

Chapter 17



Stirring Heating Plate

GMDN Code	36815
ECRI Code	16-287
Denomination	Heating Plates

The stirring heating plate or heated stirring heating plate has been developed to heat and mix fluids contained in laboratory receptacles such as flasks, test tubes and beakers.

PHOTOGRAPH OF THE STIRRING HEATING PLATE



Photo courtesy of Cole-Parmer Instrument Co.

OPERATION PRINCIPLES

Generally, the stirring heating plate has a flat surface on which are placed receptacles containing fluids to be heated and agitated. Its surface is made of good thermal conductors such as aluminium [Al] or ceramic materials. Some heating plates exclusively use radiation sources such as infrared (infrared light) for heating. Stirring hot plates have a heating element (an electrical resistor), a control system (on and off, temperature control, agitation control and its respective motor). The motors used in these types of instruments are generally of single phase induction named shaded pole¹. The speed range depends on the number of poles and the frequency of the feed voltage.

Temperature:

Room Temperature up to approximately 500 °C.

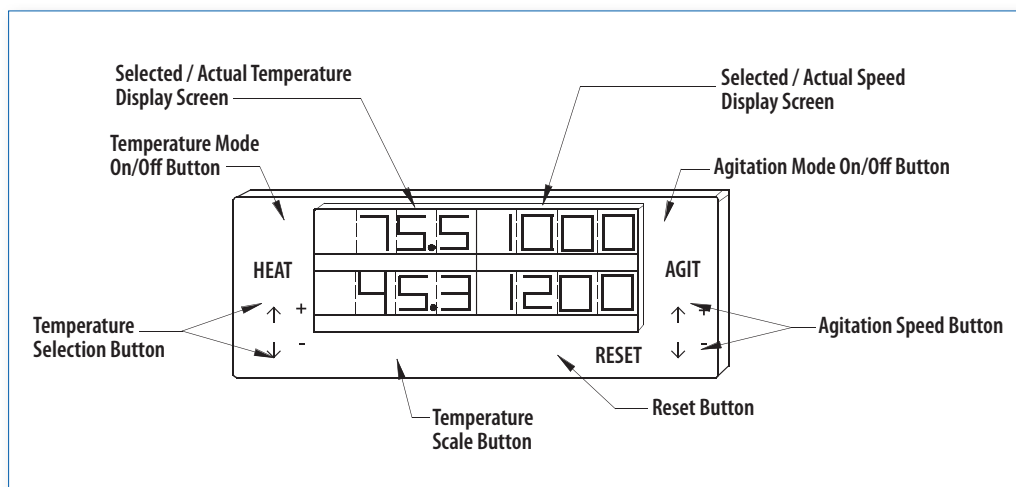
Rotation speed:

From 60 RPM up to approximately 1200 RPM.

CONTROLS OF THE STIRRING HEATING PLATE

The diagram in Figure 54 includes a typical control found on a stirring heating plate. The diagram shown corresponds to a microprocessor-regulated heating plate which is found in most modern equipment.

Figure 54. Stirring heating plate controls



¹ The power of these motors is approximately 1/20 hp; these are characterized by having a low torque and being low in price. They are called shaded pole induction motors.



The control has buttons for selecting the temperature and the stirring heating plate's speed. These can be used independently or in combination. To select the parameters, only the corresponding control button needs to be activated and the temperature and speed selected, whichever is required.

INSTALLATION REQUIREMENTS

The stirring heating plate needs to be connected to an electrical outlet in good condition with a ground pole. The outlet must be compatible with the equipment and in compliance with the national and international electrical standards. In general, stirring heating plates operate with voltages of 120 V/60 Hz, or 230 V/50-60 Hz.

For normal operation it is required to have an appropriately levelled surface with sufficient resistance to support the weight of the stirring heating plate together with that of the receptacles and liquids these may contain.

OPERATION OF THE STIRRING HEATING PLATE

Precautions

1. Always connect the stirring heating plate to an electrical outlet in good condition which has a ground pole.
2. Disconnect the equipment before carrying out any maintenance routine.
3. Avoid using the equipment in the presence of combustible or flammable materials. Avoid using equipment in environments with corrosive vapours.
4. Carefully check if substances have a low ignition point (*Flash point*). It could start a fire or an explosion if the vapour touches the surface of the heater at this temperature.
5. If working with flammable liquids, use personal protective elements: gloves and protective eyeglasses.
6. Take into account that the surface of the equipment can stay hot for a long period after being turned off or disconnected.
7. Avoid placing on the heating surface:
 - a) Metallic laminates
 - b) Materials with insulating properties
 - c) Low melting point glassware
8. Maintain a free space around the equipment to facilitate its connection and placing materials or substances needed with the equipment. Some manufacturers recommend a free space of approximately 15 cm.
9. Avoid placing combustible materials near the equipment.
10. Avoid using containers whose weight exceeds the capacity indicated by the manufacturer.

ROUTINE MAINTENANCE

The stirring heating plate is designed to work under normal conditions and requires minimal maintenance. This equipment should work without problems for several years if well installed and operated. This document presents the general routine maintenance recommended by manufacturers. Specialized procedures must be done carefully following manufacturers' recommendations.

Cleaning

Frequency: Monthly

1. Clean the equipment in a vertical position to avoid cleaning agents from reaching internal components.
2. Use a mild detergent. Apply to the external surfaces using a piece of cloth of similar texture to that of a handkerchief.
3. Verify that the equipment is completely dry before connecting it again.

Replacement of the ceramic surface

Frequency: Whenever necessary

General recommendations applicable to the substitution of the ceramic surface are presented next.

1. Verify that the heating plate is disconnected and cold. This prevents the risk of electric shock or burns.
2. Handle the equipment with extreme care since a broken ceramic surface has dangerously sharp edges.
3. Place the unit with its heating surface facing downwards.
4. Remove the screws which secure the lower cover and remove it.
5. Locate and disconnect the cables which feed the electrical resistors (in models with such elements).
6. Disconnect the cables connecting the equipment's control and the resistors.
7. Remove the screws which fasten the upper cover to the base. Verify that they do not affect the connection to the heating resistors.
8. Place the new ceramic surface in its appropriate location.
9. Observe how the safety devices of the damaged ceramic cover are positioned. Remove the safety devices and place the heating and insulating elements inside the new surface, maintaining the same alignment and distribution of the original. Put the new safety devices back.
10. Reconnect the components in the reverse order to that described above.

Replacement of fuses

Frequency: Whenever necessary

If the stirring heating plate is connected and the main switch is in the on position but it is not warming up, it is possible that a fuse needs to be changed. The following is the process for changing the fuse:

1. Place the main switch in the off position and disconnect the electrical feed cable.
2. Remove the top of the fuse compartment with a flat screwdriver.
3. Replace the fuse by a new one with the same specifications as the original.
4. Replace the fuse's compartment cover.

TROUBLESHOOTING TABLE		
PROBLEM	PROBABLE CAUSE	SOLUTION
There is no electrical power.	There is a failure in the protection fuse.	Substitute the protection fuse.
	There is a failure in the electrical connection feeding the equipment.	Check the state of the electrical connection.
	The equipment is disconnected from the electrical feed outlet.	Connect the equipment to the electrical outlet.
	The electrical feed cable is defective.	Substitute the electrical feed cable.
The plate shows no sign of warming up.	The heating function has not been selected.	Activate the heating function on the control panel.
	The heating resistor is out of service.	Substitute the heating resistor. Install replacement parts with the same characteristics as the original.
There is no rotation.	The rotation function has not been selected.	Activate the rotation control on the control panel.

BASIC DEFINITIONS

Erlenmeyer. A glass container used in laboratories to put or measure substances.

Shaded pole motor. An induction motor used in small machines. It is characterized by having a bobbin (squirrel cage rotor) requiring a rotating magnetic field for starting. Each field pole has a shading coil (copper ring) which induces currents causing the magnetic flow to become imbalanced in relation to the flow in the other portion, producing a torque in the rotor. These motors are low cost and low efficiency. Their speed can be calculated by means of the equation:

$$n(\text{rpm}) = \frac{120 f}{p}$$

Where:

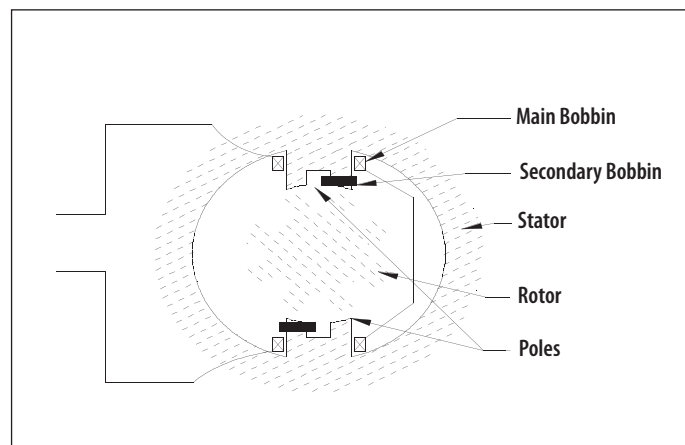
[n] = synchronous speed in revolutions per minute

[f] = frequency of voltage applied

[p] = number of poles in the stator

A diagram is included showing the inner part of the electrical circuits.

Figure 55. Induction motor



Ignition point. The temperature at which molecules of a substance react with oxygen in the air, initiating combustion. This temperature is called *Flash Point*.

Chapter 18



Refrigerators and Freezers

GMDN Code	13315	13315	17157	35486	40513	15145
ECRI Code	13-315	15-170	17-157	15-171	22065	15-145
Denomination	Refrigerators	Biological refrigerators	Laboratory refrigerators	Blood bank refrigerators	Freezer, laboratory, ultralow	Freezer, laboratory

REFRIGERATORS AND FREEZERS

Refrigerators and freezers are among the most important pieces of equipment in laboratories. They maintain a temperature controlled (refrigerated) environment for various fluids and substances. At lower temperatures, less chemical and biological activity is present so that fluids and substances are better preserved. To achieve this, the temperature of the refrigerated storage unit needs to be lower than ambient temperature. In the laboratory, different kinds of refrigerators and freezers are used. They can be grouped by temperature ranges:

- o Conservation refrigerators in the range of 2 to 8 °C.
- o Low temperature freezers in the range of -15 to -35 °C.
- o Ultralow temperature freezers in the range of -60 to -86 °C.

A unit with appropriate functions must be selected depending on the activities carried out in the laboratory. For example: if it is necessary to conserve whole blood, it will be appropriate to use a Blood bank refrigerator which provides temperatures between 2 and 8 °C. On the other hand, if it is required to conserve a particular viral or microbial stock, an ultralow temperature freezer is required. Refrigerators and freezers are essential for conserving biological substances and reagents. This chapter deals with the operational and maintenance aspects of the conservation refrigerators and ultralow temperature freezers.

PHOTOGRAPH OF A REFRIGERATED STORAGE UNIT



Photo courtesy of Cole-Parmer Instrument Co.



PURPOSE OF REFRIGERATED STORAGE UNITS

Refrigerators and freezers are used for the conservation of blood and its derivatives, biological liquids and tissues, reagents, chemicals, and stocks. In general, the higher the temperature the more chemical and biological activity is present. By reducing temperature, one can control the effects on the composition and structure of substances to be preserved. In the laboratory, systems of refrigeration are used for conserving substances such as reagents and biological elements which would otherwise decompose or lose their properties. Refrigeration, as a technique offers conditions which renders possible the conservation of elements such as blood and its derivatives needed for diagnosis, surveillance and for providing health services. It is possible to achieve extremely low temperature ranges, such as those used for master stocks conservation ($-86\text{ }^{\circ}\text{C}$) or temperatures within the range of 2 and $8\text{ }^{\circ}\text{C}$, which is sufficient for conserving reagents and diverse biological products.

OPERATION PRINCIPLES

Refrigerators and freezers function according to laws of physics regulating the energy transfer where temperature differences exist. From the second law of thermodynamics it is known that, if thermal energy needs to be transferred from a point with low temperature to another with high temperature, a mechanical task needs to be carried out. Modern refrigerators and freezers are thermal systems which function mainly using a cycle called *compression*, where refrigerant gas with special properties achieving heat transference is used. This chapter focuses on explaining how refrigerators and freezers using compression operate.

Refrigeration circuit

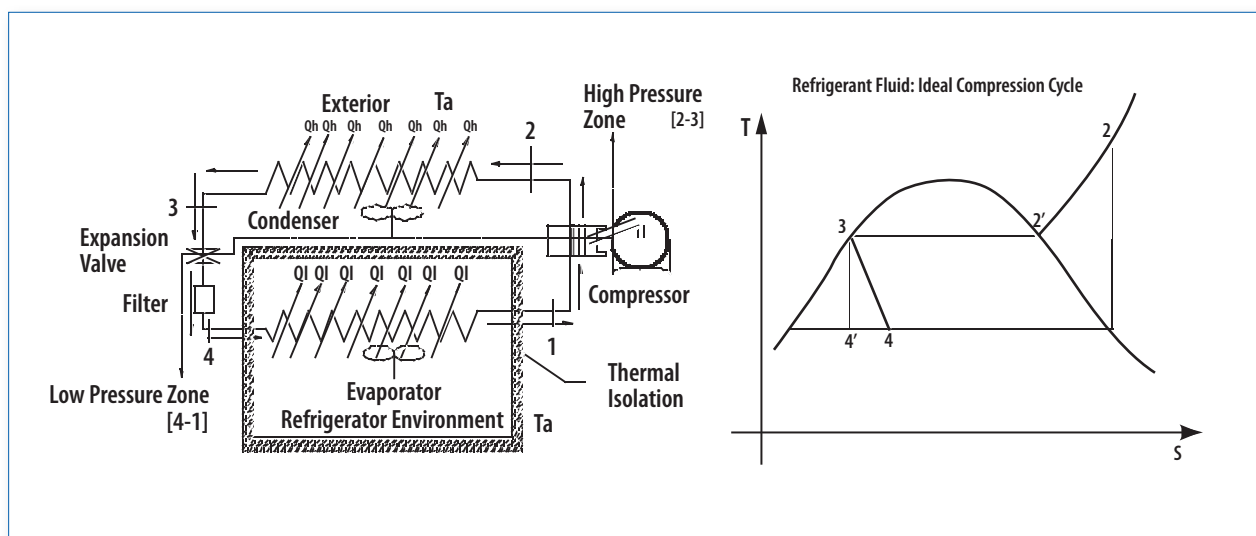
The basic circuit shown in Figure 56 demonstrates how a refrigerator functions. On the left side it is possible to distinguish the following components: evaporator, condenser, compressor, expansion valve, filter and interconnection tubing. Within each one of these components, refrigerant gas circulates.

On the right side of the figure is shown a graph of temperature $[T]$ versus entropy $[S]$, which demonstrates the functioning of an ideal¹ refrigeration cycle. The numbers on the basic diagram on the left show points of the adiabatic processes (compression $[1-2]$ and choking $[3-4]$) and the processes involved in heat transference (in the evaporator – refrigerated environment $[4-1]$, in the condenser $[2-3]$ on the exterior). The complete cycle is described as the sequence of processes $[1-2-3-4-1]$.

Evaporator. Contains a network of channels through which the refrigerant gas circulates. In the evaporator, a process of heat transference $[Q]$ occurs at a constant pressure. In order for the refrigeration process to occur, the environment to be refrigerated must be surrounded by a system of thermal isolation. This is to prevent thermal energy from entering the evaporator's zone of influence at the same rate as the refrigerant gas absorbs it. The refrigerant gas enters into a liquid phase in the evaporator by point $[4]$ (ideal) or $[4']$ (real) and while it passes through the network of evaporator channels, it absorbs heat $[Q]$ and progressively transforms into vapour. When the refrigerant gas reaches point $[1]$, it is under the form of vapour. It is then suctioned by the compressor through a tube or line.

¹ The real cycle differs from the ideal cycle by some irreversible processes not indicated in the graph for the sake of clarity and simplicity.

Figure 56. Refrigeration circuit



Compressor. Usually propelled by an electric motor, the compressor suctions the vaporized refrigerant from the evaporator (saturated) at low pressure and by means of a piston or set of pistons, exercises a process of reversible adiabatic compression on it (without heat transfer) between points [1-2]. Upon being discharged from the compressor, the vapour is hot as a result of the compression process and is delivered to the condenser in point [2].

Condenser. Similar device to the evaporator, which has a network of channels through which the refrigerant gas circulates. As the temperature of the refrigerant is higher than ambient temperature [Ta], a heat transference process [Qh] is produced from the refrigerant to the environment at constant pressure. To facilitate heat transference, the condenser tubes have thin fins which increase the transfer surface. As heat continues to be lost [Qh] as a result of the process of transference, the refrigerant returns to its liquid phase until it reaches point [3] as saturated liquid where it enters the expansion valve.

Expansion valve. Allowing the refrigerant to flow in a controlled manner, the valve exercises a resistance on the passage of the refrigerant to avoid any heat transference by an adiabatic process. As a result, the pressure in the valve is reduced in a drastic way in point [4]. A filter is generally installed at the exit of the expansion valve. Some manufacturers replace the expansion valve by a capillary tube which has an equivalent restrictive effect on the passage of the cooling fluid.

Filter. Retains humidity and impurities which may be present in the refrigerant. At the back of the filter, the system is connected again to the evaporator at point [4] and the cycle described is repeated.

Liquid collector. Sometimes placed by manufacturers before the refrigerant enters the compressor. Its purpose is to retain any portion of that fluid in liquid phase to guarantee that only vaporized refrigerant gas enters the compressor (not shown in the refrigeration diagram).

Thermal insulation. Set of materials with the property of slowing heat transference. Its function consists of preventing thermal energy from the environment to reach the refrigeration area at the same rate as the system extracts the internal thermal energy. All refrigeration equipment has adequate thermal isolation for this purpose. Among the most commonly used insulation materials are polyurethane foam and glass wool. Similarly, it is customary to manufacture interior surfaces in materials such as ABS plastic.

Service valves. Valves used for loading the refrigeration circuit with refrigerant gas. By means of these valves, the draining and filling systems are connected so that the

refrigerated storage unit operates according to specifications established by the manufacturer. Only the manufacturer and specialized technical personnel have access to these valves (not indicated in the refrigeration diagram).

Thermal protector. This is a protective device which is activated and disconnects the compressor in case overloads affecting the bobbins in the compressor's field occur (It pertains to the electrical system and is not indicated in the refrigeration system's diagram).

Note: The evaporator, as well as the condenser are made of materials with good thermal conduction properties such as aluminium [Al] and copper [Cu]. To improve heat transference, ventilation systems which induce forced convection processes have been incorporated. To attain the different temperatures (refrigeration) required in laboratories or in the industry, manufacturers have developed diverse designs and refrigerants for the targeted results.

INSTALLATION REQUIREMENTS

For their functioning refrigerators and freezers require the following precautions:

1. An electrical connection with a ground pole appropriate to the voltage and frequency of the equipment. In general depending on their capacity, refrigerators and freezers can be obtained in versions with 115 V, 60 Hz and 220-240 V, 50 Hz. Electrical connections complying with international and national electric standards used in the laboratory must be anticipated.
2. If more than one unit installed depend on the same electrical circuit, it must be verified that the capacity (electrical power) and safety devices are adequate for supplying the amount of power required by these units.
3. Directly connect the unit to the electrical outlet. Never connect a unit to an overloaded electrical outlet or one with voltage deficiencies. Avoid the use of electrical extensions. The electrical outlet must not be more than 2 m from the unit.
4. Install the unit on a levelled surface, leaving free space around the equipment. Refrigerators and freezers have a levelling system at their base which allows them to adjust to small differences in level of the floor. It is customary to leave a free space of 15 cm at the sides and at the back of the unit to facilitate ventilation of the condenser.
5. Avoid installing the unit under direct sunlight or near a heat source such as radiators or heaters. Remember that the greater the difference in temperature is between the environment and the condenser, the more efficient will the heat transference be.

REFRIGERATOR CONTROL CIRCUIT

The scheme in Figure 57 is a typical control circuit installed in refrigerators and freezers. Its purpose is to give an idea of how their diverse subsystems are interrelated. The control circuit of each model varies according to the characteristics incorporated by the manufacturer.

The following are featured as central components:

1. The main switch. It energizes the refrigerator.
2. The door switch. It turns on the light when the door is opened.
3. The compressor.
4. The evaporator's ventilators.
5. The defrosting subsystem. The switch, resistors, temporizer (5', 5", 5"', 5'''').
6. The resistor subsystem for defrosting or maintaining the equipment's components free from ice.
7. The thermostat.

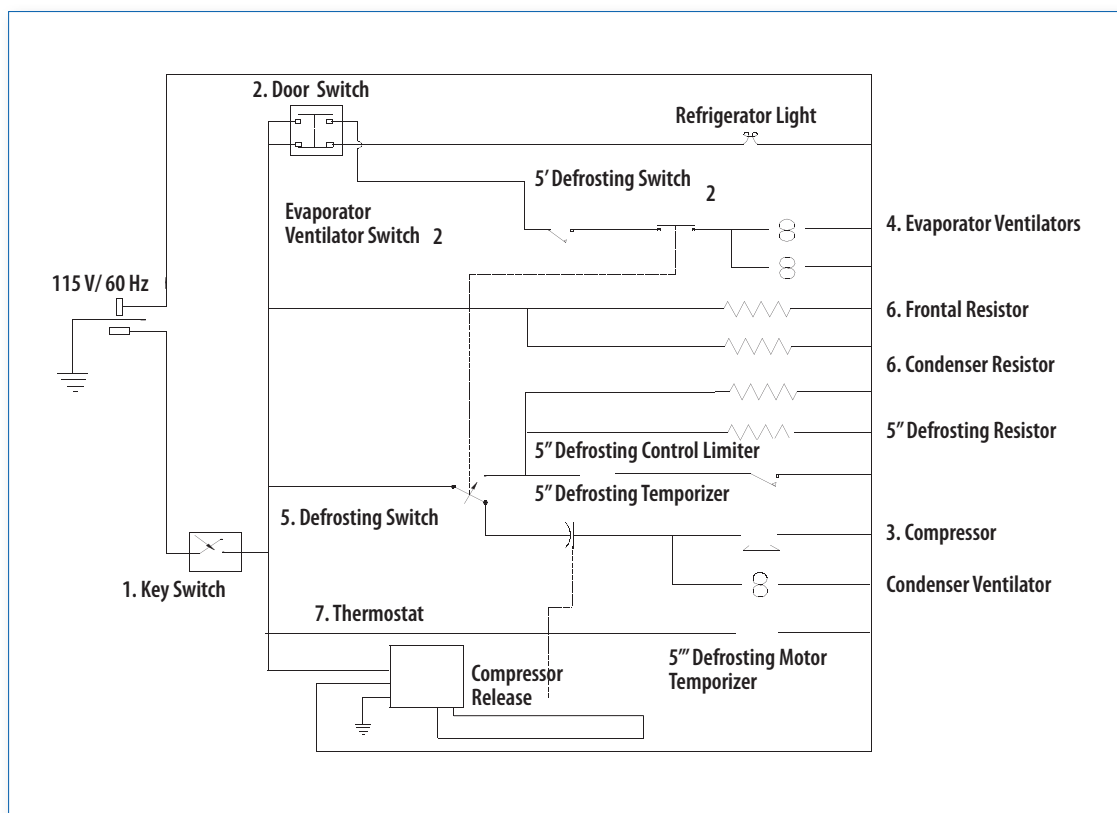
REFRIGERATOR OPERATION

Conservation refrigerators

The operation of conservation refrigerators is generally very simple. Each manufacturer gives basic recommendations. Some of these are highlighted below.

1. Connect the refrigerator's electrical feed cable to an electrical outlet equipped with a ground pole and the capacity to supply voltage at the required power.
2. Activate the on switch. Some manufacturers place key switches on refrigerators. Wait for the refrigerator to reach the operating temperature before storing any product. The manufacturers adjust the temperature of refrigerators at approximately 4 °C.
3. Select the temperature at which the alarm must be activated. Follow the instructions provided by the manufacturer.
4. Load the refrigerator according to the capacity established by the manufacturer.

Figure 57. Control circuit of the refrigerator



5. Distribute the load homogeneously inside the refrigerator. The temperature uniformity depends on the free circulation of air within the refrigerator.
6. Avoid opening the door for long periods of time in order to prevent thermal energy and humidity (from the air) from entering into the refrigerated environment. This forms ice and increases the working temperature of the refrigeration system. Open only for placing or removing stored elements.

Conservation refrigerator controls

A diagram of a recently developed control for conservation refrigerators (e.g. a Blood bank refrigerator) is shown in Figure 58.

The following controls can be seen in the diagram:

1. A main switch, activated by a key
2. Open door, low battery and abnormal technical condition indicators
3. Buttons for adjusting parameters
4. Display screen

REFRIGERATOR ROUTINE MAINTENANCE

Refrigerators are generally not very demanding from a maintenance perspective, although demanding with regards to the quality of the electrical feed systems. If connected to good quality electrical circuits and good ventilation flows around the unit, they can function for years without specialized technical service. The refrigeration circuit is sealed during manufacturing and does not have components requiring routine maintenance. The most common maintenance routines are described next. Consult

WHO’s *Manual on management, maintenance and use of cold chain equipment, 2005*, for care and preventive maintenance schedules specific to Blood bank refrigerators, plasma freezers and walk-in refrigerators and freezers used in the blood cold chain.

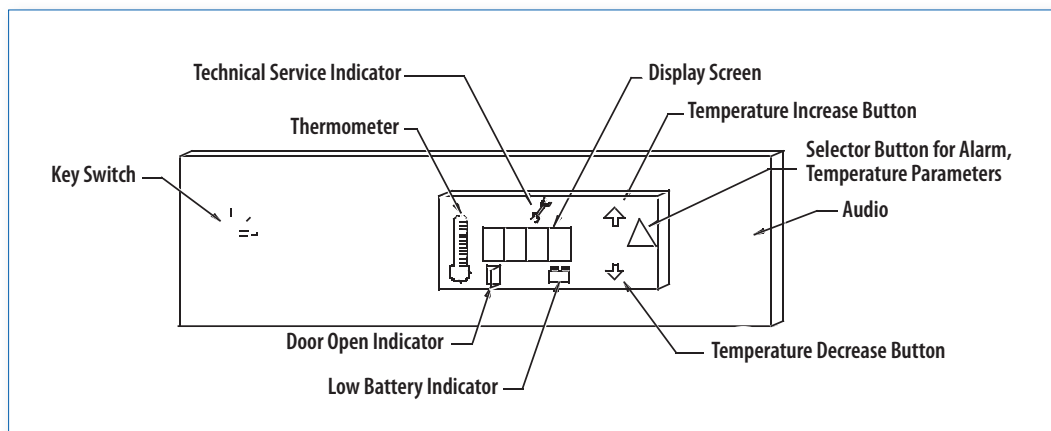
Cleaning the interior

Frequency: Every quarter

1. Verify that the refrigerator’s inner shelves are clean. These are generally made of rust proof metallic mesh. Before cleaning, any material which can interfere must be removed from the refrigerator. Move the empty shelves towards the front. Dampen a piece of cloth with a mild detergent and apply by rubbing surfaces gently. Dry and place in their original position.
2. If the refrigerator has drawers, cleaning is done the same way. Empty the drawers and dismount from the adjustment devices. Remove them from the refrigerator.
3. Once the shelves and drawers are dismounted, clean the interior walls of the refrigerator, using a mild detergent. Dry before mounting the internal accessories.
4. Apply a mild detergent with a damp piece of cloth to the drawers. Rub carefully. Dry the drawers and put them back on their mounts in the refrigerator.

Warning: Avoid using steel wool or other abrasive materials for cleaning the shelves and drawers. Avoid using gasoline, naphtha or thinners, as these damage the plastic, the packing or the paint on the surfaces.

Figure 58. Blood bank refrigerator controls



Cleaning of the condenser

Frequency: Every six months

1. Disconnect the electrical feed cable.
2. Verify the position of the condenser. Manufacturers usually place it at the lower back of the equipment. In some refrigerators, it is installed on the top part.
3. Remove the condenser's protective grids and the protective filter (not all manufacturers provide a filter).
4. Remove the dust and grime deposited on the surface of the condenser. Use an aspirator equipped with a suction brush. Run it over the entire surface of the condenser to remove grime or accumulated dust. Verify that the tubes' surfaces as well as those of the heat conducting wings are clean. Vacuum the filter as well (if present).
5. Replace the cover.
6. Connect the refrigerator to the electrical connection.

Warning: If the condenser is not clean, this will interfere with the heat transference process and the refrigerator could "heat" or function at temperatures different than selected.

The door gasket verification

Frequency: Quarterly

The door gasket is a component which must stay in a good condition for the unit to work correctly. To verify its condition, one must proceed according to the following steps:

1. Open the door.
2. Insert a strip of paper of about 5 cm in width between the door gasket and the edge of the refrigerator's body where the gasket is housed.
3. Close the door.
4. Pull the paper gently from the exterior. The paper must put up resistance when being moved outwards. If the paper can be moved without resistance, the gasket must be substituted. Perform this procedure on 10 cm of gasket at a time around the entire gasket housing.

Warning: A door gasket in bad condition produces various problems in the functioning of cooling units:

1. It allows humidity to enter which condenses and freezes inside the evaporator.
2. It increases the time needed by the compressor for maintaining the selected temperature.
3. It affects the storage temperature.
4. It increases the operational costs.

Defrosting

Frequency: Every six months

Many modern freezers have automatic cycles for defrosting the evaporator in order to avoid frost accumulation. Normally, these cycles are done with a set of electrical resistors which rapidly eliminate the frost present. Some models do not have defrosting cycles and the process is done manually on a scheduled basis. The following are the recommended procedures for defrosting.

1. Verify that the thickness of the frost is more than 8 mm.
2. Remove the contents of the compartments.
3. Disconnect the freezer.
4. Leave the door open.
5. Remove the water while it is accumulating in the compartments. Use a sponge or a piece of absorbent cloth.
6. Place a towel to avoid the melting ice from wetting the front and interior part of the refrigerator.

Warning: Never use sharp elements to remove ice or frost from the evaporator. Such an action can perforate the wall of the evaporator and allow the refrigerant gas to escape causing a serious defect which can only be repaired by a specialist.

TROUBLESHOOTING TABLE		
PROBLEM	PROBABLE CAUSE	SOLUTION
The unit is not functioning.	Blown fuse.	Check fuse.
	The equipment is disconnected.	Verify the unit's connection.
	There is no or low electricity in the feed circuit.	Test the electrical connection. Verify the main switch (breaker).
The freezer is functioning continuously but is not cooling.	The thermostat is adjusted too high.	Confirm the adjustment of the thermostat. Adjust the thermostat to a lower temperature.
	The unit contains excessive frost.	Defrost the unit.
The unit is showing fluctuations in temperature.	The temperature control is not calibrated.	Calibrate the operational temperature according to the procedure defined by the manufacturer.
	The condenser is dirty.	Clean the condenser according to the procedure cited in the maintenance routines.
The unit shows a high temperature.	The door is open.	Verify that the door is well adjusted and closed.
	Poor door seal.	Level cabinet and adjust door seal or replace gasket.
	There is a defect in the electrical feed.	Confirm that the electrical connection functions correctly.
	A warm load (liquids or solids) was placed inside the unit.	Wait for the unit to cool the load.
	The compressor is not functioning.	Verify the functioning of the compressor.
		Test to see if one of the alarms is on.
	The compressor is functioning but there is no ice in the evaporator.	Verify if the evaporator's ventilators are functioning.
	The compressor is functioning, but there is no ice in the evaporator and the evaporator's ventilators are functioning well.	A complete verification of the refrigeration system is required. Call in the specialized service technician.
Low refrigerant gas level.	Call in the specialized service technician.	
Upon operating the unit, noises similar to clicking sounds can be heard.	The compressor's thermal protector has been disconnected.	Verify that the feed voltage is correct.
Noisy operation.	Floor not stable or cabinet not levelled.	Move to an adequate floor area or adjust casters as appropriate.
	Drip tray vibrating.	Adjust tray or cushion it.
	The cooling fan hitting cover or compressor is loose.	Call in the specialized service technician.
The compressor runs continuously.	Not enough air circulation around the unit.	Move the unit to provide with sufficient clearance. Relocate if necessary.
	Faulty thermostat.	Call in the specialized service technician.
	Poor door seal.	Check seals and adjust.
	Room too warm.	Ventilate the room appropriately.
	The door is being opened too often or is not closed.	Restrict door opening or close door.
The light switch is defective.	Check if light goes out after the door is shut.	

OPERATION OF ULTRALOW FREEZERS

Ultralow temperature freezers

Operation of ultralow temperature freezers implies following a procedure recommended by their manufacturers to achieve the conditions stipulated for the equipment. The recommendations common to any ultralow freezer are highlighted next:

1. Connect the unit to an electrical outlet with a ground pole exclusively dedicated to the unit. This outlet must be in good working condition and appropriate for the electrical power required for the unit. It must also be in compliance with the national and international electrical standards. The voltage must not vary by more than +10 % or -5 % from the voltage specification on the equipment. There are units which require power of approximately 12 kW. It is then essential to have an electrical connection which is of a suitable size for such loads.
2. Select a location which has a firm and levelled floor (in all directions). It should be well ventilated and away from direct sunlight or heat sources. Some manufacturers stipulate that suitable ambient temperature is between 10 °C and 32 °C. The free space at the sides and back must be at least 15 cm. The door must open freely at an angle of 90°. Normally, manufacturers include additional devices at its base on the support wheels for levelling the unit.

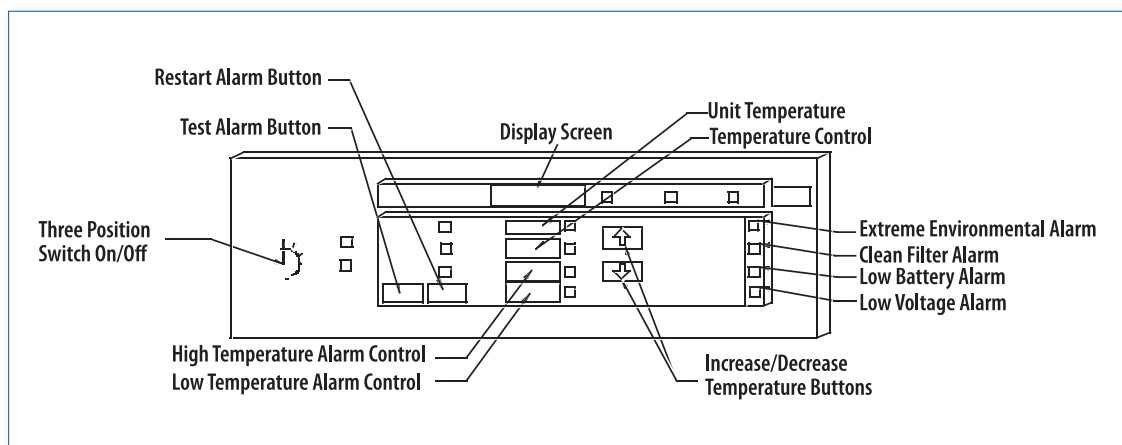
TURNING THE UNIT ON

In order to understand the freezer's operational procedures, a diagram of a control panel similar to those used in such units is presented. The diagram in Figure 59 is generic: differences in the controls used by the various manufacturers will certainly be encountered. Included next are recommendations common to all refrigerators.

Procedures

1. Connect the electrical feed cable to the electrical supply outlet.
2. Turn the key to the on position. The screen must be illuminated indicating the temperature of the cabinet. A light transmitting diode display will indicate that the unit is energized. This action will start the compressor, ventilators of the evaporator and the condenser.
3. Select the unit's operational temperature. In general, various buttons are activated simultaneously; the button corresponding to the temperature control and those to adjust the temperature. Once the desired temperature is selected, the controls are released. The screen will show the operational temperature selected. Wait a suitable time for the unit to reach the selected temperature.
4. Select the limit temperatures which will activate the alarms. These temperatures do not generally differ by more than 10 % from the operational temperature. In general, the alarms are adjusted when the unit has reached a temperature near its operational point. The procedure consists of activating the alarms' control and selecting higher and lower temperature limits so that the alarm is activated if these are exceeded. The manufacturer's recommended procedure must be followed. Usually, the control has a button which allows the alarms to be deactivated and also the option to test their functioning.
5. Ultralow temperature units have another series of alarms which warn the operators regarding the occurrence of events which can affect the adequate functioning of the unit. Among these are the following:
 - A flaw in the electric feed.
 - Low voltage.
 - Excessive room temperature.
 - The lower temperature limit is exceeded.

Figure 59. Ultralow freezer temperature control



ROUTINE MAINTENANCE

The maintenance routines of the ultralow temperature freezers are focused on the following elements described below. Consult WHO's *Manual on management, maintenance and use of cold chain equipment, 2005*, for care and preventive maintenance schedules specific to plasma freezers and walk-in freezers used in the blood cold chain.

Cleaning of the condenser

Frequency: Every six months

1. Remove the protective grid.
2. Remove and clean the filter. If too obstructed, substitute by a new one with the same characteristics as the original.
3. Verify the functioning of the ventilator.
4. Vacuum the condenser and its diffusive fins.
5. Reinstall the protective grid and the filter.

Warning: A dirty condenser prevents normal heat transference causing the unit to warm up or exceed the selected temperature limits.

Integrity of the door gasket

Frequency: Recommended quarterly

It is recommended that periodically, the integrity of the door gasket be verified. It must remain in good condition and not display cracks, punctures or tears.

Defrosting

Frequency: Recommended every six months

Whenever it is necessary to defrost the unit, it must be conducted in the following manner:

1. Transfer the products kept frozen to another unit with the same operational characteristics.
2. Turn off the unit and allow its interior to reach room temperature.
3. Remove the ice and water accumulated inside the unit.
4. If strange odours emanate, wash the inside of the unit with sodium bicarbonate and warm water.
5. Clean the exterior with a mild detergent, dry and then apply a protective wax if appropriate.

Warning: Never use sharp elements for removing ice or frost from the evaporator. Such an action can perforate the wall of the evaporator allowing the refrigerant gas to escape, dangerous for the operator and causing a serious damage which can only be repaired by a specialized repair shop.

Maintenance of the alarm system battery

Frequency: Approximately every two to three years

The alarm system battery must be changed once worn out. To substitute it, proceed as described next:

1. Remove the front cover. In general, the battery (batteries) is (are) located immediately behind the front cover.
2. Disconnect the connection terminals.
3. Remove the worn out battery.
4. Install a battery with the same characteristics as the original.
5. Connect the terminals.
6. Replace the cover.

TROUBLESHOOTING TABLE		
PROBLEM	PROBABLE CAUSE	SOLUTION
The low voltage indicator is on.	There is inadequate voltage in the electrical feed outlet.	Verify the feed voltage. Test the connection and its protective systems.
The dirty filter indicator is on.	Verify the cleanliness of the filter.	Clean the condenser's protection filter. If it is saturated with grime, substitute it for another with the same characteristics as the original.
The low battery indicator is on.	The battery is worn out.	Substitute with a battery of same specifications as the original.
The unit is not functioning.	The equipment is disconnected.	Connect the equipment to the electrical feed outlet.
	The fuse is burnt out.	Substitute with a fuse of same characteristics as the original.
The unit functions in a continuous manner.	The operating temperature selected is very low.	Increase the temperature selected.
The unit functions in a continuous manner without getting cold.	The condenser is dirty.	Clean the condenser.
	There is inadequate ventilation.	Verify and correct the ventilation.
	There is an ice build-up affecting the insulation.	Defrost the unit. Call in the specialized service technician if the problem is not resolved.
Rapid frost accumulation on the evaporator.	Leaking door gasket.	Adjust door hinges. Call in the specialized service technician if the problem persists.
The door on the freezer compartment is shut frozen.	Faulty door seal heater.	Call in the specialized service technician.
Noisy operation.	Floor not firm or cabinet not level.	Move to sound floor area or adjust casters as appropriate.
	Drip tray vibrating.	Adjust tray or cushion it.
	The cooling fan hitting cover or compressor is loose.	Call in the specialized service technician.
The compressor runs continuously.	Not enough air circulation around the unit.	Move the unit to provide with sufficient clearance. Relocate if necessary.
	Faulty thermostat.	Call in the specialized service technician.
	Poor door seal.	Check seals and adjust.
	Room too warm.	Ventilate the room appropriately.
	The door is being opened too often or is not closed.	Restrict door opening or close door.
	The light switch is defective.	Check if light goes out after the door is shut.
Other additional maintenance procedures require specialized tools and instrumentation.		

BASIC DEFINITIONS

Adiabatic process. A process in which there is no transference of heat. This implies $\Delta Q = 0$.

BTU. This is a unit for determining the heat transference in the English System. BTU is the acronym for the *British Thermal Unit*. One BTU is the quantity of heat that must be transferred for increasing the temperature of one pound of water from 63 °F to 64 °F.

Calorie. This is a quantity of heat which must be transferred to a gram of water to raise the temperature by 1 °C. This definition applies when under normal conditions (atmospheric pressure equal to 760 mm Hg, gravity acceleration equal to 9.81 m/s²); the temperature of a gram of water is increased from 14.5 to 15.5 °C.

Entropy. Measure of a system's energy that is unavailable for work, or of the degree of a system's disorder. The reversible differential changes of entropy are expressed by means of the following equation:

$$dS = \frac{dQ}{T}$$

Where:

dQ: heat absorbed from a reserve at temperature T during an infinitesimal reversible change of the state.

T: temperature of the reserve.

The following equation must be carried out for any reversible cycle change.

$$\Delta S = \int dS = \frac{dQ}{T} = 0$$

If the cycle is irreversible, it must be:

$$\Delta S = \int \frac{dQ}{T} < 0$$

Heat. This is a form of transferred energy over the limit of a system at a given temperature, to another one at a lower temperature by virtue of the temperature difference between the two systems. When a system of great mass [M] is placed in contact with another of small mass [m'] at a different temperature, the resulting final temperature is close to the initial temperature of the greater mass system. It is therefore said that a quantity of heat ΔQ has been transferred from the system of higher temperature to the system of lower temperature. The heat quantity ΔQ is proportional to the change in temperature ΔT . The proportion constant [C], called the system's caloric capacity, allows the following relationship $\Delta Q = C\Delta T$ to be established, from which it is inferred that one of the consequences of the change in temperature in a system is the transference of heat.

Latent heat. The quantity of thermal energy required for a change in phase to occur in a substance, for example: from liquid phase to vapour phase.

Refrigerant gas. A substance (i.e. coolant) used as a medium in the processes of heat absorption.

Specific heat. The quantity of heat required to increase the unit of mass by one degree.

Sensitive heat. The quantity of energy required for increasing the temperature of the refrigerant gas upon absorbing heat. For example: the quantity of heat required for raising the temperature from 15 to 20 °C or from 30 to 40 °C.

Thermal system. A device which operates in a thermodynamic cycle and carries out a certain positive quantity of work as a result of the transference of heat between a body at high temperature to a body at low temperature.

Chapter 19



Clinical Chemistry Analysers

GMDN Code	35513	—	34549*
ECRI Code	15-551	18-505	15-551
Denomination	Clinical chemistry analysers	Analysers, point-of-care (portable)	Dry chemistry analyser

* Subcategory under GMDN code 35513

Chemistry analysers measure the concentration of analytes in blood or other bodily fluids based on specific chemical reactions by photometry. Applications vary from clinical diagnostic, drug abuse monitoring to forensic testing, etc. Chemistry analysers comprise among others, dry chemistry analysers using sample-impregnated dipsticks onto which chemical reactions are detected, and wet chemistry analysers testing analytes in solution. Various models of chemistry analysers are available, some designed to measure a single analyte, e.g. glucometers, haemoglobinometers; others to measure up to more than ten. Chemistry analysers are available as bench top instruments with various degrees of automation or in portable formats. Some are adapted to tropical conditions with electronic components protected from high humidity. Chemistry analysers group a large family of instruments including various photometers and colorimeters (see Chapter 20). Other common terms used to define these are: general chemistry analyser, clinical analyser or cholesterol meter, glucometer, haemoglobinometer (see Chapter 20) etc. for single-analyte instruments.

Bench top dry chemistry analyser and related materials



Photo courtesy of F. Hoffmann-La Roche AG

PHOTOGRAPHS OF CHEMISTRY ANALYSERS

Portable dry chemistry analyser



Photo courtesy of Siemens Healthcare Diagnostics Inc. ©2008

Wet chemistry analyser



Photo courtesy of F. Hoffmann-La Roche AG



PURPOSE OF CHEMISTRY ANALYSERS

In the clinical laboratory, the chemistry analyser is used to measure one analyte or various analytes such as glucose, urea, creatine, haemoglobin, cholesterol, etc., in blood, urine, serum or plasma. It is also used to perform liver function tests.

OPERATION PRINCIPLE

Dry chemistry analyser

A dry chemistry analyser is a reflectance photometer. Figure 27 of Chapter 11 shows the interaction of light with matter and light reflection also called reflectance. Reflectance photometry quantifies the intensity of a chemical or biochemical reaction generating colour on a surface (e.g., slide, test strip, dipstick or test patch). Light is emitted at a specific wavelength onto the test strip by the instrument's light source (e.g. light emitting diodes or LEDs). The coloured product absorbs that wavelength of light. The more analyte in the sample, the more product (colour) and the less the light is reflected. The instrument's detector measures the reflectance of this colorimetric enzymatic or chemical reaction on the test dipstick or strip and converts it into an electronic signal. This signal is translated into the corresponding concentration of analyte in the bodily fluid tested and the concentration is then printed and/or shown on a LED digital display.

Wet chemistry analyser

The wet chemistry analyser is a photometer. As opposed to a spectrophotometer, it does not have a prism or transmission grating. One of several or a single colour filter is used to measure the absorption of light in liquid samples

according to the Beer- Lambert law (see Chapter 11). The wet chemistry analyser generally uses a light source such as a halogen lamp with filters. More recent models use a single LED or several LEDs at specific wavelengths. Tests performed on wet chemistry analysers are based on the production of a coloured compound of the analyte with specific reacting reagents. The colour is directly proportional to the concentration of analyte(s) in solution. Typically, measurements are performed between 304 and 670 nm or with additional filters. Some instruments have the capacity to perform kinetic measurement through time.

COMPONENTS

Dry chemistry analyser

There are various designs of dry chemistry analysers. One feature of these instruments is the compartment or window where the test strip is placed. Designs vary according to manufacturers. The compartment is either closed with a flap cover or the strip is inserted into the instrument manually or through an advance mechanism. The light source is usually one Light Emitting Diode (LED) or several, with specific wavelength(s). The approach for reflectance measurement varies in different designs of dry chemistry analysers. It can be performed directly as shown in Figure 60, or in a chamber of square or spherical shape. The following Figures show an Ulbricht's sphere (also called integrating sphere) and how it measures reflectance.

In Ulbricht's spheres, one or more LEDs of key wavelength(s), e.g. 567, 642 and/or 951 nm act(s) as the light source(s) to accommodate various tests. The receptors are two symmetrical photodiodes, the reference (D_r) and a measuring one, (D).

Figure 60. Basic diagram of reflectance photometry on a test strip. Arrows illustrate the light path. The dashes represent the change in intensity due to the effect of the colour on the reaction zone of the test strip.

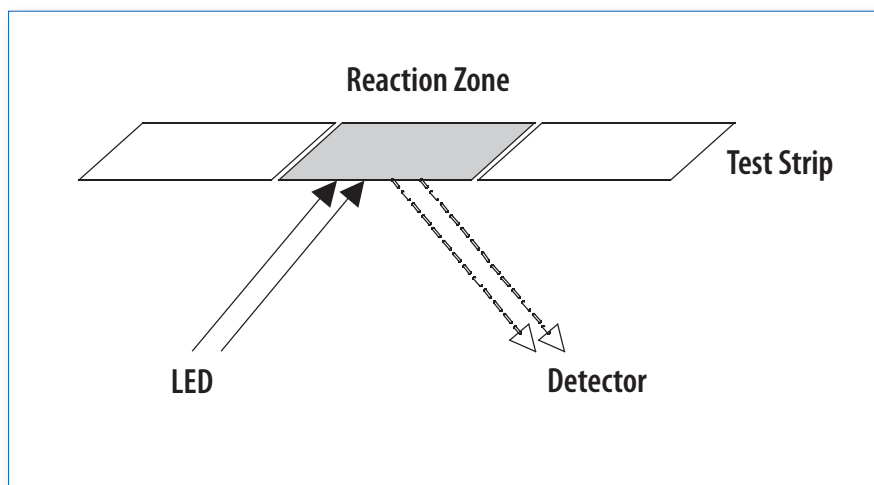


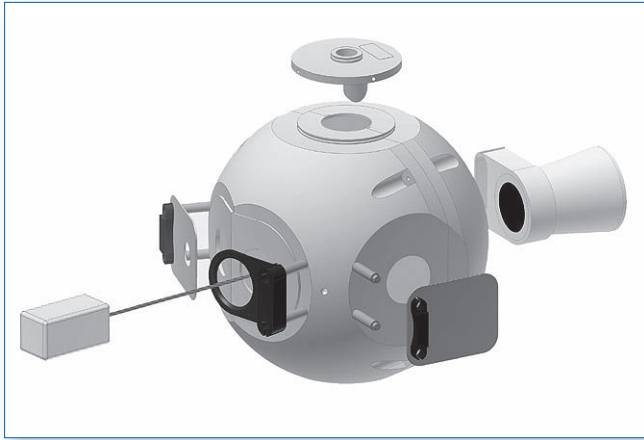
Figure 61. Ulbricht's sphere.


Photo courtesy of Gigahertz-optik GmbH

The light emitted by the LED is uniformly reflected from the white inner wall of the sphere. Photodiode D_R measures the intensity of the diffused light (I_0) and photodiode D measures the light intensity diffusely reflected from the test portion of the strip (I). The I_0/I ratio is proportional to the reflectance value R . The reflectance measured is converted into a concentration or activity value based on test-specific standard curves.

Wet chemistry analyser

Wet chemistry analysers also widely vary in design. The common basic features are the photometric components described in the Figure below. Additional accessories vary widely depending on the degree of automation and sophistication of the instrument. Wet chemistry analysers are often equipped with peripheral or integrated computer and printer. Advanced instruments provide concentration of the targeted analytes in the relevant units of measure.

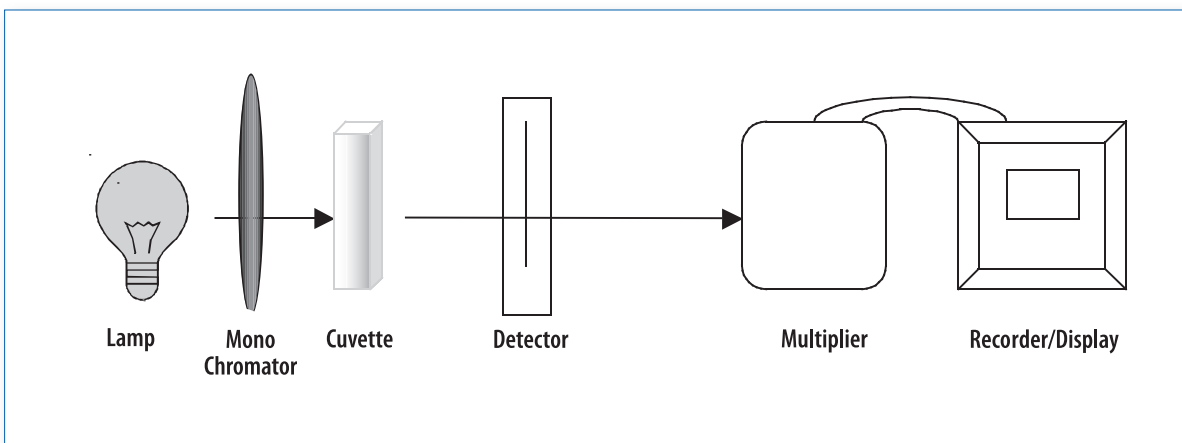
INSTALLATION REQUIREMENTS

1. Unpack the chemistry analyser carefully.
2. Ensure that the instrument is placed away from direct sunlight, stray light or heat sources.
3. Place the instrument on a firm bench near a power outlet (if not battery operated).
 - a. The outlet must have its respective ground pole in order to guarantee the protection and safety of the operator and the equipment. Chemistry analysers generally operate at 110-120 V/60 Hz or 220-230 V/50Hz.
 - b. If not battery operated, protect the chemistry analyser from power surges using a voltage stabilizer.
4. Follow the manufacturer specifications for the installation of specific models.
5. Keep specialized packaging for future use or return for repair.
6. For added safety, some instrument models may be locked in a cupboard when not in use.

OPERATION OF THE DRY CHEMISTRY ANALYSER

Only staff trained and authorized to use the **dry chemistry analyser** are allowed to operate the instrument. The procedure below is based on the use of a particular instrument. Refer to the instruction manual for other dry chemistry analyser models.

1. Connect the instrument to its power supply and switch on.
2. Warm up time should be displayed in seconds. For other instruments, wait 15 minutes before use, or as indicated by the manufacturer.

Figure 62. Basic components of a photometer. (Note that in some instruments, the filter is placed between the cuvette and the detector.)


3. When READ appears on the screen or the appropriate time has elapsed, proceed with the testing intended.
4. Take a reagent strip out of the vial.
5. Using a pipette, draw the appropriate amount of sample (e.g. 32 µl) avoiding air bubbles in the tip.
6. Remove the aluminium foil from the application zone of the strip without bending it.
7. Apply the sample to the centre of the red application zone avoiding touching the strip with the pipette tip.
8. Open the flap, place the strip on the guide and insert horizontally into the instrument until a click is heard.
9. Close the flap. The display confirms that the correct test-specific magnetic code is read by the instrument, e.g. GLU for glucose.
10. The time before the results are to appear, is displayed in seconds.
11. The concentration of the analyte is usually displayed in mg/dl.
12. After use, open the flap and remove the strip.
13. Turn off by switching off at the wall socket if applicable and removing the plug or disconnecting the battery terminals.

OPERATION OF THE WET CHEMISTRY ANALYSER

Only staff trained and authorized to use the **wet chemistry analyser** are allowed to operate the instrument. The procedure below is based on the use of a portable semi-automated wet chemistry analyser with inbuilt filters and digital display. Refer to the instruction manual from the manufacturers when using other models.

1. Connect the instrument to the power supply and switch on.
2. Warm up time should be displayed in seconds.
3. Prepare all the solutions in test tubes in a rack, i.e. blank, standards, test solutions.
4. Once the instrument is ready, blank the instrument.
5. Read each one of the test tubes.
6. Record the results.
7. Turn off by switching off at the wall socket if applicable and removing the plug or disconnecting the battery terminals.

ROUTINE MAINTENANCE OF CHEMISTRY ANALYSERS

Some chemistry analysers require minimal maintenance and automatically perform self-calibration routines. The guidelines below are general procedures applicable to most instruments. Always carefully follow the manufacturer's instructions for calibration, regular servicing and maintenance of your analyser.

Frequency: Daily

1. Any spill on, or around the instrument should be cleaned immediately.
2. At the end of the day, disconnect the power source by switching off at the wall socket if applicable and removing the plug or disconnecting the battery terminals.
3. For **dry chemistry analysers**: Do not leave test strips in the instrument. Regularly clean the window or compartment where test strips are inserted and keep it closed. Use a soft, clean damp swab.
4. For **wet chemistry analysers**: Keep the sample chamber empty and closed when not in use.
5. Cover the instrument after use.
6. Store appropriately away from dust.

Frequency: As needed

1. Replace blown fuses and bulbs according to the manufacturer's instructions.
2. If the equipment is faulty, consult a qualified biomedical engineer.

Frequency: Monthly

The window and/or front surface of the photodetector should be inspected and cleaned with lens tissue.

Frequency: Every six months

1. Inspect the instrument visually to verify the integrity of its components according to the manufacturer's specifications.
2. Verify that the buttons or control switches and mechanical closures are mounted firmly and that their labels are clear.
3. Ensure that all the accessories are clean and intact.
4. Check the adjustment and condition of nuts, bolts and screws.
5. Make sure the electrical connections do not have cracks or ruptures. Test that they are joined correctly.
6. If applicable:
 - a. Verify that cables securing devices and terminals are free from dust, grime or corrosion.
 - b. Verify that cables are not showing signs of splicing or of being worn out.
 - c. Examine that the grounding system (internal and external) is meeting the electric code requirements.
7. Make sure the circuit switches, fuse box and indicators are free from dust, corrosion and grime.
8. Check lamp alignment if recommended by the manufacturer.

Frequency: Annually

These tests must be performed by an electrician (for instruments using main power), engineer or other trained personnel. Results must be recorded and retained for follow-up through time.

1. Check the installation location for safety of the electrical (for instruments using main power only) and the physical infrastructures.
2. For instruments using main power:
 - a. Check that the voltage is appropriate and does not vary more than 5% from the voltage in the equipment specifications.
 - b. Check that the polarity of the outlet is correct.
3. Check that there is sufficient space around the instrument for the connecting cables and for adequate ventilation.
4. Test the integrity of the counter and its cleanliness.
5. Verify that the instrument is away from equipment generating vibrations and direct solar radiation.
6. Check that there is no excessive humidity, high temperature or dust.
7. Ensure that there is no source of smoke, gas or corrosive emissions nearby.

NON-ROUTINE MAINTENANCE AND TROUBLESHOOTING

These instructions are general guidelines for troubleshooting chemistry analysers. Since there are numerous models available, always refer to the instruction manual from the manufacturer and follow the steps recommended.

1. If there is no light passing through the system, or if its intensity is not constant, change the bulb.
2. If there is light in the system but no display response, change the photocell.
3. Always replace blown fuses and bulbs according to the manufacturer's instructions.
4. If the equipment is faulty, consult a qualified biomedical engineer.
5. If the chemistry analyser fails to switch on, check the electric socket outlet. Plug and check the fuse or the battery terminals.
6. In case of a major breakdown, consult a qualified biomedical engineer.

TROUBLESHOOTING TABLE		
PROBLEM	PROBABLE CAUSE	SOLUTION
The analyser does not start.	The on and off switch is in the off position.	Move the switch to the on position.
	There is no electric energy in the feed outlet.	Verify the general electric feed. Test that some safety mechanism has not misfired.
	The electric feed cable is not well connected.	Connect the feed cable firmly.
	The batteries are worn out or not well connected.	Check the batteries connection and status. Replace or recharge if necessary.
The command buttons do not respond.	The initialization of the equipment during start-up is incomplete.	Turn off the equipment and switch on again.
	An incorrect command was activated, during start-up.	
The serial port does not respond.	There was incomplete initialization of the equipment during start-up.	Turn off the equipment and switch on again.
	The interconnection cable is not properly connected.	Verify the connection.
The LCD screen is difficult to read.	The contrast control is maladjusted.	Adjust the contrasts.
	Base lighting system burnt out.	Call the company representative.
The printer is blocked.	Paper jam.	Remove the excess paper with finely pointed tweezers.
		Remove the paper and reinstall again.
The printer's paper does not auto feed or advance.	The printer paper is installed erroneously.	Reinsert the roll of paper correctly.
	The front edge of the paper is not aligned or is folded.	Reinsert the roll of paper. Cut the front edge and realign in the feed system.
	The paper feed control does not respond.	Call the company representative.
The cuvette does not fit in the sample holder compartment of the wet chemistry analyser.	The cuvette is of wrong size.	Use the size of cuvette specified by the manufacturer.
	The cuvette's adjustment mechanism is incorrectly placed.	Correct the position of the adjustment mechanism.
The test strip is not read by the dry chemistry analyser.	The strip was not placed correctly in the analyser.	Make sure the usual click is heard when the strip is placed if applicable.
		Check that the strip was placed in the analyser in the correct orientation and with the black underside facing down.
The dry chemistry analyser does not perform as expected.	The incorrect test strip was used.	Check that the strip corresponds to the test required. Repeat assay with the correct strip if needed.
	The instrument is defective.	Perform the instrument checks as recommended by the manufacturer. Some instruments provide on screen user guidance to follow and quality control strips to check the optical system.

BASIC DEFINITIONS

Analyte. Component of a bodily fluid (e.g. blood, urine, etc.) which itself cannot be measured, but with certain properties which can be measured using a medical device designed for that purpose. For example lactate cannot be measured but lactate concentration can. Common analytes evaluated in clinical chemistry include cholesterol, urea, creatin, glucose, etc., which are measured to assess the health status of patients.

Reflectance (R). Ratio between the intensity of light reflected (I_0) on a surface with that of the incident light (I), I_0/I .

Test strip. Flat testing device containing test reagents and materials used for diagnostic purposes. Test strips of various degrees of complexity have been developed. These can simply consist of filter paper with bound reactive or of an elaborated system of reagent paper, transport fibres, reagent/indicator layers and magnetic strips with data encoded. The **test or reaction zone** is the area where the reaction takes place and where it is read by a dry chemistry analyser or directly by an operator.

Note: Other relevant definitions may be found in Chapter 11.

Chapter 20

Colorimeters

GMDN Code	36910	38837	15146
ECRI Code	18-257	18-258	15-146
Denomination	Photometer, filter, automated	Photometer, filter, manual	Haemoglobin analysers (Haemoglobinometer)

PHOTOGRAPH OF COLORIMETER

Portable haemoglobinometer



Photo courtesy of Hemocue AB

PURPOSE OF THE COLORIMETER

A colorimeter is an electrically powered instrument which measures the concentration of analytes in coloured solutions. It is a simple version of a photometer. The difference in the quality of its filters makes it less sensitive. The colorimeter is used for clinical chemistry, namely for determining haemoglobin concentrations. Colorimeters are made by several manufacturers and include types with inbuilt individual removable filters or filter wheels for up to ten wavelengths. Some models are adapted for hot and humid climates with gelatine filters encased in glass to prevent fungal growth and coated individual components to prevent corrosion. Colorimeters may be

manual or semi-automated. Absorbance readings are done with needle or digital readouts. The haemoglobinometer is a portable colorimeter designed to provide direct, accurate haemoglobin concentration readings in g/dl or g/l. It will also be covered in this chapter.

OPERATING PRINCIPLE

A colorimeter uses filters to produce light of a single wavelength selected according to the colour of the solution being measured. The coloured light passes through the sample and the amount of light emerging is measured on a scale of absorbance. The absorbance is directly proportional to the concentration of the coloured compound in the solution according to Beer-Lambert law (see Chapter 11). It can usually measure reliably between 0 and 0.7 absorbance units. Calibration factors are higher for colorimeters than for photometers as they are less sensitive. Calibration factors for specific methods or reagents are usually provided by manufacturers or in the literature.

Haemoglobinometers measure the concentration of haemoglobin in blood. The majority of models is manually operated and uses main or battery cell power. New models have rechargeable batteries and/or use solar energy as a source of power. Most require dilution of blood before haemoglobin measurement. Some models use a device for collecting blood without dilution; these devices are single use and disposable, thus increasing the cost of haemoglobin estimation.

COMPONENTS

The basic components of colorimeters are similar to those of a photometer as shown in Figure 62, Chapter 19. As mentioned earlier in this chapter, these instruments are simpler and due to the quality of their filters, less sensitive. The light source may be a diode lamp emitting monochromatic light. Alternatively light produced by a tungsten or halogen lamp may be filtered to achieve the required wavelength. Depending on the model, the controls of the instrument may feature the following:

1. Display window
2. ON/OFF button
3. Cuvette chamber
4. Test button
5. Reference button
6. Various modes selection button, e.g., Absorbance/%Transmittance, Kinetics (not on all models)

INSTALLATION REQUIREMENTS

1. A clean, dust, fume and smoke free environment, away from direct sunlight is required.
2. Unpack carefully and assemble following instructions from the manufacturer if applicable.
3. Place the instrument on a firm bench and, if required, near (no more than 1.5 m away) an electric power outlet with a ground pole.
 - a. The outlet must have its respective ground pole in order to guarantee the protection and safety

of the operator and the equipment. Colorimeters generally operate at 110-120 V/60 Hz or 220-230 V/50Hz.

- b. If not battery operated, protect the instrument from power surges using a voltage stabilizer.
4. Follow the manufacturer specifications for the installation of specific models.
5. For added safety, the instrument may be locked in a cupboard when not in use. This may not be possible for large models, although these could be locked in another fashion if judged necessary.

OPERATION OF THE COLORIMETER

Only staff trained and authorized to use the **colorimeter** are allowed to operate the instrument. This section is based on the use of the portable colorimeter model, equipped with inbuilt filters and a digital display. Other models may require different procedures and manufacturer's instructions should always be followed.

1. Connect the unit to the power supply and switch ON.
2. Allow 15 minutes for the instrument's optical and electronic systems to warm up.
3. Select the correct wavelength for the compound to be tested e.g. 540 nm for haemoglobincyanide.
4. Select "absorbance" using the Mode button.
5. Arrange all the required solutions in a test rack: blank (reagent containing no sample); standard of known concentration and test solutions (samples).

Figure 63. Controls on a portable colorimeter

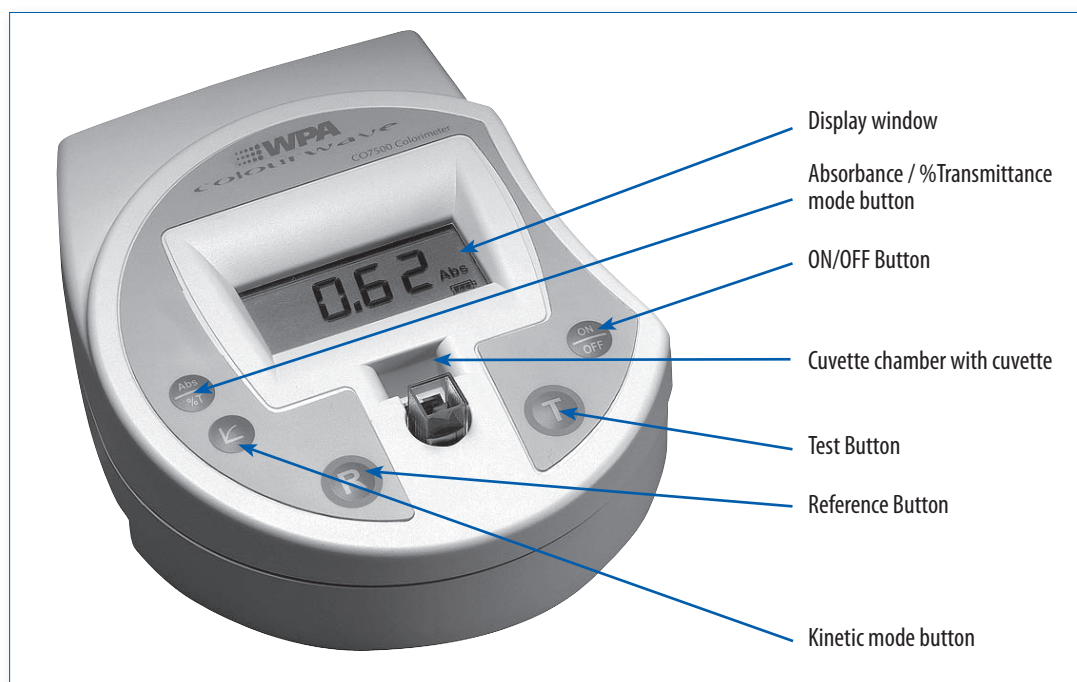


Photo courtesy of Biochrome Ltd

6. Carefully clean the cuvette using lint-free soft tissue or lens paper to avoid scratches. Always hold by the opaque ground side.
7. Transfer the blank solution into the cuvette and place it into the sample compartment with the clear sides facing the light path.
8. Close the chamber and set the display to zero using the SET BLANK control.
9. Remove the cuvette from the compartment and pour the solution back into its original test tube.
10. Pour the standard solution into the cuvette and read the absorbance.
11. Repeat step 9.
12. Read the test solutions in the same fashion.
13. Using a table of values obtained from a calibration curve derived from the instrument, read the concentration of the test samples against the absorbance.
14. After use, switch off the power supply and cover the equipment to protect it from dust.
15. Rinse the cuvette with distilled water, drain dry and wrap in soft material. Store carefully into a small box to prevent scratches and dust.
11. Remove the blank from the compartment and pour it back into the original test tube.
12. Pour the standard solution into the cuvette and place it in the compartment.
13. Close the cover and wait 3 sec. Register the reading from the digital display.
14. Remove the standard from the compartment and pour it back into the original test tube.
15. Pour the diluted sample solution into the cuvette and place it in the compartment.
16. Close the cover and wait 3 seconds and register the reading from the digital display.
17. Remove the sample from the compartment and pour it back into the original test tube.
18. Repeat steps 16-17 for each sample to be tested.
19. Rinse the cuvette with distilled water. Drain dry, wrap in soft material and store in a small box to prevent scratches.
20. Turn off by switching off or disconnecting at the wall socket if applicable. If not, remove the plug or disconnect the battery terminals.
21. Store in a locked drawer or in another suitable location.

OPERATION OF THE HAEMOGLOBINOMETER

Only staff trained and authorized to use the **haemoglobinometer** are allowed to operate the instrument. This section describes the operation of a portable haemoglobinometer with LED light source and digital display. Different models require different procedures and manufacturer's instructions should always be followed.

1. Connect the instrument to the power supply and switch ON or use the internal power source.
2. Place the ON/OFF switch on the ON position.
3. Choose readout to be used routinely, e.g. g/Dl.
4. Warm-up time should be displayed in seconds if applicable. For other models wait 15 minutes or the time recommended by the manufacturer.
5. Prepare all the solutions in test tubes in a rack, i.e. blank, standards, test solutions.
6. Leave at room temperature for 10 minutes to equilibrate.
7. Meanwhile, carefully clean the cuvette using a soft tissue to avoid scratching.
8. Avoid touching the sides of the cuvette facing the light path; hold the cuvette by the opaque sides that will not face the light path.
9. Transfer the blank solution into the cuvette and place it in the sample compartment with the clear sides facing the light path.
10. Blank the instrument: close the cover and wait approximately 3 sec and adjust the display knob at 0:00.

ROUTINE MAINTENANCE

Maintenance should be performed by qualified personnel. This section describes general routine maintenance for colorimeters and haemoglobinometers. Some models may require different procedures. Always carefully follow the manufacturer's instructions for regular servicing and maintenance of the colorimeter or haemoglobinometer.

Frequency: Daily

1. Any spill on, or around the instrument should be cleaned immediately.
2. At the end of the day, turn off the instrument or disconnect the power source or the battery terminals as appropriate.
3. Keep the cuvette chamber empty and closed when not in use.
4. Cover the instrument after use. Store appropriately, protected from dust.

Frequency: As needed

1. Replace blown fuses and bulbs according to the manufacturer's instructions.
2. If the equipment is faulty, consult a qualified biomedical engineer.

Frequency: Monthly

The window and/or front surface of the photodetector should be inspected and cleaned with lens tissue.

Frequency: Every six months

1. Inspect the instrument visually to verify the integrity of its components according to the manufacturer's specifications.
2. Verify that the buttons or control switches and mechanical closures are mounted firmly and that their labels are clear.
3. Ensure that all the accessories are clean and intact.
4. Check the adjustment and condition of nuts, bolts and screws.
5. Make sure the electrical connections do not have cracks or ruptures. Test that these are joined correctly.
6. If applicable:
 - a. Verify that cables securing devices and terminals are free from dust, grime or corrosion.
 - b. Verify that cables are not showing signs of splicing or of being worn out.
 - c. Examine that the grounding system (internal and external) is meeting the electric code requirements.
7. Make sure the circuit switches or interrupters, fuse box and indicators are free from dust, corrosion and grime.
8. Check lamp alignment if recommended by the manufacturer.

Frequency: Annually

These tests must be performed by an electrician or engineer and results must be recorded and archived for follow-up through time.

1. Check the installation location for safety of the electrical and the physical infrastructures.
2. For instruments using main power:
 - a. Check that the voltage is appropriate and does not vary more than 5% from the voltage in the equipment specifications.
 - b. The polarity of the outlet is correct.
3. Check that there is sufficient space around the instrument for the connecting cables and for adequate ventilation.
4. Test the integrity of the counter and its cleanliness.
5. Verify that the instrument is away from equipment generating vibrations and direct solar radiation.
6. Check that there is no excessive humidity, dust or high temperature.
7. Ensure that there is no source of smoke, gas or corrosive emissions nearby.

General maintenance

Refer to the general maintenance of spectrophotometer in Chapter 11 for the cleaning of spills and replacement of batteries.

Cuvette use and maintenance

Cuvettes must be rigorously clean for accurate measurements. Clean these as described in Chapter 11. Additional recommendations are as follow:

1. Always hold cuvettes by their opaque, non-optical walls.
2. Unless specified by the operator's manual, do not perform any measurements without performing a blank determination.
3. Use a single cuvette or a set of matched cuvettes for proper performance of the instrument. Note: Absorbance of cuvettes should not exceed 0.01 when measuring distilled water. To avoid incorrect results, a cuvette exceeding this limit should not be used as part of a set unless it is matched with one with the same absorbance reading when measuring distilled water.
4. Remove bubbles present in the solution by gently tapping the cuvette with the finger.
5. Ensure that there is a high enough level of solution in the cuvette (above the light beam) so that the reflection of light from the surface does not interfere with the reading.
6. All solutions used and the specimen to be measured should be clear. If the mixed reagent solution and specimen is turbid, the measurement must be repeated after checking and confirming the cuvette's transparency and cleanliness.
7. If a kinetic measurement is performed over a long period of time, seal the cuvette to avoid evaporation causing erroneously high readings.
8. When performing readings on a series of specimens, readjust the zero every 5 to 10 measurements by reading the blank solution to avoid a drift of the zero.
9. Do not leave the cuvette in the instrument.
10. If using semi-micro or micro-cuvettes, ensure correct positioning in the light path to avoid false readings due to partially reflected light.
11. Store in a dust-free box to prevent damage as scratched or damaged cuvettes can lead to incorrect measurements.

Optical filters use and maintenance

1. Handle removable filters by the circumference to avoid contamination.
2. Keep spare filters in a dust-free box to insure protection from breakage or scratches.
3. Ensure that a filter is in its slot when the lamp is turned ON to avoid damage to the photocell. Store filters in the appropriate storage box when the instrument is not in use.
4. When the instrument is cool and turned OFF, clean the filters and optical window with lens tissue as instructed by the manufacturer.

Light source use and maintenance

1. Turn OFF the lamp after each use to maximize its life span. Some manufacturers recommend keeping a record log of the instrument lamp use.
2. Check lamp periodically. Replace if it is the cause of instability in the absorption signal.

Lamp alignment

The following are procedures to align new lamps. Refer to the instructions from the manufacturer to insure the procedure is performed according to specifications of the instrument model in use.

Realign the new lamp as follows:

1. Place a clean cuvette filled with distilled water in position in the instrument.
2. Set the meter to a mid-scale reading, e.g. at 50% transmission.
3. Move each optical component slightly in turn and check if the reading was affected.
4. If needed, adjust the lamp alignment for maximum transmission.
5. Alternatively, place a white card in front of the photocell (some instruments will allow this). Observe the image of the lamp on the card. It should be vertical and in focus. If not, adjust the lamp alignment until the best image is obtained.

Troubleshooting tables containing problems sometimes encountered with colorimeters are presented below. Since instrument models vary widely the following guidelines take precedence:

1. Always refer to the instruction manual from the manufacturer.
2. If an instrument fails to switch on, if applicable, check the electric socket outlet. Plug and check the fuse or the battery terminals.
3. In case of a major breakdown, consult a qualified biomedical engineer.

TROUBLESHOOTING TABLE

Automated Colorimeter

PROBLEM	PROBABLE CAUSE	SOLUTION
The colorimeter does not start.	The on/off switch is in the off position.	Move the switch to the on position.
	There is no electric energy in the feed outlet.	Verify the main electric feed. Verify that some electrical safety mechanism has not been misfired.
	The electric feed cable is not well connected.	Connect the feed cable firmly.
The keyboard or buttons do not respond.	The initialization of the equipment during start-up is incomplete.	Turn off the equipment and switch on again.
	An incorrect command was activated, during start-up.	
The serial port does not respond.	There was incomplete initialization of the equipment during start-up.	Turn off the equipment and switch on again.
	The interconnection cable is not connected well.	Verify the connection.
The LCD screen is difficult to read.	The contrast control is maladjusted.	Adjust the contrasts.
	Base lighting system burnt out.	Call the representative.
The printer is blocked.	Paper jam.	Remove the excess paper with finely pointed tweezers.
		Remove the paper and reinstall again.
The printer's paper does not auto feed or advance.	The printer paper is installed incorrectly.	Reinsert the roll of paper.
	The front edge of the paper is not aligned or folded.	Reinsert the roll of paper. Cut the front edge and realign in the feed system.
	The paper feed control does not respond.	Call the representative.
The cuvette does not enter in the sample holder compartment.	The cuvette is of wrong size.	Use the size of cuvette specified by the manufacturer.
	The cuvette's adjustment mechanism is incorrectly placed.	Correct the position of the adjustment mechanism.
The reading shows fluctuations.	There are interferences in the light's path.	Verify that the cuvette is not scratched.
		Verify that there are no particles floating in the cuvette.
		Rub the optic walls of the cuvette with a piece of clean cloth.
		Verify that the working range (wavelength and dilution) selected is appropriate for the sample analyzed.
The reading shows negative values. There is no absorbance reading.	There is no sample.	Add a sample to the solution.
	The cuvette is incorrectly positioned.	Verify the orientation of the cuvette. Clear sides should face the light path.
	The wavelength is erroneously selected.	Adjust the wavelength to the range compatible with the analysis.
	The equipment was calibrated with a sample in place of a standard solution.	Calibrate with a standard solution or with distilled water.

Non-automated Colorimeter		
PROBLEM	PROBABLE CAUSE	SOLUTION
The source lamp does not light up.	The filament is broken.	Replace the lamp.
	The safety fuse is burnt out.	Replace the fuse.
	There is resistance in the lamp's filament.	Replace the lamp.
	The voltage is incorrect.	Review the voltage. Check the feed source.
Low readings in the meter or in the galvanometer.	The source lamp is defective.	Replace the lamp.
	The photocell is dirty or defective.	Clean or replace the photocell.
	The multiplier is defective.	Change or repair the multiplier.
	The source lamp's voltage is low.	Adjust the voltage.

BASIC DEFINITIONS

Since these instruments are based on the photometry principles, relevant definitions may be found in Chapter 11.



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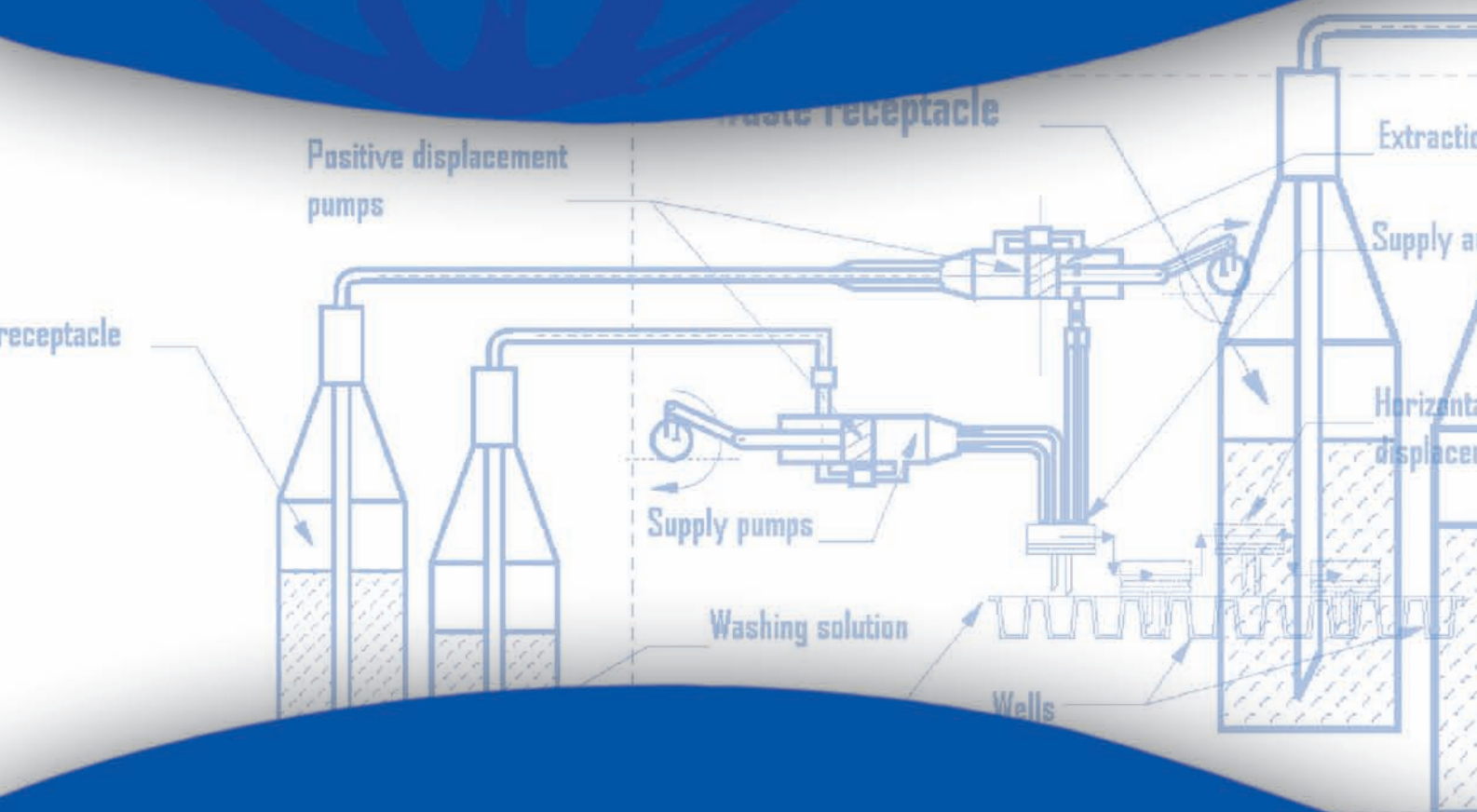
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