



NEST-ED

Technical Modules

February 2021

Newborn Essential Solutions and Technologies-Education (NEST-ED) Technical Modules provide educational support for each of the technologies included in the NEST360° bundle for newborn care. These materials are intended to strengthen locally developed neonatal and technical trainings in pre-and in-service settings and are not intended to be comprehensive technical guidelines or device-specific manuals.

**FACILITATING THE CLINICAL USE AND TECHNICAL
REPAIR OF TECHNOLOGIES FOR NEWBORN CARE
IN LOW-RESOURCE SETTINGS**

Newborn Essential Solutions and Technologies-Education
Technical Modules: Radiant Warmer

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Suggested citation. NEST360°. *Newborn Essential Solutions and Technologies-Education – Technical Modules: Thermal Management: Radiant Warmer*. (February 2021). License: CC BY-SA 4.0.

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The authors have made every effort to check the accuracy of all information and instructions for use of any devices or equipment. As knowledge base continues to expand, readers are advised to check current product information provided by the manufacturer of each device, instrument, or piece of equipment to verify recommendations for use and/or operating instructions.

In addition, all forms, instructions, checklists, guidelines, and examples are intended as resources to be used and adapted to meet national and local health care settings' needs and requirements.

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PREFACE

This series has been designed with the intent of supporting the clinical use and technical repair of technologies in newborn care units.

Newborn Essential Solutions and Technologies-Education (**NEST-ED**) Technical Modules provide educational support for each of the technologies included in the NEST360° bundle for newborn care. These materials are intended to strengthen locally developed neonatal and technical trainings in pre- and in-service settings. Of note, these materials are not intended to be comprehensive technical guidelines or to replace the use of device-specific user and service manuals or textbooks. They are to be used to facilitate the implementation of comprehensive newborn care, including bubble CPAP, in a resource limited setting.

The NEST-ED Technical Modules were developed through a combination of international standard review, international expert feedback, and multinational NEST360° expert consensus opinion. NEST-ED Modules form the backbone of all lectures, power points, job aids, and other supportive education materials supplied by NEST360°.

**THIS IS ONE MODULE IN A SERIES OF NEST-ED
CLINICAL & TECHNICAL MODULES AVAILABLE.**

To view the full series, visit the [NEST360° Resources](#) website.

ABBREVIATIONS

bCPAP	Bubble continuous positive airway pressure
BMET	Biomedical Equipment Technician
dL	Decilitre
ESD	Electrostatic Discharge
FiO₂	Increased Fractional Concentration of Oxygen
Fr	French size
HAI	Hospital acquired infections
HCWs	Healthcare workers
KMC	Kangaroo mother care
LBW	Low birth weight
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
mm Hg	Millimeters of mercury
NEST-ED	Newborn Essential Solutions & Technologies-Education
NEST360°	Newborn Essential Solutions & Technologies
nm	Nanometer
O₂	Oxygen
OGT	Orogastric tube
PCB	Printed Circuit Board
ppm	Parts per million
ROP	Retinopathy of Prematurity
PSA	Pressure Swing Adsorption
PSU	Power Supply Unit
ROP	Retinopathy of Prematurity
SpO₂	Peripheral blood oxygen saturation
UPS	Uninterruptible power supply
WASH	Water, sanitation and hygiene

NOMENCLATURE

Allen keys	Hex keys
bCPAP prongs	bCPAP patient interface
Christmas tree adapter	Barbed oxygen fitting, nipple and nut adapter
Control PCB	Main PCB
Cot	Bassinet, infant crib
Flat head screwdriver	Slot head screwdriver
Flow splitter	Oxygen splitter, flow meter stand
Glucometer	Glucose meter
Hospital Acquired Infection	Iatrogenic infection, nosocomial infection
Multimeter	Digital multimeter, Avometer
Nasal prongs	Oxygen catheter, oxygen cannula, oxygen prongs
Positive Pressure	Positive end expiratory pressure, positive airway pressure
Radiant warmer	Resuscitaire, resuscitation table
Star screwdriver	Torx screwdriver
Suction pump	Suction machine

Introduction

The NEST-ED Technical Modules have been prepared to help technical staff and students understand the basics of when and how to use equipment essential to newborn care. More importantly, the Technical Modules support staff in troubleshooting common issues, as well as prepare staff to repair equipment when it breaks down or malfunctions. Modules may be used by teaching institutions, to supplement current newborn care curricula, or by hospitals, clinical departments and individuals to update their knowledge and to better facilitate the effective and safe use of newborn care equipment. Modules should be used alongside device user and service manuals to provide additional context as needed.

Whilst reading this series, navigate to the **Table of Contents** by clicking the NEST360° logo that appears at the bottom right corner of each page: **NEST360°**

Every module has a similar structure with sections and subsections. The sections have similar headings and subheadings to make it easy for the user to navigate them. However, words may have different meanings for the various cadres of staff reading them and so to reduce misinterpretation, the heading titles are explained below.

The NEST-ED Technical Modules are intended as a flexible resource that hospitals and partners can adapt to their specific needs. The Technical Modules consist of generic content that can be applied to any model within a device category, coupled with model specific device images that can be exchanged for alternative images depending on the devices available at your facility. Individuals who are interested in gaining access to the editable NEST-ED Technical Modules should contact the **NEST Training Materials Coordinator** (Anniina Lockwood, al90@rice.edu) or the **NEST Biomedical Tech Training Director** (Sara Liaghati-Mobarhan, smobarhan@rice.edu).

CLINICAL PROBLEM

This section provides useful information on the clinical application of a device that would bear relevance to the biomedical team, not only to aid in their troubleshooting, but also for user training.

ASSESSMENT

This section explains how the device works, and what kinds of patients it is useful for. This section also includes comprehensive diagrams of internal and external views of the devices, including consumables that may be used with the device. This section also contains detailed descriptions of key device components (including alarms) and includes a diagram of typical device flow (including components and how they interact with each other, electrical current and fluid movement through the device if relevant).

MANAGEMENT

This section focuses on **clinical** management and provides step by step directions on how to set the device up for a patient, followed by instructions on starting the patient on the device and monitoring a patient whilst on the device. This section also describes how to remove the equipment from the patient when it is no longer needed. Although a biomedical engineer or a technician will not be responsible for providing care, understanding these steps will be useful in training and when assessing the device.

INFECTION PREVENTION

This section lays out the basic infection prevention measures that should always be taken when handling equipment, followed by directions for disinfecting the equipment both during and after use. This section also describes the crucial Infection Prevention and Control steps that are particularly relevant to biomedical engineers and technicians.

COMPLICATIONS

This section explains some of the common but serious clinical complications that relate to and can arise from the use of the equipment (e.g., complications that will be seen or directly apply to the patient). Biomedical engineers' and technicians' understanding of potential complications for the patient is crucial to ensure patient safety. This section also describes common device complications (e.g., complications that will be seen or directly apply to the device).

CARE & MAINTENANCE

This section describes where to place equipment for use, how to safely handle devices and their consumables, whether calibration is recommended, and how to decommission the equipment. Biomedical engineers and technicians are responsible for second-line care and maintenance to ensure the equipment lasts to their potential lifetime; as such, this section also lists the necessary daily, weekly, monthly and annual preventive maintenance steps required to keep the device in good working condition. First-line care and maintenance is the responsibility of the user and is described in the **NEST-ED Clinical Modules**.

TROUBLESHOOTING & REPAIR

This section describes steps that should be taken when a device malfunctions and first-line troubleshooting efforts have failed to address the issue. This section describes tools and spare parts that might be required to prepare for repairs and to troubleshoot failures, and provides a list of components commonly provided with the device to ensure that all components return to the ward post-repair. Finally, this section also explains steps for testing, repairing, and replacing specific parts of the device.

REFERENCES & ALERTS

References & alert boxes are included within each module to provide clarity on areas where recommendations are governed by published standards, evidence, and/or expert opinion. This is included for the dual purpose of facilitating (1) feedback and continuous improvement of NEST-ED Technical Modules and (2) implementer review of content for incorporation in local trainings.



ALERT 0.0 Subject

QUERY ALERT BOXES appear where there may be controversy or disagreement. In these cases, alert boxes provide background to the recommendations that are made in the body of the document. Relevant documents are cited and brief explanation of reasoning for current module content provided.

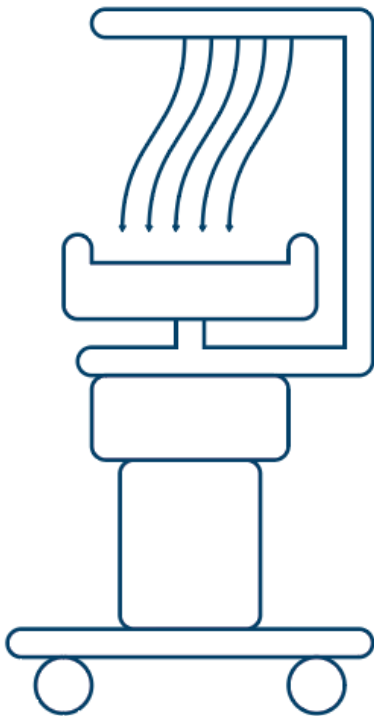


ALERT 0.0

RECOMMENDATION ALERT BOXES appear where there are recommendations based largely on expert opinion or consensus, or to emphasize an important element of care. Relevant documents are cited and brief explanation of reasoning for current module content provided.

Thermal Management

Radiant Warmer



1 Clinical Problem

Radiant warmers may be used both within the Nursery ward and the Labour or Obstetrics ward. Warmers are used exclusively for newborn or infant patients.

Newborn babies can drop their body temperature within minutes. They must be kept warm from the moment of birth, during their time in the labour ward and when transferred to the nursery. Even small drops in temperature increase the likelihood of mortality. **(Alert 1.1)**¹⁻³

Alert 1.1

Body temperature less than 36°C at birth has been recognised as an independent risk factor for death in preterm infants.¹⁻⁴

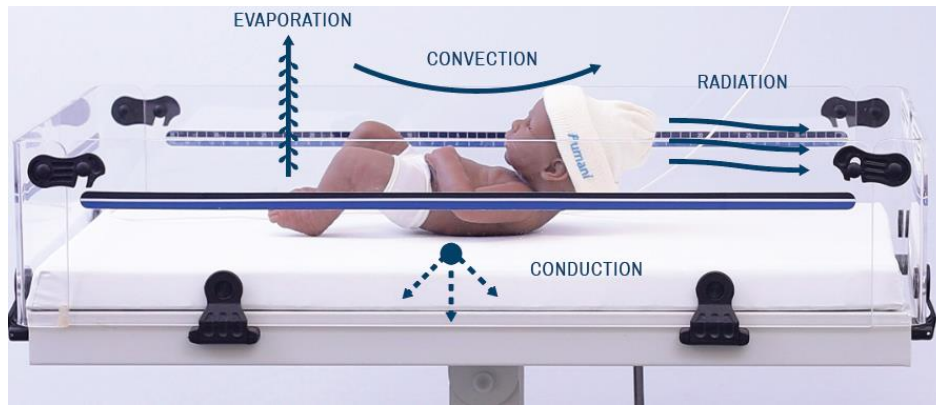
Radiant warmers may be used on all neonatal patients admitted to the nursery ward, but is especially critical for those with prematurity, low birth weight, reduced growth, low body temperature or undergoing procedures.

2 Assessment

However warm a room may feel to an adult, a neonate can lose heat. This heat loss in neonatal patients is rapid, with low body temperature (hypothermia) directly contributing to mortality.¹⁻⁴ Radiant warmers use overhead heating elements to provide radiating heat ensuring maintenance of normal body temperature (normothermia).

Newborn babies lose heat through four main mechanisms.⁵ **(2.1)**

- **Evaporation:** water loss through the skin.
- **Radiation:** heat radiating from the warmer patient towards cooler surfaces (e.g., windows or walls).
- **Conduction:** direct heat travelling from warmer surface of the skin to the cooler mat or cot on which the patient rests.
- **Convection:** air currents move heat away from the skin/body.



2.1 Mechanisms of heat loss.

Radiant warmers provide infants with a radiating heat to minimise heat loss and energy requirements for heat production, decreasing the risks of low blood sugar and increased work of breathing associated with hypothermia. **(2.2)** Radiant warmers provide an area where resuscitations, procedures, and short-term observation can take place while keeping the baby warm. Warmers may vary in complexity, including only heating functionality or heating functionality with resuscitation and oxygen equipment. All warmers include a temperature probe that provides information on the patient's temperature. **(2.3)**



2.2 Typical radiant warmer.



2.3 Typical temperature probe.

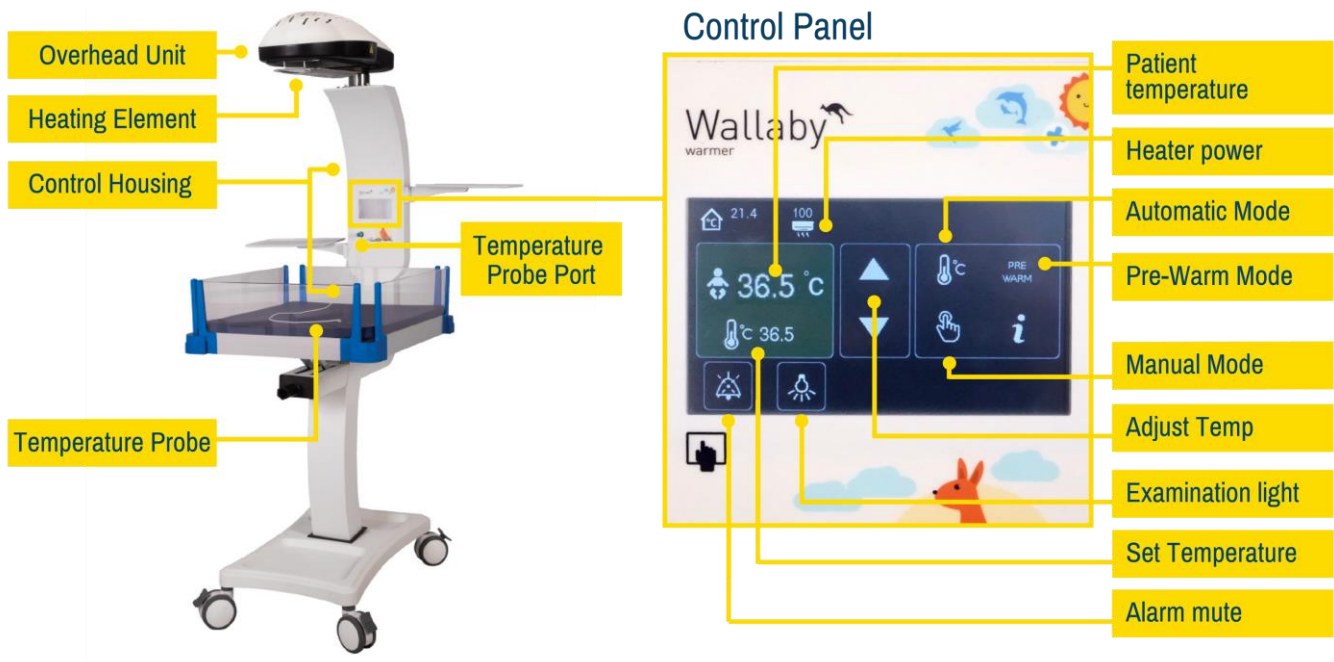
Normothermic axillary temperature in neonates ranges from 36.5°C to 37.5°C.³⁵ Every effort must be made to keep a baby's temperature within the normal range as temperature below 36°C is an independent risk factor for death in newborns.²⁴

HOW IT WORKS

Radiant warmers heat in various modes, the names and availability of which may vary based on device: **(2.4)**

- **Prewarm:** provides constant low heat for a short amount of time (typically 10 minutes or less) to warm the cot underneath the warmer. Prewarming protects the patient from conductive heat loss caused by a cold mattress.
- **Automatic:** also called **servo** or **baby mode**; uses a temperature probe on the baby to automatically adjust heat provided to maintain the patient's temperature within an acceptable range.

- **Manual:** provides a constant, unadjusting heat that is set by the user. **Patients should never be left unattended if being treated in manual mode.**

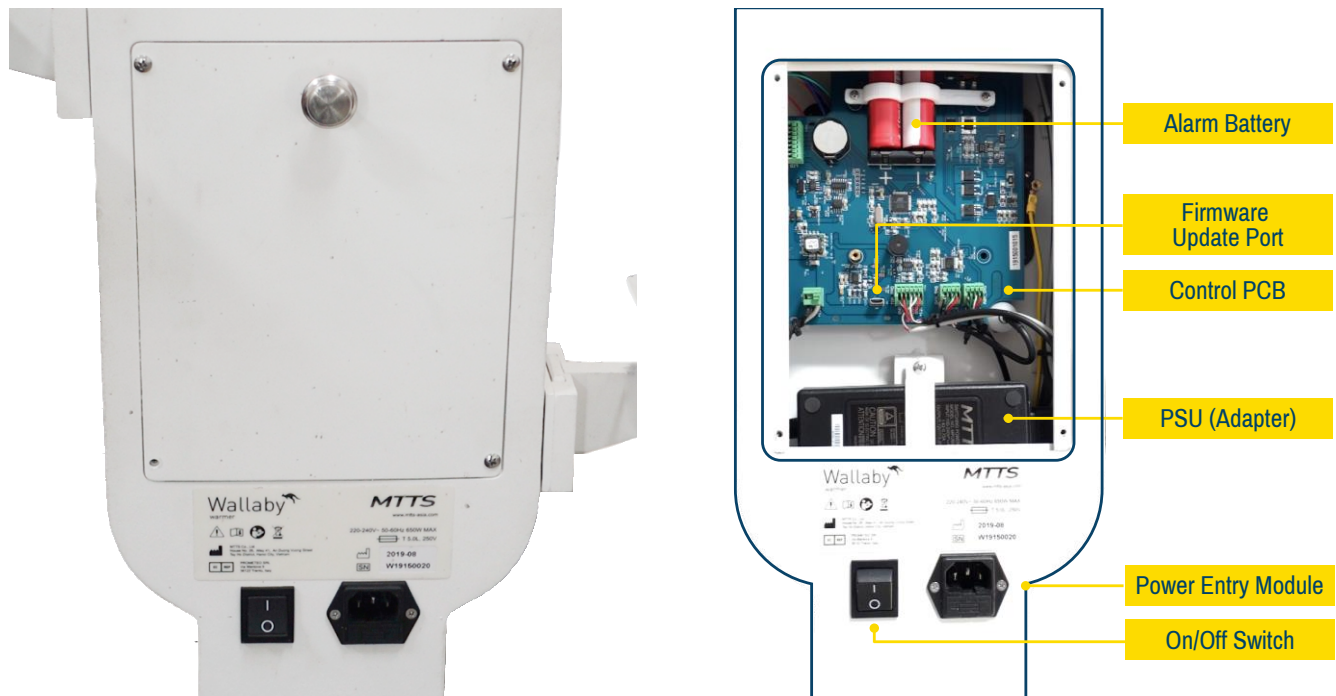


2.4 Major external components & modes of a radiant warmer.

A radiant warmer consists of a mounted overhead heating mechanism that may be transported or kept stationary with lockable castors. This heating mechanism consists of **heating elements** (typically made of ceramic or quartz). In both types of heating elements, an optically designed parabolic reflector is fitted into the heating element housing to direct the heat energy towards the **baby cot**. The baby cot may be part of the radiant warmer or the heating elements may be independent (as in phototherapy lights). Heat output from the heating elements is controlled by the main controller, which in turn is dictated by user input. In some units, a separate module is fitted to control the heater output.

The core temperature of the baby is continuously monitored by the **temperature probe** connected to the device and placed over the baby's liver. Body temperature changes can be seen in real-time on a small LCD panel. Radiant warmers are also fitted with **audiovisual alarms** to attract the attention of the medical or technical staff when a problem occurs.

Standard internal device components are annotated below in **Figures 2.5** and **2.6**. Components should be similar regardless of model. However, specific locations, visual setup and component type may vary by brand and device model. Refer to service and user manuals if model in use is different from the displayed version.

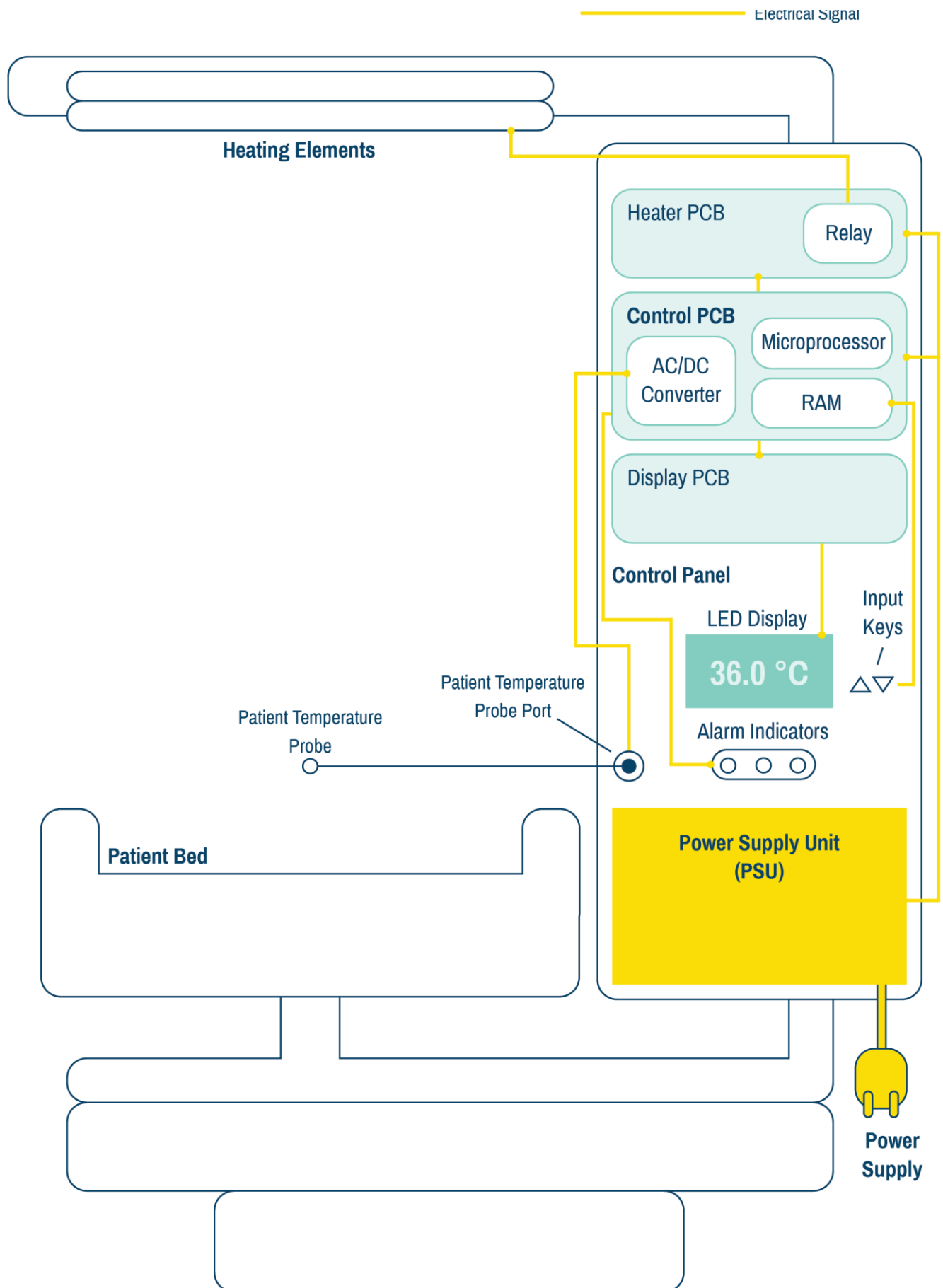


2.5 Major internal components of a radiant warmer control housing.



2.6 Major internal components of a radiant warmer overhead unit.

TYPICAL DEVICE FLOW



MAIN COMPONENTS

The following device components should be similar regardless of model. However, specific locations, visual setup and component type may vary by brand and device model. Refer to model service and user manuals if different from the displayed model for more device-specific information.

Power switch

The power switch is usually a rocker switch located on the back or side of the unit. This switch must be in the “on” position to power the radiant warmer and view the control panel.

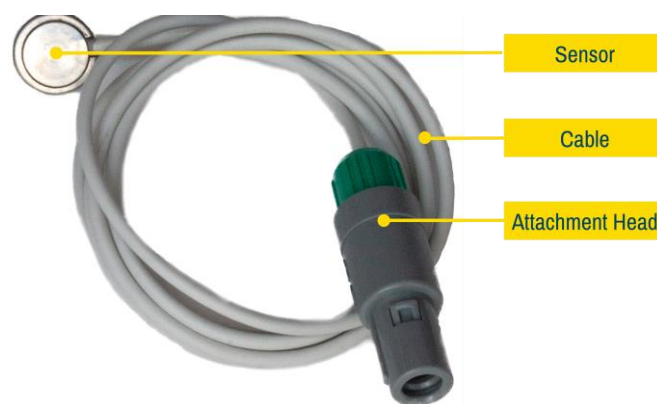
Control Panel

A control panel, usually located on the front of the radiant warmer, includes functions for operating the radiant warmer and a display of readings to assist in clinical care. Most control panels include an LCD that displays readings from the temperature probe, the set temperature for the warmer, the heat power output, fault codes, alarms, and other status readings based on the manufacture's design.

Radiant warmer controls may be located on an LCD touchscreen or may be physical buttons, knobs, or switches on the warmer. These controls are used to select the warming mode, set desired patient temperature and adjust heater output. Some radiant warmer control panels will maintain settings from the last use. For this reason, always advise the clinical or nursing staff to check the settings before initiating a patient.

Patient temperature probe

The manufacturer includes a patient temperature probe that is designed to be used with their radiant warmer model. The patient temperature probe is made up of a sensor, cable and attachment head. The patient temperature sensor should be placed on the baby's skin over the liver to read the body temperature.



2.7 Typical temperature probe.

The patient temperature probe sensor is typically made of a thermocouple that measures and feeds the patient's temperature back to the control PCB's microcontroller. The microcontroller uses the patient's temperature readings to provide feedback to the control system, which will adjust the heater output based on the comparison between the actual baby core temperature measured by the probe and the user set value (as in servo/automatic mode) or to turn off the heater (as in manual mode).

Patient temperature probe port

The patient temperature probe port on the unit is designed to fit the manufacture's specified patient temperature probe cable. The port end of the cable is inserted into the port. This cable links the control system and the patient temperature probe to provide the patient's temperature readings to the PCB microcontroller.

Power Supply Unit (PSU)

PSUs are located internally in the radiant warmer and are usually **linear** or **switch-mode power supplies**. The main function of the PSU is to convert 110/220 VAC mains power to low voltage regulated DC power for use in other electronic circuits in the system as per design. PSUs typically include a transformer, rectifiers, voltage regulators, and filters.

Control PCB

The control PCB includes the microcontroller and regulates all the system operations and electronic circuits. All auxiliary control units, if fitted, report to the main control PCB. The control system's microcontroller performs regular self-tests during operation. Whenever the system detects an issue with the temperature control system or working state, the device will issue a corresponding visual or audio alarm.

The LCD, the heater output, alarms, and monitoring of system operations are controlled through the control PCB. Comparator circuits on the control PCB compare the signal from temperature probes and the set temperature value (as in servo/automatic mode). It uses this input to control the heater output using relays (either solid state or electromechanical) which switch the heating element on/off to maintain the set temperature.

Heating elements

There are two main types of heating elements used in radiant warmers: ceramic and quartz. They are usually between 800 W or 1000 W, and they release radiant heat in the far infrared wavelength that is easily absorbed by the neonate's body.

- **Ceramic heating elements** use a heating wire (e.g., nichrome) encapsulated in a ceramic material. When power is applied the ceramic plate warms and radiates heat to the cot.
- **Quartz heating elements** consist of a coiled heating element enclosed in a quartz tube. When electricity is applied, the quartz warms, and radiates heat to the baby cot.

Both ceramic and quartz elements use an optically designed parabolic reflector that is fitted to project heat energy onto the baby cot.

Internal battery

Usually rechargeable, the internal battery operates alarms and temperature monitoring and display for 6 to 8 hours during power failure. The internal battery is usually linked to the control PCB and, in most modern models, is recharged as the radiant warmer is in use on mains power.

Firmware

Radiant warmer firmware is the software that carries out the basic functions of the radiant warmer. This software is stored in the memory within the radiant warmer's hardware. The manufacturer may issue occasional updates to the firmware that will need to be applied to existing radiant warmers per the manufacturer's instructions.

Audiovisual alarms

The control PCB's microcontroller performs regular self-tests during operation. Whenever the system detects an issue with the temperature control system or working state, the device will issue a corresponding visual and/or audio alarm or error code. The common alarms found on radiant warmers are:

- **Temperature Alarm:** works only in servo/automatic mode. It activates when the baby's temperature (measured by the patient temperature probe) deviates from the user set temperature by ± 0.5 to 1°C (depending on model). A visual alarm flashes and is followed by an audible alarm.
- **Probe Failure Alarm:** works only in servo/automatic mode. It activates when the probe fails electronically, or when the probe is disconnected from the warmer. During a probe failure, the heater deactivates and a visual alarm flashes followed by an audio alarm.
- **System Failure Alarm:** activates when systems fail or calibration deviates from expected values.
- **Heater Failure Alarm:** activates when a heater defect is detected.
- **Power Failure:** activates when a power failure is detected. Battery power supports this audible alarm during power outages.

Manufacturers may include different alarms and error codes based on model. Refer to the manufacturer user or service manual for a complete description of alarms and error codes.

Baby cot

Some radiant warmers include an attached baby cot. The cot often includes removable side panels that should be in place and secure when the baby is in the cot to prevent falls. The cot may also include a knob underneath the cot to adjust the position of the cot.

3 Management

These instructions are helpful for a biomedical engineer or technician both in user training and in assessing the appropriate functionality of the device. Management covers how to use the radiant warmer, including set up for a patient, patient commencement, care whilst on the device and removal of the patient from the device.

SETTING UP FOR A PATIENT

- 1 Plug power cable into the radiant warmer. **(3.1)** Plug power cable into a wall socket & surge protector if available. Switch on the power. **(3.2)**
- 2 Select manual setting at 25% or **Prewarm** setting (if available on model). **(3.3)**



3.1 Plug in the radiant warmer.



3.2 Switch on the power.

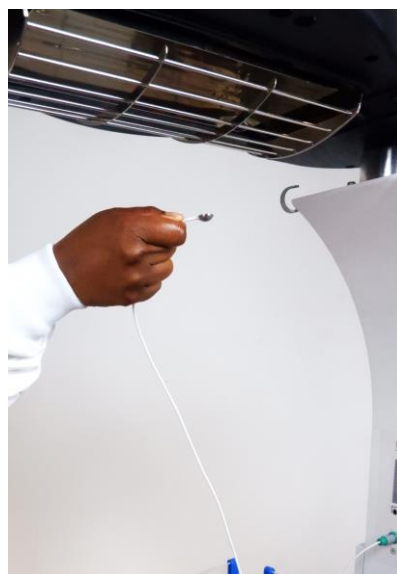


3.3 Select Pre-Warm setting to warm bedding.

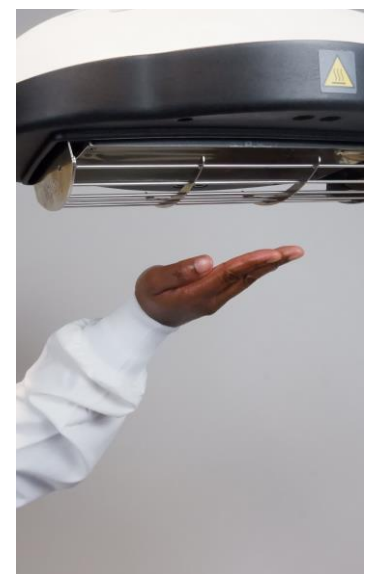
- 3 Plug temperature probe into the infant temperature probe port. **(3.4)** Hold temperature probe in hand and move hand directly under overhead heating elements to check for heat. **(3.5)** You should be able to feel heat emitting from the heating elements and observe the temperature displayed on the radiant warmer begin to steadily increase. **(3.6)**
- 4 **Prewarming is critical to prevent rapid conductive heat loss in neonatal patients.** Always advise the clinical or nursing staff to allow bedding to warm while waiting for the baby to arrive in the nursery, be transferred to the radiant warmer, or be delivered in the labour ward.



3.4 Plug in the temperature probe.



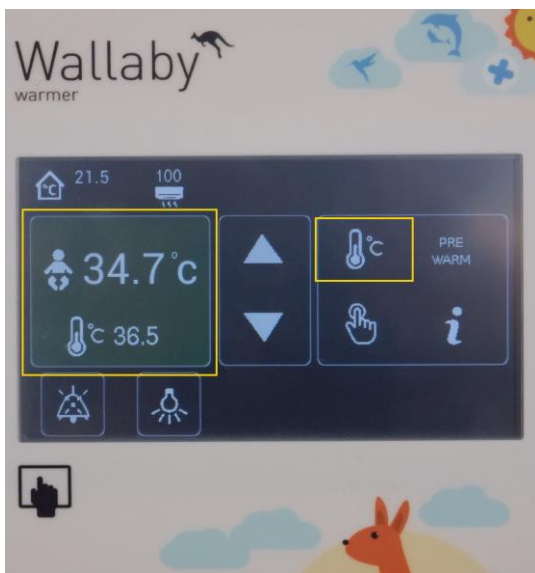
3.5 Pass the temperature probe underneath the heating elements.



3.6 Feel heat emitted from elements.

STARTING A PATIENT

- 1 Ensure radiant heater has been prewarmed. If the radiant warmer has not been prewarmed, then take steps to do so. Prewarming is essential in order to prevent infant from conductively losing heat to the mattress when initially placed on the warmer.
- 2 Change the radiant warmer from **Pre-Warm** to **Servo/Automatic** mode. **(3.7)**
- 3 Position infant in middle of radiant warmer cot, maintaining additional treatment tubing (e.g., CPAP tubing, IV lines) in place. **(3.8)**
- 4 Use gauze and 70% alcohol to clean temperature probe.
- 5 Place temperature probe directly above infant's liver and secure with tape or elastic bandage. **(3.9)** If a child needs to be cared for in a prone position, then place the probe over the infant's flank. The probe should be secured firmly enough that it will not fall off the patient, but not so firmly that it is pressing into the infant's skin.



3.7 Switch to servo mode.



3.8 Place the patient in the centre of the cot.



3.9 Place & secure temperature probe.

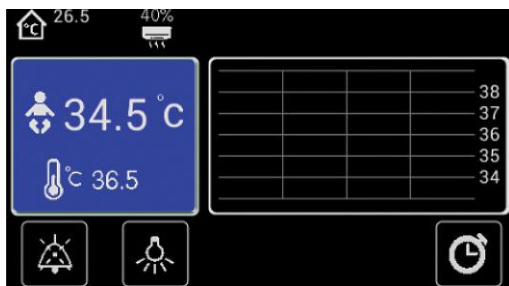
- 6 If used in servo mode, the **set temperature** for the baby is usually set to a default 36.5°C. The user may change the set temperature depending on patient's clinical status.
- 7 If the radiant heater is used in manual mode, the baby must be constantly attended as there is a real danger of overheating. Some heaters will automatically shut off after a certain amount of time in manual mode and will need to be restarted.

! Alert 3.1

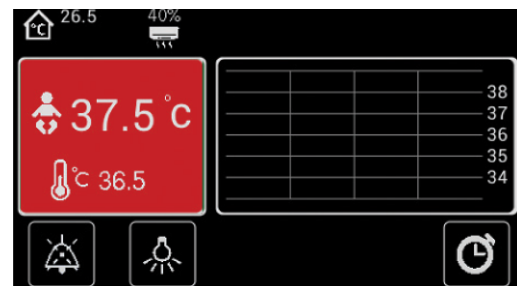
Each radiant warmer should be used for one baby with a temperature probe dedicated for that patient. **Sharing of a radiant warmer and temperature probe poses a risk for inaccurate temperature regulation and poor infection control.** If multiple patients are sharing one warmer, regular temperature monitoring must be conducted using a temperature probe or thermometer.

CARING FOR A PATIENT

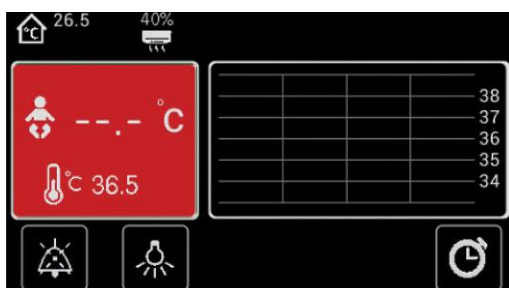
- 1 Clinical or nursing staff should monitor the patient's temperature 5 minutes after starting on radiant warmer, and then 4 hourly (if in **servo** mode) or every 30 minutes (if in **manual** mode). **(Alert 3.2)** At each monitoring point, probe placement should be checked to ensure the patient has not become tangled in the probe cable and that the probe sensor has not detached.
- 2 Alarms should be immediately addressed by the medical or technical staff when possible:
 - **Temperature:** the infant temperature probe has recorded temperatures below **(3.10)** or above **(3.11)** the safe range for the patient. Assess if the patient is too hot or cold and change the radiant warmer settings accordingly. Check probe is not dislodged from the baby.
 - **Probe:** the temperature probe is not secured in the radiant warmer appropriately or the probe has malfunctioned. **(3.12)** Make sure the probe is plugged in; if the alarm continues, replace the probe or contact your maintenance department.
 - **Power:** the mains power has failed. **(3.13)** Turn off the power button on the radiant warmer control and move the patient to a working warmer.
 - **System:** the radiant warmer has recorded a problem with its system. **(3.14)** This may result in the radiant warmer no longer providing heat or no longer monitoring the patient. The patient should be moved to a working warmer and the malfunctioning device removed for service.



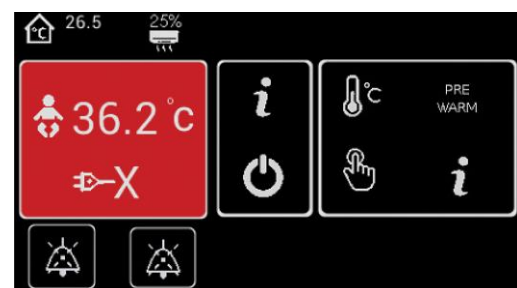
3.10 Low Patient Temperature alarm.



3.11 High Patient Temperature alarm.



3.12 Probe Failure alarm.



3.13 Power Failure alarm.



3.14 System Failure alarm.

Alert 3.2

In some devices, the microprocessor is programmed to reduce heater output to 60% and activate an alarm when it has been in manual mode without adjustment for more than 15 minutes. The microprocessor is also programmed to cut heater output to 0% and trigger an alarm if the patient's measured temperature reaches 40°C or above.

REMOVING A PATIENT

- 1 Collect:
 - Gauze
 - 70% alcohol
- 2 Gently remove tape/bandage holding temperature probe from patient.
- 3 Disinfect probe site on patient and temperature probe with gauze and alcohol. Remove patient to appropriate level of care (i.e., KMC, swaddled in bassinet, etc.).
- 4 Turn off warmer using switch and unplug.
- 5 After the patient has been off the warmer for 30 minutes, check the patient's temperature to ensure normal body temperature is maintained.

4 Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units.

CLINICAL INFECTION PREVENTION

- 1 Clean hands with soap and water or 70% alcohol before and after placing a patient in a radiant warmer or handling any consumables that will be used on a patient (e.g., temperature probe).
- 2 Ensure that all patient-related consumables (including probes) are new or have been cleaned thoroughly before use. **(Alert 4.1)** Any patient-related consumables must be cleaned before they are used to assess another patient on the radiant warmer.
- 3 All patient-related consumables should be stored in a clean, dry location. Any cables should be loosely wrapped and secured, preventing sharp bends or kinks which will decrease the lifetime of the cables. Do not pinch or bend the cables.
- 4 As mentioned in **Radiant Warmer: Management**, each radiant warmer should be used for one baby with a temperature probe dedicated for that patient. Sharing of a radiant warmer and temperature probe poses a high risk for infection transmission between patients. If the

patient probe and surfaces are not cleaned thoroughly before using, infection can also be transmitted.

DISINFECTION AFTER USE

- 1 Turn off and unplug the radiant warmer, if not using with another patient. Allow to cool.
- 2 Immediately after every use, use gauze and 70% alcohol to thoroughly wipe:
 - a Temperature probe, including cable and plug head
 - b Control panel
 - c Power button
 - d Mattress
 - e Bassinet walls & floor
- 3 Housing of the radiant warmer should be cleaned according to ward guidelines for disinfecting surfaces. **(Alert 4.1)**

BMET INFECTION PREVENTION

- 1 Any piece of equipment used in providing patient care must be handled carefully, as it may be contaminated and have the potential to spread infection.
- 2 Clean and disinfect radiant warmer housing and components whilst wearing PPE as appropriate (e.g., rubber gloves, apron, face protection, etc.) **before any repairs or maintenance are made.**
- 3 Avoid any contact between used piece of equipment and skin, mucosa or clothing.
- 4 Post-maintenance, decontaminate all tools and surfaces used with 70% alcohol or according to manufacturer guidelines. Do not use equipment until it has fully dried following decontamination.

Alert 4.1 Disinfecting Equipment

Disinfection of equipment should always comply with manufacturer guidelines. WHO recommends 0.5% dilution of chlorine (0.5% or > 100ppm available sodium hypochlorite) as the standard disinfectant for materials and surfaces contaminated by blood or body fluids.⁶ For metal and rubber surfaces, which may be corroded by chlorine, 70% alcohol is also commonly utilised for low level disinfection.

Other appropriate low-level disinfectants include quaternary ammonium, improved hydrogen peroxide and Iodophor germicidal detergent.⁷ Phenolic germicidal detergent is also listed in this category but should not be used in neonatal wards since affordable, effective alternatives are available; and, there are concerns it may cause hyperbilirubinemia and/or neurotoxicity in neonates.⁸

Please see dedicated NEST module on Infection Prevention and Control for further details on risks, benefits and utilisation of chemical disinfectants. For comprehensive guidance on infection prevention and control we recommend utilising Reference Manual for Health Care Facilities with Limited Resources Infection Prevention and Control (Caston-Gaa & Ruparelia, 2018).

5 Complications

Equipment in newborn care units are highly specialised. Without proper knowledge and skills, this equipment can be potentially dangerous for the infants, families and care providers.

CLINICAL COMPLICATIONS

- **Hypothermia & cold stress:** if the device is not prepared correctly, is malfunctioning, or the baby is left exposed for a long period of time, there is a risk of hypothermia. This is associated with a significant increase in mortality and morbidity.
- **Hyperthermia & heat stress:** hyperthermia can occur in patients whilst on manual mode who are not monitored regularly or on servo mode if the temperature probe falls off as they may become overheated. Hyperthermia increases morbidity and mortality.⁹⁻¹³
- **Pressure sores:** pressure sores may develop if the patient is incorrectly positioned, is lying on additional tubing/equipment, or the temperature probe is not positioned correctly.
- **Falls:** the cot sides of the radiant warmer must be in place to prevent the baby falling off the mattress on to the floor.
- **Infection:** if the temperature probe or infant warmer are not cleaned thoroughly before use, infection can be transmitted. Care should be taken particularly for consumables that are marked as single-use but are reused in practice (such as temperature probes).

DEVICE COMPLICATIONS

- **Hyperthermia due to probe mismanagement:** if the device is set to automatically adjust its temperature based on the patient's temperature (servo mode) and the patient temperature probe falls off the patient or is not well secured **(5.1)**, the radiant warmer may overheat in an attempt to compensate for what it observes as a low body temperature. This puts the patient at risk for a body temperature > 40°C and clinical harm.



5.1 An unsecured temperature probe may cause the radiant warmer to overheat.

- **Alarms:** radiant warmers have in-built alarms that should sound if the patient's temperature is above or below a set normothermic range. If this range is not appropriately set, alarms may sound inappropriately.
- **Fire:** if linen is placed on the radiant heater head, heat and dust may build up and pose a fire hazard. Linen should never be stored on top of the device or close to the heating elements. Although treatment devices (e.g., phototherapy units, oxygen concentrators) can be used with a radiant warmer, care should be taken to ensure that the direct line of heat to the patient from the radiant warmer heating elements is not obstructed.

6 Care & Maintenance

Biomedical engineers and technicians are responsible for second-line care and maintenance to ensure equipment lasts to their potential lifetime.

POWER SOURCE

Radiant warmers are powered with mains/socket power. Radiant warmers are typically the largest consumers of power in a nursery and should be plugged into **their own socket and surge protector** if available. **(6.1 & 6.2)** Radiant warmers typically draw too much power to be used with small-scale solar systems. In most cases, the cost (both financially and energetically) to run radiant warmers during a power cut prevents them from being used with backup power.



6.1 Radiant warmers should be plugged into their own socket.



6.2 Radiant warmers should be plugged into a surge protector if possible.

WARD LOCATION

Radiant warmers should be placed against a wall with the power cable/stand facing the wall and control panel facing the middle of the nursery room. **(6.3)** Warmers should be away from any windows to avoid air currents providing the potential for additional convective heat loss. Windows are preferably kept closed.



6.3 Appropriate placement with the power cable port facing the wall and display LCD facing away from the wall.

DEVICE CALIBRATION

Manufacturers do not typically recommend calibration for any radiant warmer components. Should the radiant warmer begin to provide temperature readings inaccurate to patient condition

or respond incorrectly to user feedback, the manufacturer may be contacted to recommend a firmware update or other repair.

DECOMMISSIONING

Assuming appropriate use and consistent maintenance, a radiant warmer may last 3 or more years. Generally, it is more fiscally responsible to repair radiant warmers when necessary, although there are some low-cost models that may be cheaper to replace rather than repair. When decommissioning a radiant warmer, heating elements, control and heating circuit board components and housing components should be taken apart and stored for further use. If the LCD, heating elements or various PCBs are still in good condition, these parts may be repurposed for other devices. Typically, the control PCB should only be repurposed for devices of the same manufacturer and model, although components from the circuit board may be desoldered and repurposed independently. **(Alert 7.3)**

PREVENTIVE MAINTENANCE

After Each Use

- ☐ Turn off, unplug and allow the radiant warmer to cool. Use gauze & 70% alcohol to wipe:
 - ☐ Temperature probe, including cable and plug head
 - ☐ Control panel
 - ☐ Power button
 - ☐ Mattress
 - ☐ Bassinet walls & floor

See **Radiant Warmer: Disinfection After Use** and **Alert 4.1** for more information.

- ☐ Visually inspect radiant warmer components.

Weekly

- ☐ Test the heating elements and temperature probe:
 - ☐ Plug in the machine. Connect the temperature probe. Turn the power switch to ON. Leave the machine on for 1 minute.
 - ☐ Hold the temperature probe in the palm of your hand and hold your hand near the overhead heating elements. Slowly move it from the part of the heating element closest to the stand, moving towards the outside end of the heating element. You should feel your hand progressively heat as it moves and see the temperature reading on the machine steadily increase.
- ☐ Document cumulative hours and preventive maintenance actions taken.

Monthly

- ☐ Perform **Weekly** preventive maintenance steps.
- ☐ **Test the power loss alarm:** while the radiant warmer is plugged in and turned on, turn off the power at the wall socket. An alarm should sound.
- ☐ Check the operation of the baby cot, tilting mechanism and drawers.
- ☐ Document cumulative hours and preventive maintenance actions taken.

Quarterly

- ☐ Perform **Monthly** preventive maintenance steps.
- ☐ Check functionality of device in Information page or test the device in self-diagnosis mode. Observe general functionality and safety checks.
- ☐ Measure ground resistance and leakage currents. Inspect electrical components for signs of excessive heat or deterioration.
- ☐ Document cumulative hours and preventive maintenance actions taken.

Annually

- ☐ Perform **Quarterly** preventive maintenance steps.
- ☐ Confirm supply of spare heating elements, temperature probes, control PCBs, LCDs and power cables are adequate to support estimated replacement for next year.
- ☐ Document cumulative hours and preventive maintenance actions taken.

7 Troubleshooting & Repair

Biomedical engineers & technicians are responsible for providing rapid maintenance, troubleshooting & repair support for users.

PREPARE FOR REPAIR

ACCESSIBLE TOOLS	SPARE PARTS	DEVICE CHECKLIST
Digital multimeter Phillips, star & flat head screw drivers Allen keys Adjustable wrench Spanner (various sizes) Needle nose pliers Wire strippers Phase tester	Heating element Power cable Temperature probe Temperature probe port Control PCB LCD	<input type="checkbox"/> Radiant warmer <input type="checkbox"/> Patient temperature probe <input type="checkbox"/> Power cable (if detachable) <input type="checkbox"/> Bassinet walls <input type="checkbox"/> Bassinet mattress

TROUBLESHOOTING FAILURES

The radiant warmer does not turn on.

Probable Cause:	Faulty power supply
Components to Check:	Power cable and switch physical integrity & continuity Power entry module fuse(s) physical integrity & continuity PSU continuity & voltage

The radiant warmer turns on but is not heating, or the system failure alarm sounds.

Probable Cause:	Faulty heating element or microcontroller
Components to Check:	Heater terminal wires physical integrity & continuity Heating element resistance Heater PCB (if pertinent) voltage Firmware edition Control PCB & associated components continuity

The radiant warmer turns on, but the temperature probe does not read the patient's temperature and the probe alarm sounds.

Probable Cause:	Faulty temperature probe
Components to Check:	Probe & probe port physical integrity Control PCB & associated components continuity

The power failure alarm does not sound when there is a power cut.

Probable Cause:	Low alarm battery voltage
Components to Check:	Alarm battery voltage Battery wiring continuity

Discoloured or black spots obstruct view of the display.

Probable Cause:	Damaged LCD
Components to Check:	LCD physical integrity

REPAIR & REPLACE

Where technically possible and not likely to obstruct clinical care, repairs may be made within the newborn care ward. Use discretion to determine if this is appropriate or if the device should be removed to the biomedical workshop for more testing or repair.

Alert 7.1

All testing, repair and replacement steps should be conducted with the power to the device switched off and the power cable removed from mains power, unless otherwise stated.

Testing & replacing the power supply fuses

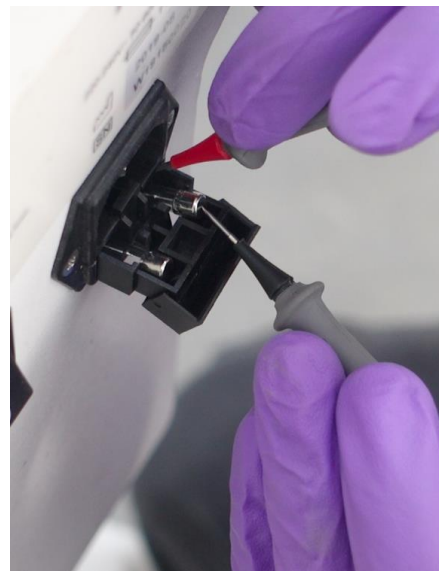
Fuses may be located both on the radiant warmer housing and on the power supply cable. Fuse integrity may be visually assessed or evaluated by testing the continuity across the fuse. **(7.1 – 7.6)** Always refer to the manufacturer specifications for replacement fuses to ensure that the device remains electrically sound in standard operation.



7.1 Use a screwdriver to open the fuse drawer.



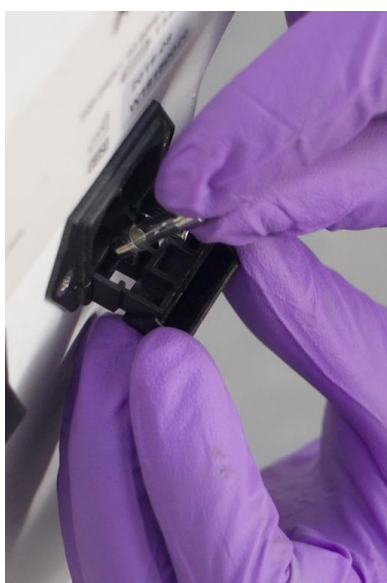
7.2 Pull out the fuse drawer to view the fuses.



7.3 Test the fuses with a multimeter.



7.4 If replacement is needed, remove the faulty fuse.



7.5 Replace with fuse of comparable specifications.



7.6 Close the fuse drawer.

Testing & replacing the power switch

Power switches should be tested in both the off and on positions to confirm functionality. In the **On** position, the switch terminals should be continuous. In the **Off** position, the switch terminals should show a high resistance, or **OL** in most multimeters. **(7.7 – 7.9)** Although the switch may be tested whilst in circuit to preliminarily check the switch, best practice is to then remove it completely from the circuit and retest to confirm.

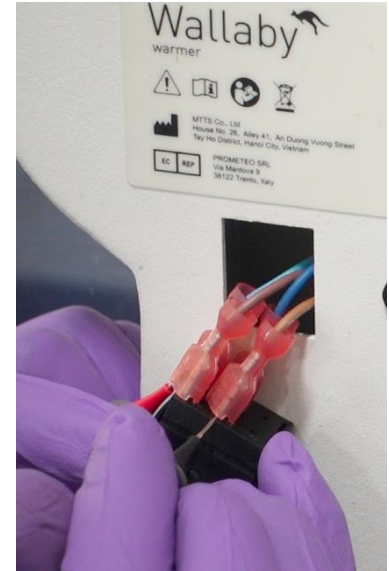
If the switch shows continuity or discontinuity inappropriately, assess the switch for visible physical or electrical damage. If the switch is visibly damaged or dislodged, assess whether it can be repaired with glue or solder. If it cannot be easily repaired, replace the switch. Refer to manufacturer specifications for replacement switches to ensure the device remains electrically sound in standard operation.



7.7 Remove the power switch from the housing.



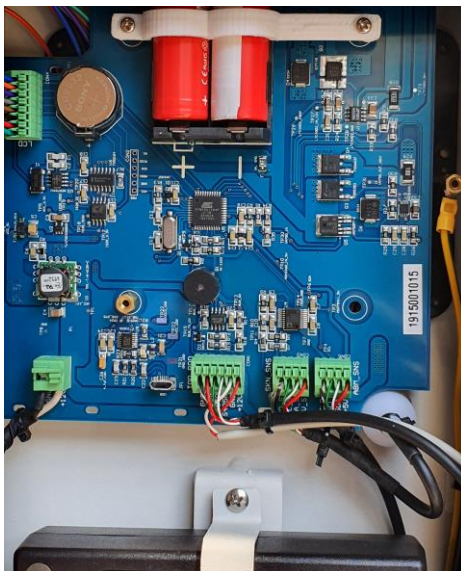
7.8 Pull out the power switch to access switch terminals.



7.9 Test the power switches in Off & On positions.

Testing & replacing control PCB and associated components

In most cases, if one element of the control PCB has malfunctioned, the entire control PCB should be replaced. Visually assess the PCB for burnt or damaged components. **(Alert 7.2)** Internal wiring continuity leading from the power supply to the control PCB and from the control PCB to the heating element may also be assessed for replacement. **(7.10 – 7.12)**



7.10 Visually assess the control board.



7.11 Remove the PCB power supply covers.



7.12 Confirm voltage at the PCB power supply with specifications.

! Alert 7.2

Printed Circuit Boards (PCBs) contain components that are sensitive to electrostatic discharge (ESD) and can damage the board if not handled properly. As when handling any ESD-sensitive PCB, observe standard ESD safety procedures.

Testing & replacing the power supply unit and module

Test the power supply module's continuity without the device connected to power. **(7.13 – 7.14)** Testing the power supply unit and module cannot always be completed appropriately without checking the alternating voltage at the power supply unit. **This should be completed with caution**, as the power to the device must be switched on to accurately measure the voltage delivered. If the power supply unit or module is damaged, contact the manufacturer to request a replacement part.



7.13 Unscrew power supply module from housing.



7.14 Pull the module from the housing.



7.15 Confirm continuity across the module.

Testing & replacing heating elements & element components

Testing the heating elements and associated components involves checking for loose or physically damaged wiring, terminals and heating elements. A visual check can be conducted for these components to assess basic physical damage (e.g., cracked elements, melted or loose terminal wires).

Electrically, heating elements and wiring should be assessed for continuity or resistance. The alternating voltage at the heating elements can also be measured: **this should be completed with caution**, as the power to the device must be switched on to accurately measure the power supply to the heating elements. Damage to heating elements will display as very high resistance or no continuity. **(7.16 – 7.18)**

If the heating elements are physically or electrically damaged, contact the manufacturer to request a replacement part and replace. **(7.19 – 7.21)** In some cases, the heating element may be replaced with repurposed parts from other nonfunctioning radiant warmers. This is generally not advisable as replacement parts from varying models or manufacturers may not be compatible with device microcontroller or firmware (causing incorrect temperature readings or system errors) or the system specifications for the heating element (creating the potential for further damage to other parts of the device or electrical fire).

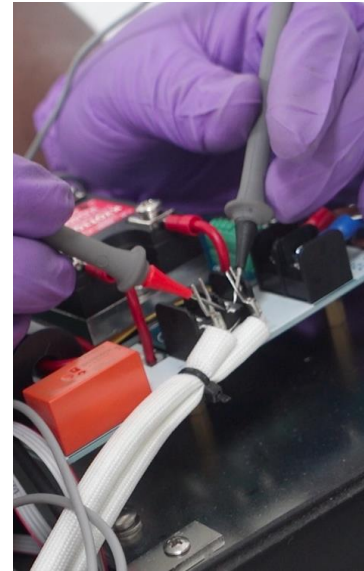
If repurposing, replacement parts should be checked with the manufacturer to ensure specifications are within standard for the device.



7.16 Use a screwdriver to open the heater housing.



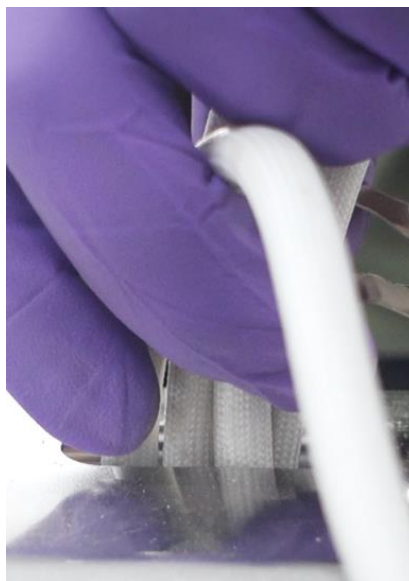
7.17 Remove housing and set aside.



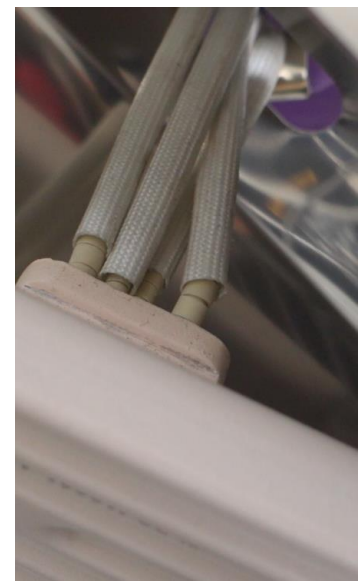
7.18 Test heating element terminals with a multimeter.



7.19 If replacing, remove clip securing the element.



7.20 Pass faulty element through hole in element housing.



7.21 Withdraw the faulty element from below the element housing.

Repairing & replacing the temperature probe or probe port

The radiant warmer temperature feedback system relies on the temperature probe and the temperature probe port being physically and electrically sound. If the temperature probe is visibly damaged, replace with a spare probe.

The temperature probe port should also be assessed externally and internally for physical damage. If the patient temperature probe port is visibly damaged or dislodged, assess whether the part can be repaired with glue or solder. If it cannot be easily repaired, contact the manufacturer to request a replacement part. In some cases, the probe port may be replaced with repurposed parts from other non-functioning radiant warmers. This is generally not advisable:

- If the radiant warmer from which the replacement probe port is taken is a defunct model, the concomitant temperature probe may be difficult to find.
- Replacement parts from varying models or manufacturers may not be compatible with the microcontroller or firmware of the radiant warmer, causing incorrect temperature readings or system errors.

After providing any maintenance on the probe or probe port, confirm the probe's accuracy by measuring different temperatures that are within the expected range of the system using a thermocouple.

Updating the radiant warmer firmware

If the radiant warmer has malfunctioning firmware, communication may be lost between the microcontroller and temperature probe or heating element. Contact the manufacturer to confirm that a firmware update is needed and coordinate the update, if possible.

Testing & replacing the alarm battery

The alarm battery is typically responsible for powering basic display functions and alarms in the event of a power outage. The specifications for battery voltage should be available in the manufacturer's service manual, but are typically 9V. Both the voltage across the battery terminals and the continuity of the wires from the battery to the control board should be tested and the battery or wires replaced if necessary.

Testing & replacing the LCD

The LCD is typically damaged by incorrect use, particularly when the user pushes with too much force on the screen. If the damaged areas do not hinder viewing or use of the display, the radiant warmer may be used without significant issues. However, if the damaged areas prevent easy use, the LCD should be replaced. Contact the manufacturer to request a replacement part specific to the radiant warmer model.

Alert 7.3 Repurposing Parts

In some cases, parts on the unit may be replaced with a repurposed or recycled part from another piece of equipment being used for parts. **Repurposed parts should be considered with caution and guidance from the manufacturer to ensure specifications of the repurposed part is compatible with the equipment.** This includes spare parts and accessories that may not be compatible with multiple systems.

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