on the ceiling below.

6.2 Safety during maintenance

1. **Are you trained?** Only work on the cooling equipment if you have been trained to do so.
2. **Turn off the power.** Switch off the power before starting work.
3. **Beware of moving parts.** When carrying out maintenance on moving parts, switch them off wherever possible. Replace all covers and guards after finishing the work.
4. **No flames, no smoking.** Refrigerant gas or liquid can be dangerous. Do not use naked flames and do not smoke if the possibility exists of refrigerant leaking from the equipment.
5. **Remember to turn the power back on.** When you have finished work, turn the power back on and check that both cooling units are working.

6.3 Troubleshooting the cooling equipment

The cooling equipment is not working properly when any of the following events occur.

1. The condensing unit does not start.
   Refer to Table 2.
2. The temperature in the room is too high.
   Refer to Table 3.
3. The temperature in the room is too low.
   Refer to Table 4.
4. The temperature in the room is correct but the condensing unit runs for long periods.
   Refer to Table 5.
5. The temperature in the room is correct but the condensing unit is unusually noisy.
   Refer to Table 6.

The above-mentioned fault-finding tables are intended to help you to identify the general sources of problems. Each manufacturer's cooling equipment is different and you must not carry out repair work on the equipment yourself unless you have been trained to do so.

These tables can help you to find faults if a cold room or freezer room is not working properly. Start at the top of each table. Answer the question in the first box. If the answer is "No", follow the "No" line to the right and find what steps you need to take to correct the fault. If the answer to the question is "Yes", follow the "Yes" line and answer the next question in the same way. Do not carry out any of the work shown in shaded boxes unless you have been trained to do so. If you are unable to find or correct the fault, act as follows.

- If there is a standby refrigeration unit, switch it on.
- If there is no standby refrigeration unit and the defective unit cannot be repaired within a few hours, implement the contingency plan (see Section 7).
- Immediately instruct the repair technician to repair the faulty unit.

Work safely and systematically

1. Safeguard the vaccine. Your first priority is to safeguard the vaccine. Do nothing that will put it at risk.

2. Check and check again. Do not jump to conclusions. Check and check again until you are satisfied that you have found the fault.

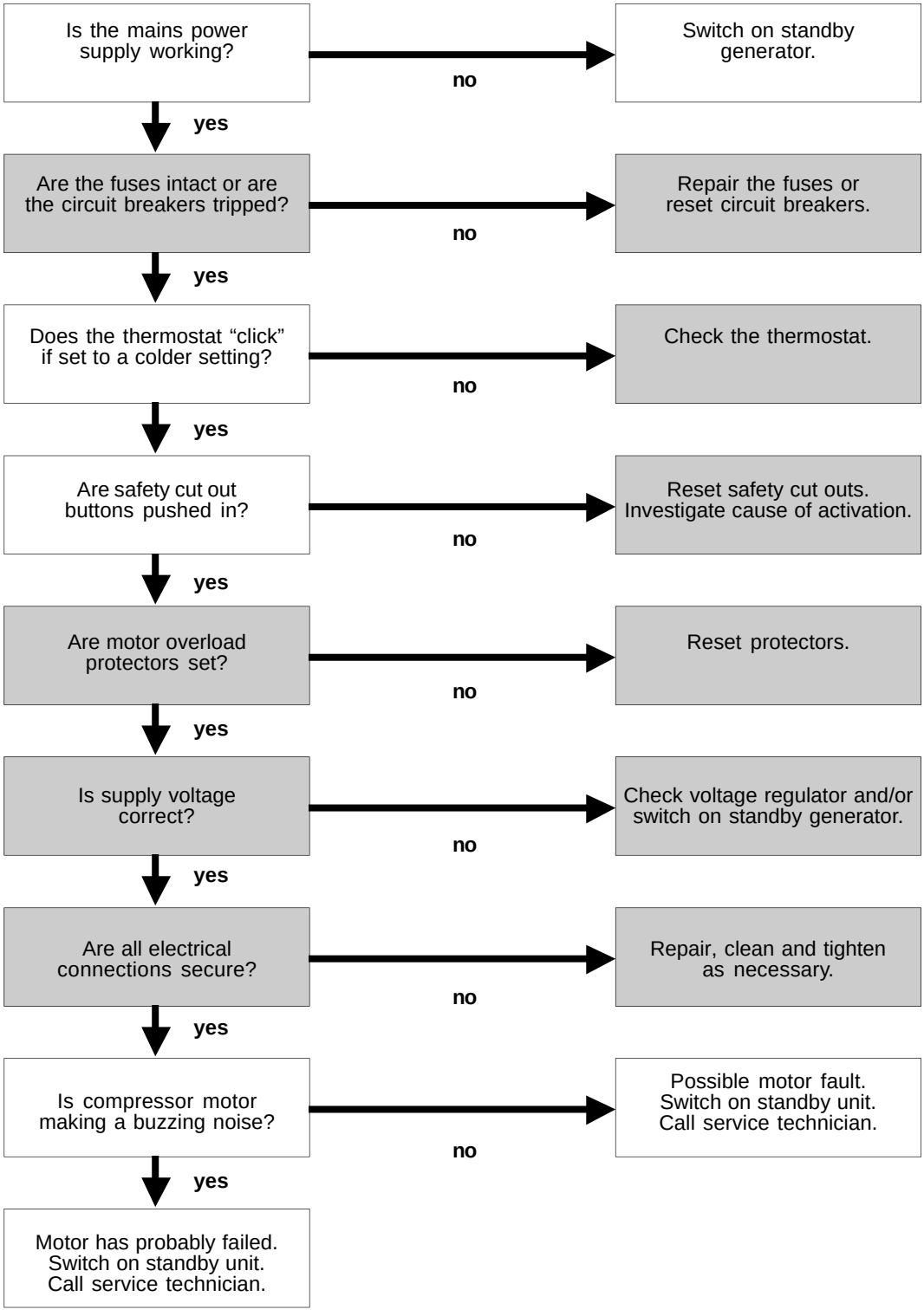
3. Switch off the power supply. Switch off the power before checking fuses or touching electrical connections.

4. Beware of moving parts. Moving parts such as fans and belts are dangerous. Switch off the power before working on or near moving parts.

5. Only do work for which you are trained. Some items on the fault-finding charts are shown in shaded boxes. Do not attempt to do the work described unless you have been trained to do so.

6. If in doubt, STOP and ask for advice from somebody who is trained to maintain and repair the equipment.

Table 2. The condensing unit does not start



Work safely

- Switch off power before checking fuses or securing electrical connections
- Moving parts can be dangerous
- Do not carry out work shown in shaded boxes unless you have been trained to do so

Table 3. The temperature in the room is too high

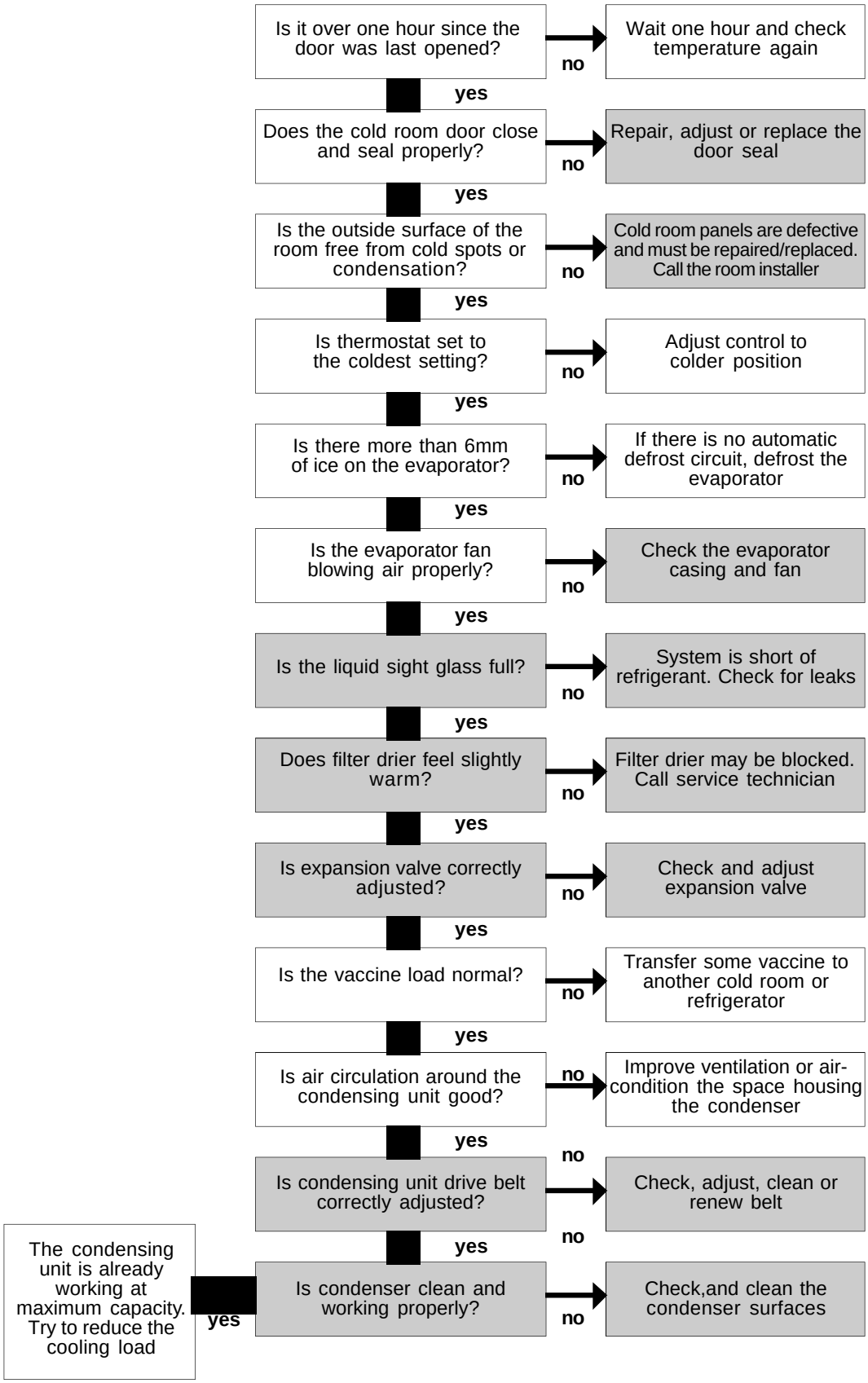


Table 4. The temperature in the room is too low

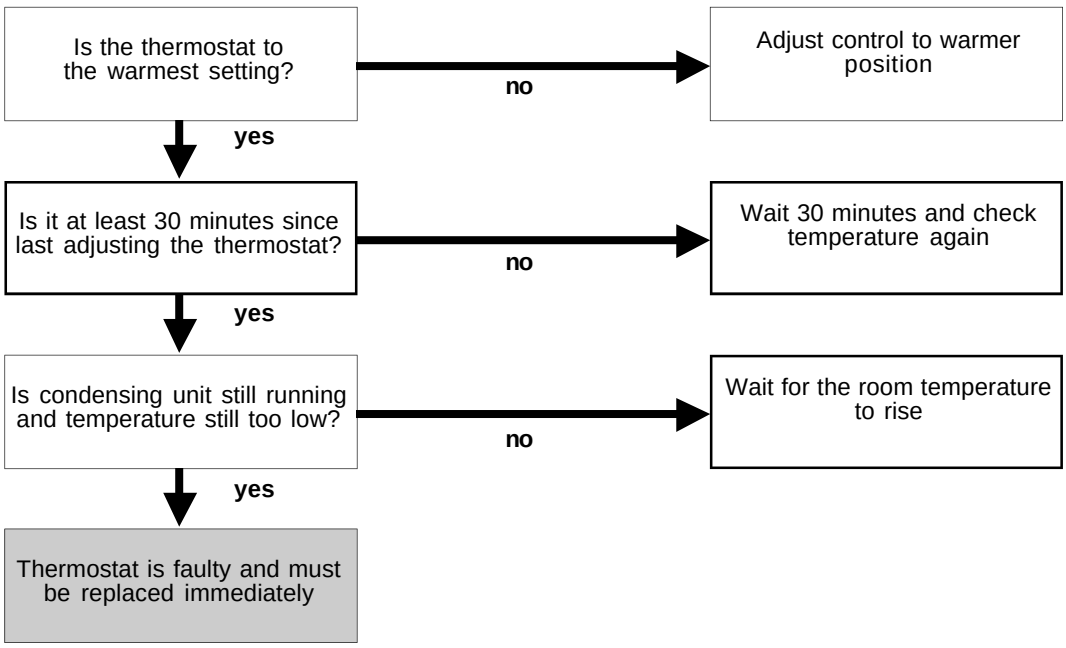


Table 5. The temperature in the room is correct but the condensing unit runs for long periods

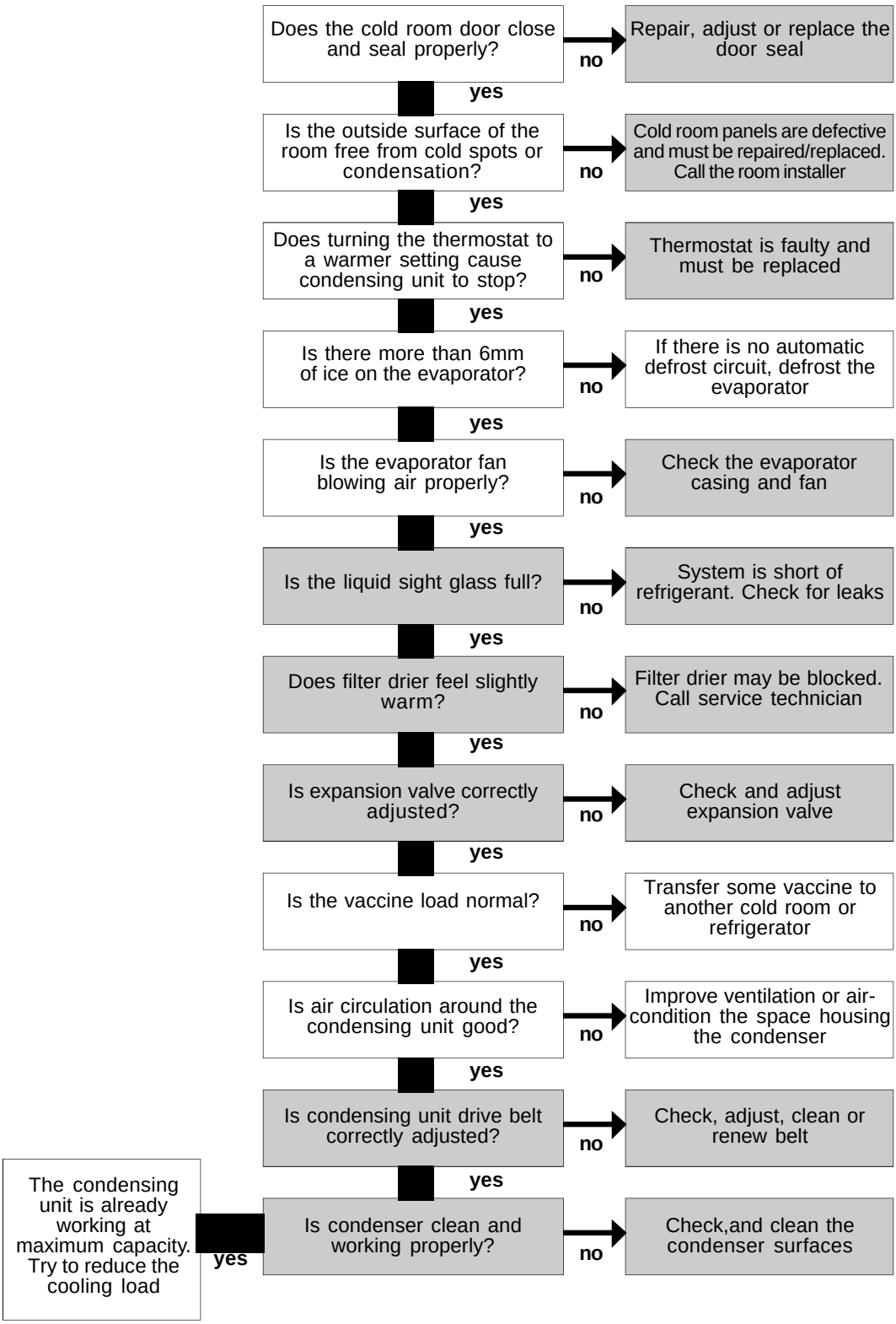


Table 6. The temperature in the room is correct but the condensing unit is unusually noisy

Table 6.1. Loose, rattling noises

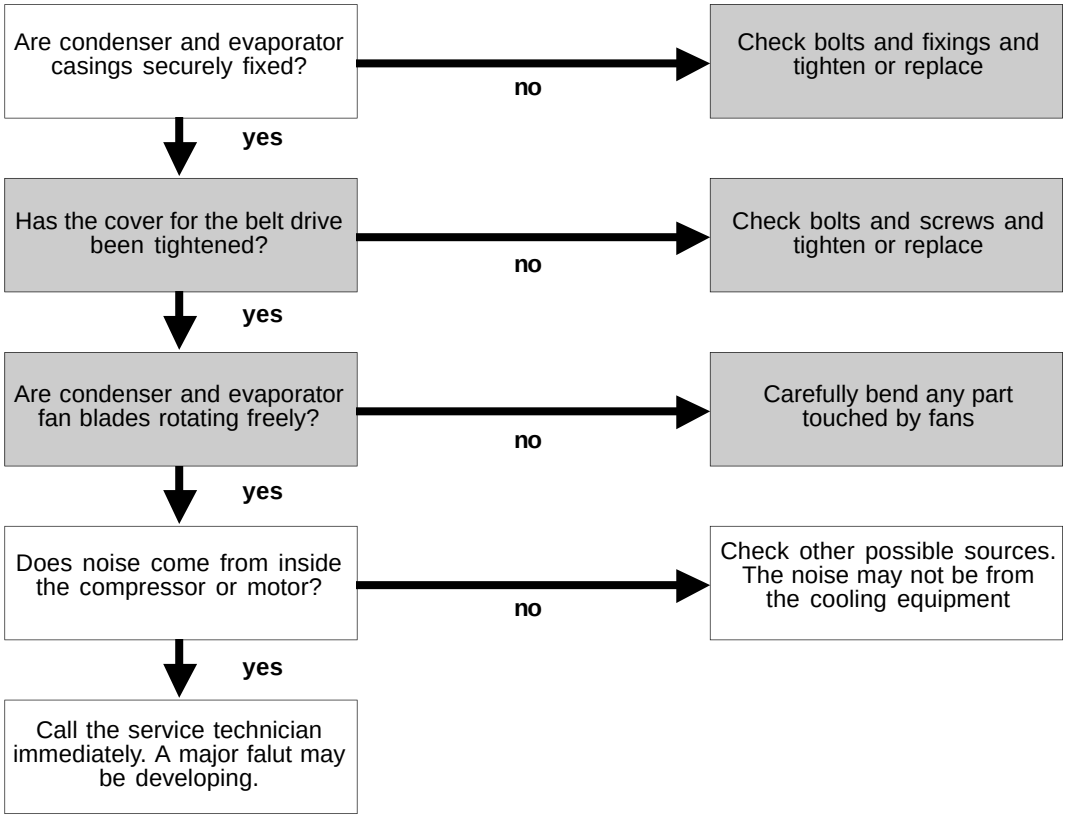


Table 6.2. Dry, squeaking noises

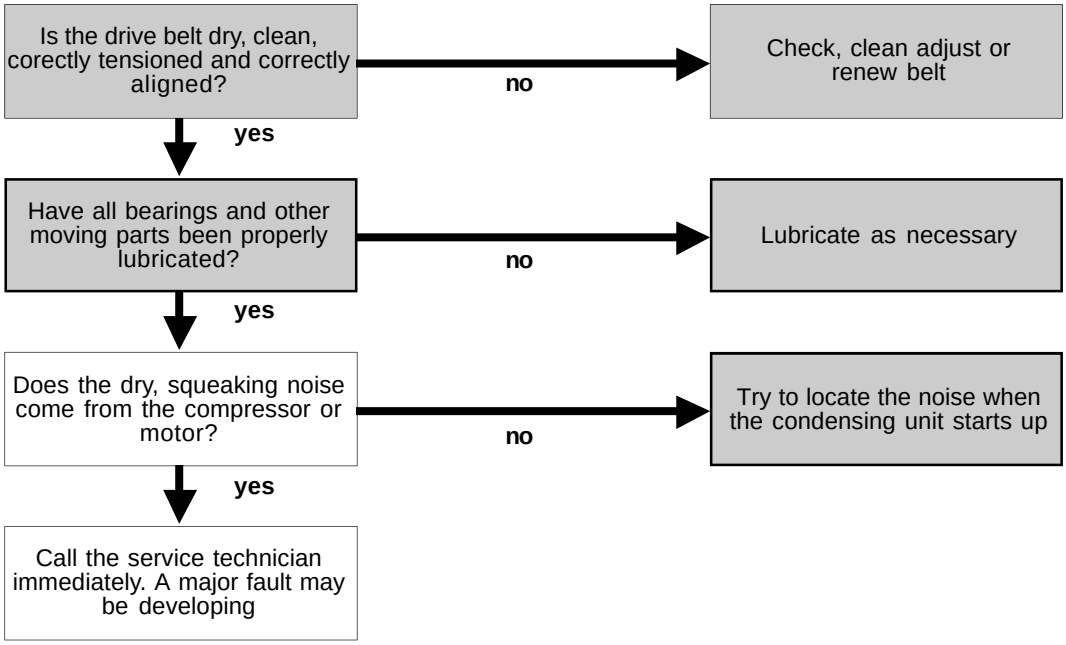


Table 6.3. Heavy knocking or banging noises

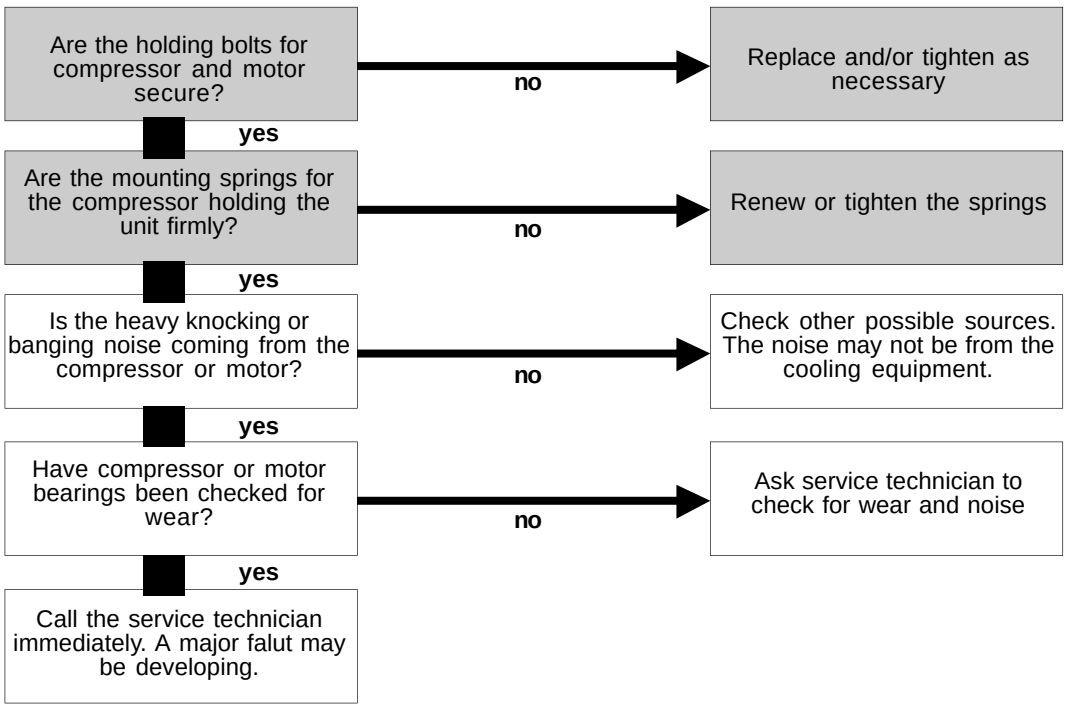
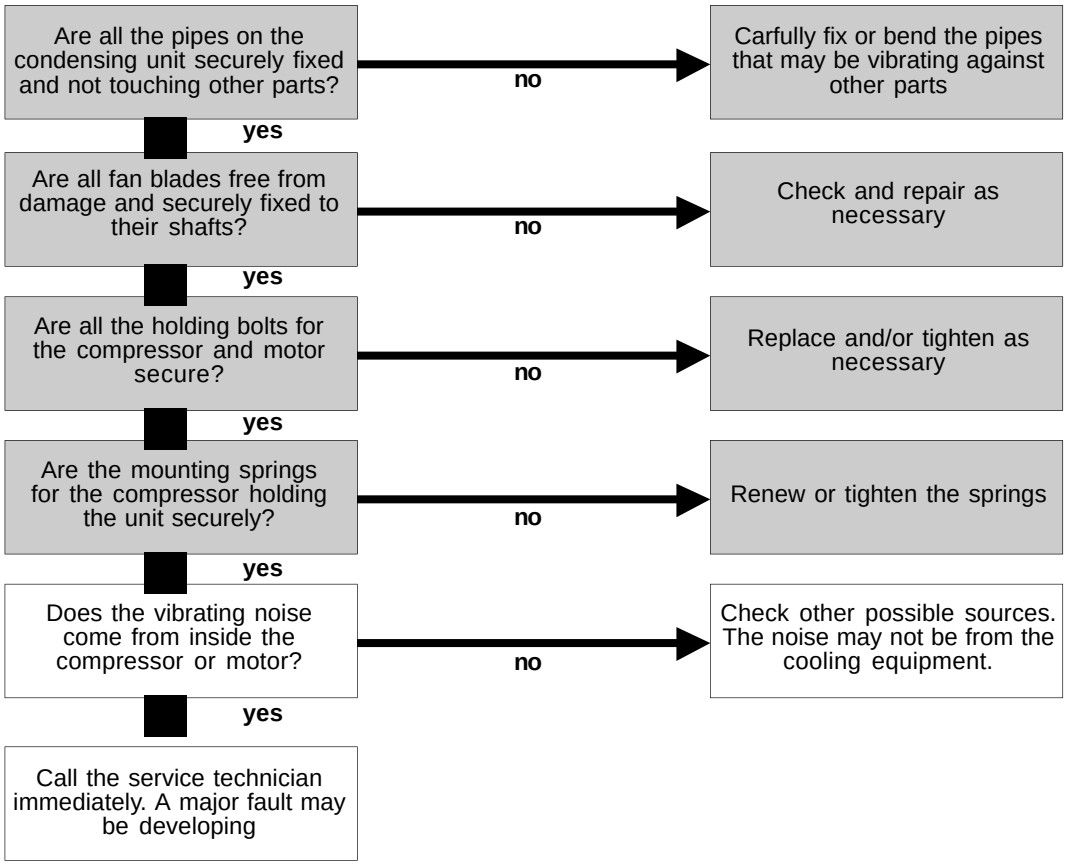


Table 6.4. Regular vibrating noises



7. Contingency planning

7.1 Safe storage rules

Every vaccine store must have a contingency plan for keeping vaccine safe if the refrigeration equipment fails. It is impossible to give precise directions about how this should be done, as circumstances vary. Whatever the circumstances, however, the following three rules apply in an emergency.

1. **Freeze-sensitive vaccines.** Maintain vaccines at +2°C to +8°C.
2. **Freeze-dried vaccines packed with diluent.** Maintain vaccines and diluents at +2°C to +8°C.
3. **Freeze-dried vaccines packed without diluent.** Maintain vaccines at +2°C to +8°C. Store diluents at room temperature as normal.

Make sure that your staff know these rules.

7.2 Review contingency options

Some of the possible contingency options are indicated below.

- Move the vaccine to another public service cold store.
- Move the vaccine to a private sector cold store.
- Borrow or hire a refrigerated vehicle.
- Obtain ice from a commercial ice-maker and store it inside the cold room or freezer room in plastic or metal containers. Closely monitor the room temperature and keep the ice supply replenished until repairs are carried out. *Never* use dry ice. Dry ice may lower the temperature of the cold room to below 0°C. Moreover, when it evaporates (sublimes) it gives off carbon dioxide gas. This may build up in the cold room and could suffocate anybody who enters the room.

7.3 Prepare and maintain the contingency plan

Follow the guidance given below.

- Prepare at least two alternative plans.
- Whatever plans you choose, make sure they are discussed and agreed beforehand with your staff and with all the other parties involved.
- Confirm the plan in writing. Keep a copy in the vaccine store. Make sure your staff know where it is.

- Check alternative stores to ensure that they are in good condition, have adequate space and are capable of maintaining vaccine at the correct temperature. There is no point moving stock to another cold room if the result is that all your freeze-sensitive vaccine is frozen and destroyed.
- Do not wait until an emergency occurs. Rehearse the plans *before* they are needed.
- Prepare a list of emergency contact names, addresses and telephone numbers and post a copy of the list in the vaccine store. Keep the list up to date.
- Make sure that emergency contacts can be made both inside and outside normal working hours.

Since major equipment failures are likely to be infrequent, make sure that you review and renew the plans at regular intervals, e.g. every three months. There is no point in reaching an agreement with an outside provider who is no longer able to help you when an emergency happens, perhaps after an interval of months or years.

Be safe, be watchful, be thorough and think ahead. If you observe these rules you will look after the vaccine well.

The Department of Vaccines and Biologicals was established by the World Health Organization in 1998 to operate within the Cluster of Health Technologies and Pharmaceuticals. The Department's major goal is the achievement of a world in which all people at risk are protected against vaccine-preventable diseases.

Five groups implement its strategy, which starts with the establishment and maintenance of norms and standards, focusing on major vaccine and technology issues, and ends with implementation and guidance for immunization services. The work of the groups is outlined below.

The *Quality Assurance and Safety of Biologicals team* team ensures the quality and safety of vaccines and other biological medicines through the development and establishment of global norms and standards.

The *Initiative for Vaccine Research* and its three teams involved in viral, bacterial and parasitic diseases coordinate and facilitate research and development of new vaccines and immunization-related technologies.

The *Vaccine Assessment and Monitoring team* assesses strategies and activities for reducing morbidity and mortality caused by vaccine-preventable diseases.

The *Access to Technologies team* endeavours to reduce financial and technical barriers to the introduction of new and established vaccines and immunization-related technologies.

The *Expanded Programme on Immunization* develops policies and strategies for maximizing the use of vaccines of public health importance and their delivery. It supports the WHO regions and countries in acquiring the skills, competence and infrastructure needed for implementing these policies and strategies and for achieving disease control and/or elimination and eradication objectives.

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