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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – I – MEDICAL EQUIPMENT MAINTENANCE AND TROUBLESHOOTING – SBMA3001

1.1 Testing of AC and DC power supply

A power supply is an electrical device that converts the electric current that comes in from a power source, such as the power mains, to the voltage and current values necessary for powering a load, such as a motor or electronic device. The objective of a power supply is to power the load with the proper voltage and current.

A power supply can be external, often seen in devices such as laptops and phone chargers, or internal, such as in larger devices such as desktop computers.

A power supply can either be regulated or unregulated. In a regulated power supply, the changes in the input voltage do not affect the output. On the other hand, in an unregulated power supply, the output depends on any changes in the input.

The power at the input and output can be either alternating current (AC) or direct current (DC):

Direct current (DC) occurs when the current flows in one constant direction. It usually comes from batteries, solar cells, or from AC/DC converters. DC is the preferred type of power for electronic devices.

Alternating current (AC) occurs when the electric current periodically inverts its direction. AC is the method used to deliver electricity through power transmission lines to homes and businesses

Key Takeaways

- A faulty power supply can lead to improper sensor operation
- Issues with a power supply will manifest throughout the entire circuit
- Conduct power supply testing *e*arly in the troubleshooting process
- Potential to damage fine electronics.

Required Equipment for Power Supply Testing

Properly calibrated voltmeters and current meters

Oscilloscope with bandwidth up to 20MHz

Sufficient input power source

Programmable adjustable load

- **Input Power**
- The power provided by your power supply is the key factor, but the first parameter to test is the voltage and current on the input side of your power supply. Verify the input power supply falls in the operating range for your power supply as listed in the specification or datasheet. Just like our sensors, an improper input voltage to a power supply hinders proper operation whether you are using an AC/DC or a DC/DC power supply.
- **Output Voltage Accuracy**
- The LED display (when applicable) on your power supply may read 5.00VDC, but this may not always be accurate. Checking the accuracy of the output voltage with a properly calibrated voltmeter is a great way to verify this output voltage. Strictly speaking, you only need to verify that the output voltage is stable and within the operating range of your device. However, you may wish to continue to calculate the output voltage accuracy.

Test Procedures for DC and AC supply

- Set the input voltage to the nominal requirement for your power supply.
- Set the output voltage load to its maximum rated value.
- Measure the output voltage ($\mathbf{V_{OUT}}$) with the calibrated voltmeter.
- **Noise**
- Set of random high or low-frequency spikes to the power supply.
- Noise can be removed by shielding the wires and operating as far from electrical noise sources as possible.

1.2 Grounding/ Earthing

A Ground is a conducting connection, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of earth. It provides safety, system protection and performance are the three main reasons to earth a system. Proper grounding techniques are necessary for safety, equipment operation and performance.

NEED OF GROUNDING:

To protect people and equipment from dissipating stray energy from:

1. Electrical faults (fuses, breakers etc.)

2. Lightning strikes

3. Radio Frequency

4. Static discharges

Issues related to improper or No grounding

Estimation of at least 15% of power quality problems are related to grounding. Lightning strikes on equipment with poorly maintained protection systems destroy millions of dollars of equipment and lost production every year. Electric shocks, vibrations & noise from electronic devices due to improper wiring, also lead to mankind loss also. Equipment grounding" refers to the connection to power system ground of all non-current carrying metallic parts of a power system that may come into accidental contact with circuit phase and neutral conductors.

Types of grounding

Single stake: The simplest form. Variety of lengths from a few feet to many feet long made of materials such as brass, galvanised or stainless steel, the size and material as required locally . It is used for lightning protection on stand-alone structures such as pole mounted transformers or radio towers, it can also be used as a back up to a utility ground.

Ground rod group: It is used for lightning protection on larger structures or protection around potential hotspots such as substations.

Ground plate: It is mainly used for telecoms applications. It is good where the deeper ground has high resistivity. For areas where there is rock (or other poor conducting material) fairly close to the surface ground plates are preferred as they are more effective

Ground mesh: The design is a network of bars connected together. They are mainly used at larger sites such as electrical substations. At substation site an area of ground could be reserved at the start of the life of the substation with a ground mesh under the whole of the site. As the site grows over a period of years new equipment can easily be installed and grounded by the mesh.

Testing of grounds:

Resistivity method(Wenner method): Used to determine which type of earthing is to be used by knowing the resistance(RE) .

Fall of potential testing(Three or Four pole method): It is the commonly used method of testing. The name refers to the number of connections made to the ground tester. The forth pole of the connection is made if the wire to connect to the system under test is particularly long >> 4 meters.

Selective measurement method: It is based on the Fall of Potential test. A current clamp is used to isolate the test current injected into the electrodes under test, the current will flow to earth by any path.

Stake less method: This eliminates the need for temporary ground stakes. It is mainly used inside buildings Airports Urban locations Chemical and industrial plant. The temporary ground stakes are replaced by two current clamps. The first clamp generates a voltage on the ground condutor, the second clamp measures the current flowing due to the generated voltage.

Two pole method: It uses nearby metal structures as a temporary spike. Metal water pipes are typically used for the testing.

Earth Wires

Electrical wires follow standard color coding that helps classify each wire function in the circuit. **In India wires are RGB mode i.e. Red- Green- Black**. Each of these RGB wire have different functions.

Red – Red wire signifies the phase in electric circuit. It is he live wire which cannot be connected to another red wire or black wire. Red is used in some types of switch leg. Switch leg

is the wire that comes off from the bottom terminal of a switch and when the switch is turned on becomes hot. This is the leg that turns the load off and on.

Black – Black wires signifies neutral wire in electric circuit. The neutral wires is connected to neutral bus bar inside an electric panel. A bus bar is and conductive metal bar that attracts the electric current for distribution purpose.) Black wire can be connected to black wire only and no other color wire. Black wire being neural, it does carry charge/current. It mainly carries the unbalanced load i.e. the return current that we call. Return current is the electricity/current not being used and the return current to the electrical board/panel.

Green – Green wire stands for grounding/ earthing in electric circuit. A green wire should be on can be connected to green wire only (no other wire). Grounding wires are usually not meant for lights and fan purposes. Green wires are chiefly used for socket purpose. Socket could be for AC, geyser, TV, microwave, etc. Normally, switches have only 2 wires i.e. neutral and phase.

1.3 Shielding

The objective of electromagnetic, electric and magnetic shielding is to provide a significant reduction or elimination of incident fields that can affect sensitive circuits. It prevents the emission of components of the system from radiating outside the boundaries limited by the shield. The basic approach is to interpose between the field source and the circuit a barrier of conducting or magnetic material.

Shielding effectiveness is the reduction in magnetic, electric or electromagnetic field magnitude caused by the shield. The effectiveness of a shield depends on the shield material as well as the characteristics of the incident field (far or near field), which is defined by the distance between the source and the victim. The techniques for shielding depend on the type of source; whether the source is a magnetic field, electric field or electromagnetic field source.

The shielding effectiveness (S) in dB, is calculated as the sum of three components, - reflection loss (R), absorption loss (A) and a correction factor (B).

$$S = A + R + B$$

Types of Shielding

Electromagnetic shielding

The electromagnetic wave is generally used to describe a far-field. When an electromagnetic wave passes through a medium, - absorption and reflection losses occurs.

Electromagnetic wave propagates perpendicular to the shield surface, the absorption and reflection losses (in dB)

$$A = 131.4 \cdot t \cdot \sqrt{f \cdot \mu_r \cdot \sigma_r}$$

$$R = 168 - \left(10 \cdot \log \frac{\mu_r \cdot f}{\sigma_r}\right)$$

where t is the thickness of the shield in m., f the frequency, μ r the relative permeability and σ r the conductivity.

Electric shield fielding

Electric shielding consists of conductive barriers, metal enclosures, metal conduits or cable coverings around circuits. The spatial electric shield acts as a capacitive voltage divider between the field source and the circuit.

Magnetic field shielding

There are 2 different ways for shielding against low frequency magnetic fields.

1.Deviation of the magnetic flux with high permeability material.

2.The shorted tuned method, which consists in the generation of opposing fluxes that cancel the magnetic field in the area of interest.

Magnetic material such as steel or mu-metal makes a better magnetic field shield at low frequencies than does a good conductor such as aluminum or copper.

Cable Shielding

The main goal of a shield is to avoid perturbing fields to penetrate into the internal conductors or perturbing currents in the central conductors to radiate. The type of shield material (non magnetic materials) and the shield connections have a direct influence in the performance of the shield. When a cable's shield is grounded at one end only the opposing

end of the shield is under grounded and it can represent a fire and shock hazard if the cable's shield becomes energized.

The reasons for the ground to be being energized could be; AC power system ground faults, accidental contact of the shield at some point along its length with a conductor of another system or higher voltage, lightning, etc.

1.4 Guarding

It is used to prevent or minimize current leakage from a high impedance source.

Purpose:

It reduces common mode capacitance, eliminated leakage currents in circuits. No voltage should be passed through a guard.

Guarding is usually implemented using a voltage follower. In this configuration, the voltage difference between the positive and the inverse inputs of the Opamp is very small and the Opamp output voltage is held at almost the same potential as the positive input.

Guard circuits are mainly used to eliminate the errors, which are caused by leakage currents.

1.6 Insulation

Insulators are used to hold conductors in position, separating them from one another and from surrounding structures. They form a barrier between energized parts of an electric circuit and confine the flow of current to wires or other conducting paths as desired. It is a necessary requirement for the successful operation of all electrical and electronic apparatus. Electrical conductors are insulated using materials with high electrical resistance in order to limit, as much as possible, the flow of current outside the conductors. The quality of these insulating materials changes over time due to the stresses affecting the equipment. These changes reduce the electrical resistivity of the insulating materials, thus increasing leakage currents that lead to incidents.

Insulation resistance tests detect aging and premature deterioration of the insulating properties before they reach a level likely to cause the incidents

Insulation failure causes

Electrical stresses: It is mainly linked to over-voltages and under-voltages.

Mechanical stresses: It is because of frequent start-up and shutdown sequences can cause mechanical stresses.

Chemical stresses: The proximity of chemicals, oils, corrosive vapors and dust, in general, affects the insulation performance of the materials.

Stresses linked to temperature variations: When combined with the mechanical stresses caused by the start-up and shutdown sequences, expansion and contraction stresses affect the properties of the insulating materials. Operation at extreme temperatures also leads to aging of the materials.

Environmental contamination: The build-up of mold and particulate deposits in warm, moist environments also contributes to the deterioration of installations' insulation properties.

Insulation Resistance Measurement

Insulation resistance measurement is based on Ohm's Law. It is performed by injecting a known DC voltage lower than the voltage for dielectric testing and then measuring the current flowing, it is very simple to determine the value of the resistance. If the value of the insulation resistance is very high, so by measuring the low current flowing, the Megohmmeter indicates the insulation resistance value. The resistance characterizes the quality of the insulation between two conductors and gives a good indication of the risks of leakage currents flowing.

Testing Methods

Short-time or spot-reading measurement

It is the simplest method. The technique involves applying the test voltage for a short time (30 or 60 seconds) and noting the insulation resistance reading at that moment. The measurement is standardized at a reference temperature and the level of humidity should be noted for comparison with the previous measurements.

Testing methods based on the influence of the test voltage

The method involve measuring successive insulation resistance values at specified times. If the insulation material is in good condition, the leakage or conduction current is low. If the insulation material is in poor condition (damaged, dirty and wet), the leakage current is

constant and very high. By examining the variations of the insulation value according to the test voltage application time, it is possible to assess the quality of the insulation.

Polarization Index

Two resistance readings are taken at 1 minute and 10 minutes, respectively. The ratio of the 10-minute insulation resistance over the 1-minute value is called the Polarization Index (PI)

This test is used to assess the quality of the insulation.The measurement method using the polarization index is ideal for testing solid insulating circuits.

1.7 Circuit Breakers

A circuit breaker is a mechanical switch that automatically operates to protect a circuit from the damage caused by fault current. It automatically breaks the circuit upon sensing a huge draw of current flow due to overloading or short circuit. It can also manually break open the circuit for maintenance or fault clearance. It can safely close & open a circuit to protect it from damage. A circuit breaker breaks the supply to the circuit when the current exceeds its rated current. The current may exceed due to numerous reasons such as overloading, short circuit, voltage spikes, etc.

The main objective of a circuit breaker is to safely break open the circuit

- It should momentarily withstand the fault current
- It should safely break open the circuit
- It should quickly extinguish the arc.
- Its terminals should withstand the voltage after breaking.
- It should prevent the arc from re-striking.

Once it detects the fault current, it trips & interrupts the current flow. It breaks open the circuit using some sort of stored mechanical energy such as spring or a blast of compressed air to separate the contacts. it can also use the fault current to break open the contacts using thermal expansion or an electromagnetic field using a solenoid.

Principle of Operation of Circuit Breakers

The main duty of a Circuit Breaker is to switch ON and OFF the electrical circuits during normal or abnormal operating conditions, once or several times repeatedly. The operating principle of a

circuit breaker is very simple. A typical circuit breaker consists of a fixed and a moving contact called Electrodes. These contacts are closed under normal circuit operating conditions. If the system becomes faulty, the contacts will open automatically and alternatively, these contacts can also be opened manually whenever desired (for example, during maintenance). Under faulty system conditions, a simple mechanism will pull the moving contacts away as a result of trip coil getting energized and essentially opening the circuit.

An important phenomenon that occurs during the opening of the contacts is the Arc Phenomenon. If a fault is detected on any part of the system, the contacts of the circuit breaker are separated and during this process, an arc is struck between them. Until the arc discharges, the current in the circuit continues to flow. The arc not only delays the circuit interruption but also produces a significant amount of heat that could potentially damage the circuit breaker itself or the entire system. Hence, one of the main challenges in circuit breakers is to extinguish the arc as quickly as possible.

Types of Circuit Breakers

Circuit breakers are essentially switches installed inside a breaker box that protect your home's electrical components from overheating or catching fire. When an electrical short or overload occurs, a circuit breaker mitigates the problem by interrupting the flow of electricity. There are three basic circuit breaker varieties: standard breakers (which include both single-pole and double-pole circuit breakers), ground fault circuit interrupter circuit breakers (GFCIs) and arc fault circuit interrupter circuit breakers (AFCIs).

Single-Pole Circuit Breakers

Single-pole circuit breakers are the type most often found in homes today. They're named single-pole because they're designed to monitor the current of a single wire and trip in the event of a short or electrical overload. Single-pole breakers are intended to accommodate between 15 and 30 amps and deliver 120 volts to the circuit.

Double-Pole Circuit Breakers

Double-pole circuit breakers monitor the flow of electricity through two wires simultaneously. They're easily recognized as a single breaker with two interlinked, side-by-side switches. This type of breaker will trip if one or both of the wires short out or becomes overloaded. Double-pole circuit breakers deliver either 240 volts or 120/240 volts to an electrical circuit and can accommodate anywhere from 15 amps to 200 amps. Circuits that supply power to appliances that require a substantial amount of energy, such as washing machines and dryers, demand double-pole breakers.

GFCI Circuit Breakers

GFCI circuit breakers are designed to protect against a line-to-ground fault. This is when a dangerous electrical path occurs between a grounded element and an electrical current. GFCI breakers also offer protection against an electrical short or overloaded current. These breakers are required by some electrical codes for areas in the home that can become wet such as bathrooms, laundry rooms and outdoor areas.

AFCI Circuit Breakers

AFCI circuit breakers are designed to trip when arcing is detected within electrical wiring. This occurs when an electrical cord becomes damaged or its coating becomes too thin and it presents a serious risk of a fire. Standard single-pole and double-pole circuit breakers won't always detect electrical arcs because they're only tripped by excessive heat. AFCI circuit breakers are required as part of electrical code on newer houses.

Testing

Testing of circuit breakers is more difficult as compared to other electrical equipment like transformer or machine because the short circuit current is very large. Testing of the transformer is mainly divided into two groups, type tests, and routine tests

Type Tests of Circuit Breaker

Type tests are conducted for the purpose of proving the capabilities and confirming the rated characteristic of the circuit breaker. Such tests are conducted in the specially built testing

laboratory.Type tests can be broadly classified as the mechanical performance test, thermal test, dielectric or insulating test, short circuit test for checking the making capacity, breaking capacity, short time rating current and operating duty.

Mechanical Test – It is mechanical ability type test involving the repeated opening and closing of the breaker. A circuit breaker must open and close at the correct speed and perform its designated duty and operation without mechanical failure.

Thermal Test – Thermal tests are carried out to check the thermal behavior of the circuit breakers. The breaker under test deal with the steady-state temperature rises due to the flow of its rated current through its pole in a rated condition. The temperature rise for rated current should not exceed 40° for current less than 800A normal current and 50° for normal value of current 800A and above

Dielectric Test – These tests are performed to check power frequency and impulse voltage withstand capacity. Power frequency tests are kept on a new circuit breaker; the test voltage changes with a circuit breaker rated voltage.

The test voltage with a frequency between 15-100Hz is applied as follows. (1) between poles with circuit breaker closed (2) between pole and earth with circuit breaker open, and (3) across terminals with circuit breaker open.

In impulse tests impulse voltage of specified magnitude is applied to the breaker. For outdoor circuit dry and wet tests are conducted.

Short -Circuit Test – Circuit breakers are subjected to sudden short-circuits in short-circuit test laboratories, and oscillograms are taken to know the behavior of the circuit breakers at the time of switching in, during contact breaking and after the arc extinction.

The oscillograms are studied with particular reference to the making and breaking currents, both symmetrical and asymmetrical restriking voltages, and switchgear is sometimes tested at rated conditions.

Routine Tests of a Circuit Breaker

Routine tests are also performed as per recommendations of the standards of Indian Engineering Service and Indian Standards. These tests are performed on the manufacturers' premises. Routine tests confirm the proper functioning of the circuit breaker. The routine tests confirm the proper functioning of the circuit breaker.

Power frequency voltage test being the same as mentioned under the heading of type tests, the millivolt drop test is performed to determine the voltage drop within the current path of the breaker mechanism. Operational test is performed on the breaker by simulating its tripping by artificially closing the contacts of the relays.

1.8 Transformer

A transformer is an electrical device that uses the principle of electromagnetic induction to transfer energy from one electric circuit to another. It is designed to either increase or decrease AC voltage between the circuits while maintaining the frequency of the current

It is used in various fields like power generation grid, distribution sector, transmission and electric energy consumption.

The basic transformer has three parts: the primary winding, the secondary winding, and the magnetic core. The primary winding is connected to a live source of AC power. This produces an alternating magnetic field that surrounds the winding. This induces an EMF in the secondary winding. If the circuit of the secondary winding is closed, then AC current will flow through it. These windings share the magnetic core, which is usually made out of laminated steel sheets and provides a low reluctance path for the magnetic field. The ratio between the output voltage and input voltage is the same as the ratio of the number of turns between the two windings. In a step-down transformer, the secondary winding will have fewer turns than the primary, and in a step-up transformer, it will have more.

Applications Of Transformer

- The transformer transmits electrical energy through wires over long distances.

- Transformers with multiple secondary's are used in radio and TV receivers which require several different voltages.
- Transformers are used as voltage regulators

Testing

1. Turns Ratio Testing

Turns ratio transformer testing is commonly used to ensure that the winding ratio between the primary and secondary coils are aligned to recommended specifications. This type of transformer testing also ensures the transformer will provide either step-up or step-down voltage. A step-down transformer, for instance, comprised of 100 primary turns and 10 secondary turns will work to reduce the voltage by a factor of 10 — corresponding to the secondary coil — while multiplying the current by 10 as well.

2. Insulation Resistance Testing

Insulation resistance transformer testing, also known as the Megger test, is used to determine the quality of insulation within the transformer itself. These tests are conducted with a megohmmeter, one of the necessary transformer test instruments, that operates similar to a multi-meter. In order to pass the test, the insulation of a transformer must be determined to have a greater resistance than defined by international standards for that transformer type. If it measures any lower it could signify an issue with the insulation which may require replacement.

3. Power Factor Testing

Power factor transformer testing is the process wherein the power loss of the insulation system is tested by measuring the a ngle the resulting current of power that occurs when AC voltage is applied. For the test results to be optimal, the angle of the current should measure 90 degrees; however, more often than not, insulation is never perfect. As a rule, the closer to 90 that the current is, the better the insulation is. This test is completed with a power factor test kit, and it can be completed regularly throughout the life of the transformer. This can help detect deteriorating or malfunctioning insulation over time and give you an idea of when the transformer will need to be replaced.

4. Resistance Testing

This type of transformer testing once a transformer has been left to settle at the same temperature of the surrounding air. The reason for this is to check for any differences between the opens and windings within the transformer. This helps ensure that all the circuits are still wired and connected correctly. This test is conducted using an ohmmeter.

1.9 Contractor

Contractor is an electromechanical control device that used to make or break the connection between the load and power supply. The use of a contactor is similar to the relay. But the device used for higher current carrying application is known as a contactor and the device used for lower current applications is known as Relay. The contactor is electrically controlled and usually powered at a much lower level than the switched circuit. These electrical devices feature multiple contacts. These contacts are in most cases normally open and provide operating power to the load when the contactor coil is energized. Contactors are most commonly used for controlling electric motors.

Contactors can break current over a wide range of currents, from a few amperes to thousands of amperes, and voltages from 24 VDC to thousands of volts.

1.10 Relay

A relay is a form of electrical switch that is operated by electromagnet which changes over the switching when current is applied to the coil. An electromechanical relay or electrical relay can use a small current to switch a much larger current and enable both circuits to be electrically isolated from each other.

Application Of Relay

- Relays are used for isolating a low voltage circuit from high voltage circuit.
- They are used for controlling multiple circuits.
- They are also used as automatic change over.
- Microprocessors use relays to control a heavy electrical load.

- Overload relays are used for protection of motor from overload & electrical failure.

Relay testing

1. Visual and Mechanical Inspection

Testing and maintenance of protective relays always begins with a thorough visual and mechanical inspection. If the circuit to be tested is in service, one relay at a time should be removed (if applicable) so as not to totally disable the protection.

Inspect the relay and case for physical damage and verify that the entire unit is clean. For new installations, be sure that all shipping restraint material has been removed.

Tighten the relay case connections and inspect the cover for correct gasket seal. Inspect shorting hardware, connection paddles, and/or knife switches.

Inspect the relay unit for foreign material, particularly in disk slots of the damping and electromagnets. Remove any foreign material from the case and ensure the cover glass is clean.

2.Insulation Resistance Tests

Perform insulation-resistance tests on each electromechanical relay circuit-to-frame and ground. Procedures for performing insulation-resistance tests on solid-state and microprocessor relays should be determined from the relay instruction manual.

3.Electrical Tests

Apply voltage or current to all microprocessor-based relay analog inputs and verify correct registration of the relay meter functions and verify SCADA metering values at remote terminals.

4.Protection Element Tests

Operation of protection elements for devices listed in the attached reference should be calibrated using manufacturer's recommended tolerances unless critical test points are specified by

the *setting engineer*. When critical test points are specified, the relay should be calibrated to those points even though other test points may be out of tolerance.

Under normal operating conditions, microprocessor-based relay operating characteristics do not change over time. Operating times are affected only by the relay settings and applied signals.

5. System Functional Tests

It may be desirable to prove the correct interaction of all sensing, processing, and action devices as a complete unit by means of system functional tests.

When performing system functional tests, all interlock safety devices should be verified for fail-safe functions in addition to their individual design function. The correct operation of all sensing devices, alarms, and indicating devices should also be verified.

Lock-out relay and block close circuits should be tested, along with relay self-test, power supply failure

A relay will usually have a coil, pole terminal and a set of contacts. The set of contacts that are open when the relay is not energized are called normally open (N/O) contacts and the set of contacts that are closed when the relay is not energized are called normally closed (N/C) contacts. The following steps can be used to perform the testing of the relay using a multimeter.

- Keep the multimeter in the continuity check mode.
- Check for continuity between the N/C contacts and pole.
- Check for discontinuity between N/O contacts and the pole.
- Now energise the relay using the rated voltage. For example use a 9V battery for energising a 9V relay. The relay will engage with clicking sound.
- Now check for continuity between N/O contacts and pole.
- Also check for discontinuity between N/C contacts and pole.
- As a final test, measure the resistance of the relay coil using a multimeter and check whether it is matching to the value stated by the manufacturer.

If all the above tests are positive we can conclude that the relay is healthy.

1.11 CT vs PT

Function

- A current transformer function is to reduce the high current in power lines.
- A potential transformer function is to reduce the high voltage of power lines.

Connection

- A Current Transformer is connected in series with the power line so all the current flows through it.
- A potential transformer is connected in parallel to the power lines so all the voltage appears across it

Number of turns in windings

- In CT, the number of turns in the primary is far less than the number of turns in the secondary windings.
- In PT, the number of turns in the primary is far more than the number of turns in the secondary winding.

Input

- The input of the current transformer is a constant current that flows through the power line.
- The input of a potential transformer is a constant voltage across the power lines.

Output

- The output of the current transformer ranges between 1 to 5 amperes.
- The output of the potential transformer ranges between 100 to 220 volts.

Secondary terminals precaution

- In CT, the terminals of secondary winding cannot be left open as there is a very high voltage gradient between them. It allows short circuits.
- In PT, there is a very low voltage at its secondary; therefore, it can be left open. But it should not be short-circuited.

Types

- The two types of CT are wound type and core type transformer.

- The two types of PT are electromagnetic and capacitor voltage types.

Core

- The core of CT is made of a lamination of steel.
- The core of PT is made of high-quality steel that operates at a very low flux density.

1.12Panel Wiring

Panel wiring is used to outline each device, as well as the connection between the devices found within an electrical panel.

Electrical panel wiring diagrams must follow local authorities that dictate the standards that must be respected within the panel.

Every wiring diagram includes:

– Hardware components,

– Power sources,

– Ground chassis,

– Terminals,

– Wires

– Numbers, letters, and some nomenclatures.

- Each diagram will have an abbreviation and legend page.
- This page has
- A three-phase AC electric motor symbol
- A solenoid valve symbol
- An MCCB with thermal and short circuit protection
- A contactor (the coil and its contacts) and all the other electrical symbols you need to read the wiring diagram.

1.13Megger's Testing Equipment

It is testing equipment. Insulation resistance IR quality of an electrical system degrades with time, environment condition, i.e., temperature, humidity, moisture and dust particles. They also

get impacted negatively due to the presence of electrical and mechanical stress. It is necessary to check the IR of equipment at a constant regular interval to avoid any measure fatal or electrical shock.

Types- Electronic and Manual

Electronic instrument is a Battery operated device.

Parts:-

Digital Display :- A digital display to show IR value in digital form.

Wire Leads :- Two nos of wire leads for connecting megger with electrical external system to be tested.

Selection Switches :- Switches use to select electrical parameters ranges.

Indicators :- To indicates various parameters status i.e. On-Off. For Example Power, hold, Warning, etc.

Advantages

Level of accuracy is very high.

IR value is digital type, easy to read.

One person can operate very easily.

Works perfectly even at very congested space.

Very handy and safe to use.

Disadvantages of Electronic Type Megger

Require an external source of energy to energies i.e. Dry cell.

Costlier in market.

Manual

Manual instruemt is a hand operated device

Parts:-

Analog display:- Analog display provided on front face of tester for IR value recording.

Hand Crank:- Hand crank used to rotate helps to achieve desired RPM required generate voltage

which runs through electrical system.

Wire Leads**:-** Used same as in electronic tester i.e. For connecting tester with electrical system.

Advantages

- Oldest method for IR value determination.
- No external source required to operate.
- Cheaper available in market.

Disadvantages

- At least 2 person required to operate i.e. one for rotation of crank other to connect megger with electrical system to be tested.
- Accuracy is not up to the level as it's varies with rotation of crank.
- Require very stable placement for operation which is a little hard to find at working sites.
- Provides an analog display result.

Construction

- Deflecting and Control coil : Connected parallel to the generator, mounted at right angle to each other and maintain polarities in such a way to produced torque in opposite direction.
- Permanent Magnets : Produce magnetic field to deflect pointer with North-South pole magnet.
- Pointer : One end of the pointer connected with coil another end deflects on scale from infinity to zero.
- Scale : A scale is provided in front-top of the megger from range 'zero' to 'infinity', enable to read the value.
- D.C generator or Battery connection : Testing voltage is produced by hand operated DC generator for manual operated Megger. Battery / electronic voltage charger is provided for automatic type Megger for same purpose.
- Pressure Coil Resistance and Current Coil Resistance : Protect instrument from any damage because of low external electrical resistance under test.

Working

The voltage for testing produced by hand operated megger by rotation of crank in case of hand operated type, a battery is used for electronic tester. 500 Volt DC is sufficient for performing test on equipment range up to 440 Volts. 1000 V to 5000 V is used for testing for high voltage electrical systems. Deflecting coil or current coil connected in series and allows flowing the electric current taken by the circuit being tested. In hand operated megger electromagnetic induction effect is used to produce the test voltage i.e. armature arranges to move in permanent magnetic field or vice versa, where as in electronic type megger battery are used to produce the testing voltage. As the voltage increases in external circuit the deflection of pointer increases and deflection of pointer decreases with a increases of current. Hence, resultant torque is directly proportional to voltage and inversely proportional to current. When electrical circuit being tested is open, torque due to voltage coil will be maximum and pointer shows ‘infinity’ means no shorting throughout the circuit and has maximum resistance within the circuit under test. If there is short circuit pointer shows ‘zero’, which means ‘NO’ resistance within circuit being tested.

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – II – MEDICAL EQUIPMENT MAINTENANCE AND TROUBLESHOOTING – SBMA3001

2.1 Printed Circuit Boards

Printed circuit boards (PCBs) are the foundational building block of most modern electronic devices. Semiconductors, connectors, resistors, diodes, capacitors and radio devices are mounted to, and "talk" to one another through the PCB. It is used to mechanically support and electrically connect electronic components using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate.

Types

1. Rigid PCBs

Rigid PCBs are constructed of a rigid fiberglass substrates, making them practical and inexpensive, but inflexible. They are easier and less expensive to manufacture than their more flexible counterparts but much less versatile and hard to fit into unusual geometries or small areas.

2. Flexible PCBs

Flexible PCBs feature relatively good bending and folding capabilities to fit into confined and oddly shaped spaces. This quality makes them highly versatile and able to be used to package smaller electronic devices. Additionally, as they are highly adaptable, the product does not have to be built to fit around the PCB's restrictions. Compared to rigid PCBs, they can offer greater resistance to heat.

3. Rigid-Flex PCBs

Rigid-flex PCBs combine the most attractive qualities of both rigid and flexible PCBs. Unlike the other two types of circuit boards, these PCBs contain all of the electronic interconnectivity buried within the board, thereby reducing the board's weight and overall size. They are an excellent choice when ultra-light packaging is a key requirement. Additionally, they are more durable and reliable while retaining great strength and flexibility. Conventional PCB's can be as simple as a single layer of circuitry or can go to fifty layers or more. They consist of electrical components and connectors linked via conductive circuits – usually copper, with the purpose of routing electrical signals and power within and between devices.

Compared to traditional wired circuits, PCBs offer a number of advantages. Their small and lightweight design is appropriate for use in many modern devices, while their reliability and ease of maintenance suit them for integration in complex systems. Additionally, their low cost of production makes them a highly cost-effective option.

Applications

- Medical- Electronics in computers, imaging systems, MRI machines and radiation equipment. Compact and lightweight medical devices, such as hearing aids, pacemakers, implantable devices, and truly tiny cameras for minimally invasive procedures.
- Aerospace- for instrument panels, dashboards, flight controls, flight management and safety systems.
- Military- Military vehicles, ruggedized computers, modern weapons, and electronics systems (e.g., robotics, guidance, and targeting systems).

Materials and Construction

The primary materials used in the manufacture of PCBs are fiberglass or plastic substrates, copper, solder mask, and nomenclature ink.

Fiberglass & Plastic Substrates

PCBs can be constructed on rigid or flexible base materials depending on the intended PCB design. Rigid PCBs often use FR4 or polyimide fiberglass, while flexible circuits and rigid-flex flexible layers typically use high-temperature polyimide films.Common plastic substrates for flexible circuits include polyimide (PI), liquid crystal polymer (LCP), polyester (PET), and polyethylene naphthalate (PEN). The purpose of the substrate is to provide a non-conductive base upon which the conductive circuits can be constructed and insulated from one another. Polyimide and LCP laminates are typically used in high reliability or high signal speed applications. Polyester and polyethylene napthalate laminates are primarily chosen for their low cost, and usually are just single layers of circuitry.

Copper

Due to its high electrical conductivity, copper is the most used conducting material for circuitry in PCBs. The laminates described above, all come with thin sheets of copper foil laminated to one or both sides of the plastic. The fabricator then uses the gerber files supplied by the designer, to image and etch the circuits to meet the customer's requirements. The thickness and number of layers required are largely dependent upon the application for which the PCB will be used. multi-layered PCBs are constructed by alternating layers of copper circuitry and insulating materials to complete the PCB.

Soldermask

Soldermask is a liquid, usually an epoxy material, that is applied onto the outerlayers of rigid PCBs. It is also commonly used on the rigid sections of rigid flex PCB's. Soldermask is primarily designed to insulate the copper circuits on outerlayers from oxidation from the environment. Soldermask is also designed to control and retain the flow of solder when the components are assembled to the PCB. Without soldermask, the liquid solder could flow out onto the surface of the PCB, connecting two adjacent circuits and short out the board. The most common color for soldermask is green, but blue, black, red, amber, clear, white and many other colors exist as well.

Nomenclature

Once the soldermask layers are completed, identifying information, marks and sometimes bar codes, are printed onto the soldermask. These marks are called nomenclature, and they will also be defined by files that were included with the other gerber layers. They are printed onto the solder mask to help assure accurate assembly of the PCB.

Issues and troubleshooting

Plating Voids

When plating thru-holes in the PCB, you will drill holes and puncture the materials on the PCB all the way through, and follow up with adding a layer of copper through an electroplating

process. This will add a thin layer of electroless copper or with a direct metallization process using graphite to the PCB, a process known as deposition. Through the deposition, it is possible to create voids in the plating. These voids are gaps or holes in the plating and can prevent electrical currents from passing through the whole. If there was not an even layer added through the deposition process, it could cause air bubbles, contamination, and many other issues..

Insufficient Copper-to-Edge Clearance

Because copper is a conductive metal, it is an active component of a PCB. However, copper can also cause many PCB issues because it is vulnerable to corrosion. To prevent corrosion from occurring, other materials cover the copper. When you trim the PCB though, if there isn't enough clearance between the copper and the edge of the PCB, the coating will also be trimmed and cause the copper to be exposed.

Slivers

When PCBs undergo the fabrication process, thin slivers of solder mask or copper are among the possible byproducts. There are two scenarios that allow for these wedges to form:

- If long strips of copper are etched and a sliver comes undone before enough time has passed for it to dissolve. The sliver could possibly fall into a chemical bath and get passed onto another board.
- If a portion of a printed circuit board is cut either too wide or too narrow.

Either possibility could seriously corrupt the functionality of a PCB. Slivers can leave plating exposed that would otherwise be protected with solder mask. Alternately, slivers could end up connecting two different sections of copper. Both scenarios are liable to reduce the life of a printed circuit board.

Slivers can be avoided by designing sections with minimum widths, reducing the chances of producing slivers.

Incomplete Solder Mask Between Pads

A part of the metal that is left exposed on a circuit board is known as a pad. The pad is where foreign parts are soldered to during the assembly of a PCB. However, solder mask is sometimes either incomplete or missing entirely between two facing pads. In addition to leaving copper exposed, this can create unintended contact between pins.

Chemical Leakage

There are many different chemicals used throughout the manufacturing process of a PCB. Although there are steps to ensure all traces of each chemical is cleaned away, there is the possibility of small traces being left behind. Chemical leakage will eventually cause corrosion and short-circuiting.

Electromagnetic Issues

Electromagnetic compatibility (EMC) and electromagnetic interference (EMI) are two issues that are common on PCBs. EMC generates, propagates, and invites electromagnetic energy. EMI is the unwanted and damaging effects from the EMC. If there is too much EMI, the result is a defective board. Quite commonly, electromagnetic issues are from design flaws.

Automatic test equipment

- The test equipment usually contains a guard system. This guard system functions to isolate any components from all the other components on the board.
- In these types of equipment, there is a test program written for a particular type of board. The components are tested in sequence according to this test program. The designations of possible defective components are automatically printed on paper so that such components can be identified and replaced.

2.2 Sensors and calibration

Sensors are common devices used to detect a change in a physical state and quantify the measurement results in a particular scale or range. In general, sensors can be classified into two

types - analog and digital sensors. **Analog sensor** senses the external parameters (wind speed, solar radiation, light intensity etc.) and gives analog voltage as an output. **Digital Sensor** produce discrete values (0 and 1's). Discrete values often called digital (binary) signals in digital communication.

Sensor calibration is an adjustment or set of adjustments performed on a sensor or instrument to make that instrument function as accurately, or error free, as possible. These are some of the advantages of calibration. An adjustment or set of adjustments performed on a sensor or instrument to make that instrument function as accurately, or error free, as possible.

Errors in Sensor Measurement

Error is simply the algebraic difference between the indication and the actual value of the measured variable.

Error due to Improper Zero Reference

Modern sensors and transmitters are electronic devices, and the reference voltage, or signal, may drift over time due to temperature, pressure, or change in ambient conditions

Error due to Shift in Sensor's Range

The "sensor's range" may shift due the same conditions just noted, or perhaps the operating range of the process has changed.

Error due to Mechanical Wear or Damage

Error in sensor measurement may occur because of mechanical wear, or damage. Usually, this type of error will require repair or replacement of the device.

Proper calibration will yield accurate measurements, which in turn, makes good control of the process possible. When good control is realized, then the process has the best chance of running efficiently and safely.

Calibration Methods

As Found or Five point check

This is simply performing a calibration prior to making any adjustments. If the current instrument calibration is found to be within the stated tolerance for the device, then re-calibration is not required.

To perform an "as-found" check, an accurate and precise instrument is used to develop process signals corresponding to 0%, 25%, 50%, 75% and 100% of the process range of the transmitter. The corresponding transmitter output, in milliamps, is observed and recorded. In order to check for hysteresis, a phenomenon whereby the sensor output for a process value is different going 'downscale' as it is going 'upscale', the output signals corresponding to 100%, 75%, 50%, 25%, and 0% in order are recorded.

Deviations (Errors) of a Sensor

The deviations at each check point are calculated and compared to the deviation maximum allowed for the device. If the deviation is greater than the maximum allowed, then a full calibration is performed. If the deviation is less than the maximum allowed, then a sensor calibration is not required.

Analog Sensor Calibration

A current meter is attached to the output to measure the transmitter's 4-20 milliamps output. Ideally, a National Institute for Standards and Testing-calibrated simulator and current meter are used.

In an analog transmitter, zero and span are adjusted to reduce the measurement error. With an analog transmitter, there is a ZERO and SPAN adjustment on the transmitter itself.

ZERO and SPAN adjustment.

Zero adjustment is made to move the output to exactly 4 milliamps when a 0% process measurement is applied to the transmitter, and the Span adjustment is made to move the output to exactly 20 milliamps when a 100% process measurement is applied. Zero and span adjustments are interactive; that is, adjusting one moves the other.

Digital Sensor Calibration

With a digital transmitter, we can adjust the incoming sensor signal by adjusting the Analog to Digital converter output, which is called “sensor trim”, and/or the input to the Digital to Analog converter in the output circuit, which is called “4-20mA trim” or “output trim”.

2.3 Display Interface

An interface is something that facilitates communication between two objects. It is used to transmit video, potentially also audio and other technologies between the signal source (typically a computer, docking station, DVD player etc.) and the display unit (monitor, projector). All display interfaces continuously fetch the frame buffer data (the buffer in the system memory that contains the image to be displayed) and transmit the same to the display. Display size, contrast, color, brightness, resolution, and power are key factors in an interface.

Types

DisplayPort – a digital interface designed by VESA (Video Electronics Standards Association).

HDMI- The most widespread digital standard for transmitting video or audio signal.

Digital Visual Interface – interface for connecting a monitor to a computer. DVI was created with the intention of creating an industry standard for communication between display devices.

Video Graphics Array – a computer standard for display devices. A 15-pin connector with pins arranged in three rows. The VGA connector is used for transmitting analogue signal.

USB-C has the capability of providing Video, Audio, Power, and Data and is the common port found on most new computers.

HDR - High Dynamic Range» , an imaging technique used to make displayed scenes look very similar to how the human eye would see them.

2.4 Power Supply Design

The components required to design a power supply are-

Transformer - A device which has two sets of windings, one primary and the other one is the secondary.

Diode – Device that converts an AC to DC. A single, double or four diodes as a bridge can be used.

Capacitor Filter- This converts a pulsating DC into pure or to remove distortion from signal

Regulator- A linear integrated circuit used to provide a regulated constant output voltage.

Fuse- safety

Steps involved in the design

Step 1- Selection of a regulator IC depends on the output voltage. For 5 V power supply design, LM7805 is commonly used. The requirements of the regulator as to be checked from the data specification chart.

Step 2- Selection of transformer. A transformer is used to step down the main AC to 7 V value. For this design, a transformer of current rating 1A and a secondary voltage of 6V can be used.

Step 3- Selection of diodes. The selected diode must have the current rating more than the load current (i.e. in this case is 250mA). And peak reverse voltage (PIV) more than peak secondary transformer voltage. IN4001 diode is used because it has a current rating of 1A more than the desired rating, and a peak reverse voltage of 50V. Peak reverse voltage is the voltage a diode can sustain when it is reverse biased.

Step 4- Selection of smoothing capacitor. For selection of capacitor filter the features are its voltage, power rating, and capacitance value. The voltage rating is calculated from the secondary voltage of a transformer. Capacitor voltage rating must be at least 20% more than the secondary voltage. So, if the secondary voltage is 8.4 V (Peak value for 6V (RMS)), then your capacitor voltage rating must be at least 50V.

Step 5: Safety/ Fuse. The input fuse will protect our supply in case of overloading. A rule of thumb for selecting the fuse rating is, it must be at least 20% more than the load current.

2.5 Safe Electrical Practises

The safety practises to be followed by any person especially people handling electrical equipments are-

1. Avoid contact with energized electrical circuits.
2. Treat all electrical devices as if they are live or energized.
3. Disconnect the power source before servicing or repairing electrical equipment.
4. Use only tools and equipment with non-conducting handles when working on electrical devices
5. Never use metallic pencils or rulers, or wear rings or metal watchbands when working with electrical equipment
6. When it is necessary to handle equipment that is plugged in, be sure hands are dry and, when possible, wear nonconductive gloves, protective clothes and shoes with insulated soles.
7. If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
8. If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord or person. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt.
9. Equipment producing a “tingle” should be disconnected and reported promptly for repair.
10. Drain capacitors before working near them and keep the short circuit on the terminals during the work to prevent electrical shock.
11. Never touch another person’s equipment or electrical control devices unless instructed to do so.
12. Enclose all electric contacts and conductors so that no one can accidentally come into contact with them.
13. Never handle electrical equipment when hands, feet, or body are wet or perspiring, or when standing on a wet floor.

14. When it is necessary to touch electrical equipment (for example, when checking for overheated motors), use the back of the hand.

15. Do not wear loose clothing or ties near electrical equipment.

2.6 **Cables and standards**

The cable that is used for the transmission and distribution of electrical power is known as the electrical power cable. It is used for the transmission of high voltages in places where overhead lines are impractical to use.

The power cable is made of three main components, namely, conductor, dielectric, and sheath. The conducting path for the current in the cable is provided by the conductor. The insulation or dielectric withstands the service voltage and isolates the live conductor with other objects. The sheath does not allow the moistures to enter and protects the cables from all external influences like chemical or electrochemical attack and fire.

Types

- Ribbon Electric Cables

  It consists of multiple insulated wires running parallel with one another and is used for transmission of multiple data simultaneously. For example, this is used to connect the CPU with the motherboard and are generally used for interconnection of networking devices.

- Shielded Cables

  It consists of 1 or 2 insulated wires which are covered by a woven braided shield or aluminium Mylar foil for better signal transmission and removing irregularities in the frequency of power and external interference in radio. These cables transmit high voltage electric current and are protected by a shield.

- Twisted Pair Cables

  It has two or more insulated copper wires which are twisted with each other and are colour-coded. These types of wires are usually used in telephone cables and the resistance to external interference can be measured by the number of wires.

- Coaxial Cables

  This consists of solid copper or steel conductor plated with copper which is enclosed in the metallic braid and metallic tape. This is entirely covered with an insulated protective outer jacket. These type of cables are used for computer networking and audio-video networking.

- Fibre Optics Cable

  There are these types of cables which transport optical data signals from an attached light source to the receiving device. We are pretty much aware of what is an optical fibre and its uses in a wide variety of applications.

Nomenclature of electrical cables according to standards

Each cable has a standard designation. This designation is composed of a set of letters and numbers, each with a specific meaning. This designation refers to a series of product characteristics (materials, nominal tensions, etc.) that facilitate the selection of the most suitable cable for your needs, avoiding possible errors in the supply of one cable by another.

When a cable does not clearly indicate these data, it may be a defective cable, which does not comply with safety regulations or guarantee the cable's life and proper operation.

2.7 Fuse

Fuse is a safety device that protects electrical circuits from the effects of excessive currents. It consists of a current-conducting strip or wire of easily fusible metal that melts, and thus interrupts the circuit of which it is a part, whenever that circuit is made to carry a current larger than that for which it is intended.

Scre plug fuse- short bit of wire (the fusible element) enclosed in a fireproof container that has a screw-threaded base; the wire is connected to metal terminals at both the screw base and at the side, and the whole is covered with a transparent glass or mica window for seeing whether the fuse has melted.

Types

One Time Only Fuse- Contains a metallic wire, which burns out, when an over current, over load or mismatched load connect event occurs, the user has to manually replace these fuses

Resettable Fuse- Automatically reset after the operation when fault occurs at the system.

Current limiting and non – current limiting fuses- produce high resistance for a very short period while the non – current limiting fuse produces an arc in case of high current flow to interrupts and limit the current in related and connected circuits.

Working

Fuses works on the basis of heating effect of Current. The wire within the fuse melts when too much current flows through it, thereby stopping or interrupting the current. It is a sacrificial device - once a fuse has operated it is an open circuit, and must be replaced or rewired, depending on its type.

Properties

Low melting point- breaks or melts as soon as high current passes through it.

High resistance (more heat production) with material with low resitivity (to allow current to flow)

Economical.

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UNIT – III – MEDICAL EQUIPMENT MAINTENANCE AND TROUBLESHOOTING – SBMA3001

Rules of Engagement

There are nine rules and three thought processes used to troubleshoot engineered products—unfortunately, these do not work on people as they do on engineered products.

1. Look at the device/procedure/process.
2. Listen to the user/device/procedure/process.
3. Smell.
4. Is the application correct for the device/procedure/process?
5. Is there power?
6. Is there an input?
7. Is the processor/amplifier/etc working?
8. Is there an output?
9. Is there a memory/program/system problem?

The three thought processes are as follows:

1. Look for the obvious.
2. Think simple.
3. Don't overcomplicate the problem.

3.1 Testing of Surgical Equipment

Function

Electrosurgery is the application of a high-frequency electric current to biological tissue as a means to cut, coagulate, desiccate, or fulgurate tissue. Its benefits include the ability to make precise cuts with limited blood loss in hospital operating rooms or in outpatient procedures. Cautery, or electrocautery, is the application of heat to tissue to achieve coagulation.

Procedure

In electrosurgical procedures, the tissue is heated by an alternating electric current being passed through it from a probe. Electrocautery uses heat conduction from an electrically heated probe, much like a soldering iron. Electrosurgery is performed using an electrosurgical generator (also referred to as power supply or waveform generator) and a hand piece including one or several electrodes, sometimes referred to as an

RF Knife , or informally by surgeons as a "Bovie knife" after the inventor. Bipolar electrosurgery has the outward and return current passing through the handpiece, whereas monopolar electrosurgery returns the current through a plate normally under the patient. Electrosurgery is commonly used in dermatological, gynecological, cardiac, plastic, ocular, spine, ENT, orthopedic, urological, neuro-and general surgical procedures as well as certain dental procedures.

Troubleshooting

Electrosurgery Units / Cautery Machines Fault	Possible Cause	Solution
1. Equipment is not turning on	No power from mains socket Electrical cable fault	Check power switch is on. Replace fuse with correct voltage and current if blown. Check mains power is present at socket using equipment known to be working. Contact electrician for rewiring if power not present. Try cable on another piece of equipment. Contact electrician for repair if required.
2. Equipment is on but shows error signal	Footswitch pedal may have been depressed as unit is turned on or front panel buttons may be stuck. Probe,	Note error code and turn unit off. Check footswitch and front panel buttons. Disconnect all foot pedals.

	patient cable or plate malfunction Possible internal malfunction	Turn on unit again. Check connections and plugs on all cables are tight Call biomed technicians.
3. Equipment is on but output is absent, weak or intermittent	Power setting is too low Malfunctioning accessory Incomplete or incorrect connection Possible internal malfunction	Adjust power, check manual Check connection or replace item Check correct probe / footswitch cord are well connected Call biomedical technician
4. Continuous interference with monitors	Faulty ground connection Poor filtering systems in monitoring equipment	Check all monitors and power connections. Use separate outlets for each medical device. Replace monitoring device
5. Monitor interference occurs only when electrosurgery is activated	Metal-to-metal sparking Cords and cables are bundled, touching or damaged High power setting Continued interference	Check all connections are tight Remove cable cluttering, replace damaged cords Reduce power setting, use blend mode Contact biomedical technician
7. Pacemaker or internal cardiac defibrillator interference	Equipment activation is causing battery or implant malfunction	Stop procedure immediately, perform emergency care and call implant supplier before restarting procedure.
8. Electrical shocks to user	Wiring fault	Refer to electrician

Daily	
Cleaning	Remove any dust / dirt and replace equipment cover Remove any tape, paper or foreign body from equipment

Visual checks	Check all fittings and cables are properly connected Check there are no signs of spilled liquids or cable damage
Function checks	Check foot / probe switch smooth operation. Check return plate cable disconnection alarm before use.

Weekly	
Cleaning	Unplug, clean outside with damp cloth and dry off
Visual checks	Inspect filters, clean or replace if needed. If any plug, cable or socket is damaged, replace
Function checks	Check proper operation of all controls, indicators and visual displays on the unit. If not recently used, check operation on wet soap

3.3 Troubleshooting surgical lights

Surgical lights provide lighting in surgical suites and are designed to illuminate the surgical site for optimal visualization of small, low-contrast objects at varying depths in incisions and body cavities. A setup consists of a single- or multiple-lighthead assembly attached to a suspension arm. The surgical lighting fixture can be either mounted at a fixed point on a ceiling or wall or positioned along a ceiling-mounted track. Types of lamps include tungsten, quartz, and/or xenon halogens and light-emitting diodes (LEDs).

Problems

Patients were reportedly burned by lights in which heatprotection filters were removed. Burns were reported when multiple surgical lights operated at or near maximum intensity were focused on the same field. Bumping lights can create cracks or fractures that may cause the support mechanism to break or paint chips to fall into the surgical field. Dirt or fingerprints on a quartz-halogen lamp can cause the bulb to fail prematurely, become discolored, or explode. Other reported problems include disconnection and/or falling of fixture components.

Lamp testing-

Put a white piece of paper in the working area of the surgical light. An arc-shaped shadow appears in the area. Then the bulb is already in an abnormal working state and needs to be immediately Replace the lamp.

Check every day whether the disinfection handle of the surgical lamp is working properly, that is, whether it can be flexibly moved and the braking is accurate. The inspection method is as follows: If you can hear two “clicks” clearly during installation, it means that the installation is in place and the disinfection handle is in normal working state.

Check the backup power system of the surgical lamp once a month, that is, whether the battery is used normally. The inspection method is as follows: cut off the connected 220V power supply and see if the backup power supply can start normally.

3.4 Testing of ventilators

Ventilator problems can be roughly divided into three categories:

Equipment problems

The ventilator system fails to function as it should. The root cause can be a missing, malfunctioning, or incompatible part, or other interference with the system’s proper functioning. Recall again that the ventilator is just one of six required parts!

Operation problems (also known as user errors)

These are related to the indications for and timing of intubation, mechanical ventilation, and extubation; ventilator settings; and responses to ventilator alarms. In this case, the ventilator system is typically functioning properly.

Clinical problems

A ventilated patient is not a passive physical model. Patient changes are inevitable during mechanical ventilation. For this reason, ventilator settings need to be adjusted. For instance, the assist/control mode works for a passive patient, but not for an active patient. So as you can see,

clinical problems are closely related to operation problems. In ventilator terminology, both ‘operation problems’ and ‘clinical problems’ are known as ‘application problems.’

The five most common MV equipment problems:

(a) gas supply failure,

Gas supply failure

Air or oxygen supplies can stop completely because of:

◆Discontinuation of the central gas supply, malfunction of the air compressor, or empty gas cylinders.
◆Connection failure
If both gas supplies fail, mechanical ventilation stops immediately, and the ventilator alarms

Inadequate or restricted gas supply

In this case, the gas supply is available, but the supply pressure is too low or the supply gas flow is restricted.

Wet supply gas

The air and oxygen supplied to ventilators should be cold (close to room temperature), dry, and clean. Wet supply gas is abnormal, typically resulting from an under-performing compressor or rarely, from moisture in the central supply pipeline. The water trap usually has a microfilter to capture any particles and droplets in the supply gases before entering the ventilator.

(b) Electrical supply failure

A ventilator cannot run without electrical power. For almost all ventilator systems, AC power serves as the primary source of electricity. Many modern ventilators also have an internal battery as a secondary source to bridge temporary AC power loss. Transport ventilators can also be powered with DC power from ambulances or airplanes.

AC supply problems

AC power interruption

The most common AC supply problem is blackout or the unexpected interruption of the local or regional AC power supply. A common preventive measure is an emergency diesel generator, which should start immediately when the local AC supply fails.

AC voltage and frequency mismatch

The voltage and frequency of the regional AC supply must match the specified requirements for the ventilator. A mismatch causes the ventilator to malfunction or become damaged.

AC connection problems

Even when both the AC power supply and the connected ventilator are technically in order, AC power may still be problematic due to faulty connection between the two. Possible connection issues include:

◆Accidental unplugging of the power cord: AC may be interrupted by inadvertent unplugging (e.g. during routine room cleaning). Unplugging can occur at either side of the power cord, but more often it occurs at the wall side. When the power cord becomes unplugged, the ventilator annunciates an alarm. In such a case, the internal battery ensures continuous mechanical ventilation.
◆Poor or loose connection: This can have multiple causes but a single common result: unreliable AC supply to the ventilator, causing intermittent ventilator functioning.
◆Dead socket: The socket in use is not powered.
◆Broken power cord: The power cord may appear intact, but an internal wire is faulty.
◆Plug-socket mismatch: This can occur at either the wall or device side of a power cord.

Internal battery problems

Whenever the AC supply fails, the ventilator battery can serve as a temporary power source so that mechanical ventilation continues. However, internal battery capacity is limited.

(c) gas leak

The core of an intermittent positive pressure ventilator (IPPV) system is a gas tubing system in which the gas pressure changes regularly, driving the gas to move as designed. This system has to be gas tight. The gas should exit the ventilator system exclusively via the expiratory valve.

Typically the pressure inside a ventilator system is greater than atmospheric pressure, more positive during inspiration, and less positive during expiration.

Leakage in breathing circuit	**Leakage in airway**	**Leakage in lungs**
Worn plastic or silicone rubber tubes	Airway disconnection, i.e. ETT or TT	Bronchopleural fistula or an abnormal gas exit via a chest tube
Disconnection	Leak around an ETT, e.g. uncuffed neonatal ETT, unintended deflated tube cuff	Leaking test lung
Unsealed part, e.g. water trap not tightly closed	Cracked item in artificial airway, e.g. proximal flow sensor, HME, CO_2 probe, flex tube, closed-suctioning device	
Cracked plastic items such as humidifier chamber, water trap, connectors, or nebulizer jar	Leaking airway interface for NIV, e.g. poorly fitting mask	
Open ports, e.g. water chamber refill port, temperature probe port, or side port of a filter	Gas leaking through open mouth during NIV	

Auto-triggering:

Auto-triggering is the phenomenon where a ventilator is triggered by pneumatic artefacts rather than the patient's inspiratory efforts. The ventilator itself is unable to differentiate the two and delivers a mechanical breath in either case.

Typically, auto-triggering presents as a series of quick rhythmic mechanical breaths

Once the leak is identified, the remedy is simple and straightforward:

◆Reconnect the system;
◆Replace the broken or cracked items;
◆Close the open port;
◆Reinflate the ETT cuff;
◆Use optimally fitting masks for non-invasive ventilation.

(d) Occlusion

cclusion is an unexpected increase in resistance to flow of passing gas, impairing the system performance.

Common causes of occlusion

Occlusions of the gas passageway can be classified according to their characteristics, as follows:

◆Size: minor, noticeable, complete;
◆Location: airway, inspiratory limb, expiratory limb;
◆Type: internal tube occlusion, external tube compression.

Airway occlusion	**Inspiratory limb occlusion**	**Expiratory limb occlusion**
Kinked ETT ETT or TT too thin Excessive tracheal secretions	Neonatal circuit used for an adult Bent or kinked tube	Neonatal circuit used for an adult Bent or kinked tube

Clogged HME filter	Compressed tube Inner diameter of connector too small Overly long heating wire bunched inside inspiratory limb	Compressed tube Inner diameter of connector too small Occluded expiratory filter Blocked expiratory valve

ETT: endotracheal tube; HME: heat and moisture exchanger; TT: tracheal tube.

3.5 Testing and troubleshooting patient monitors

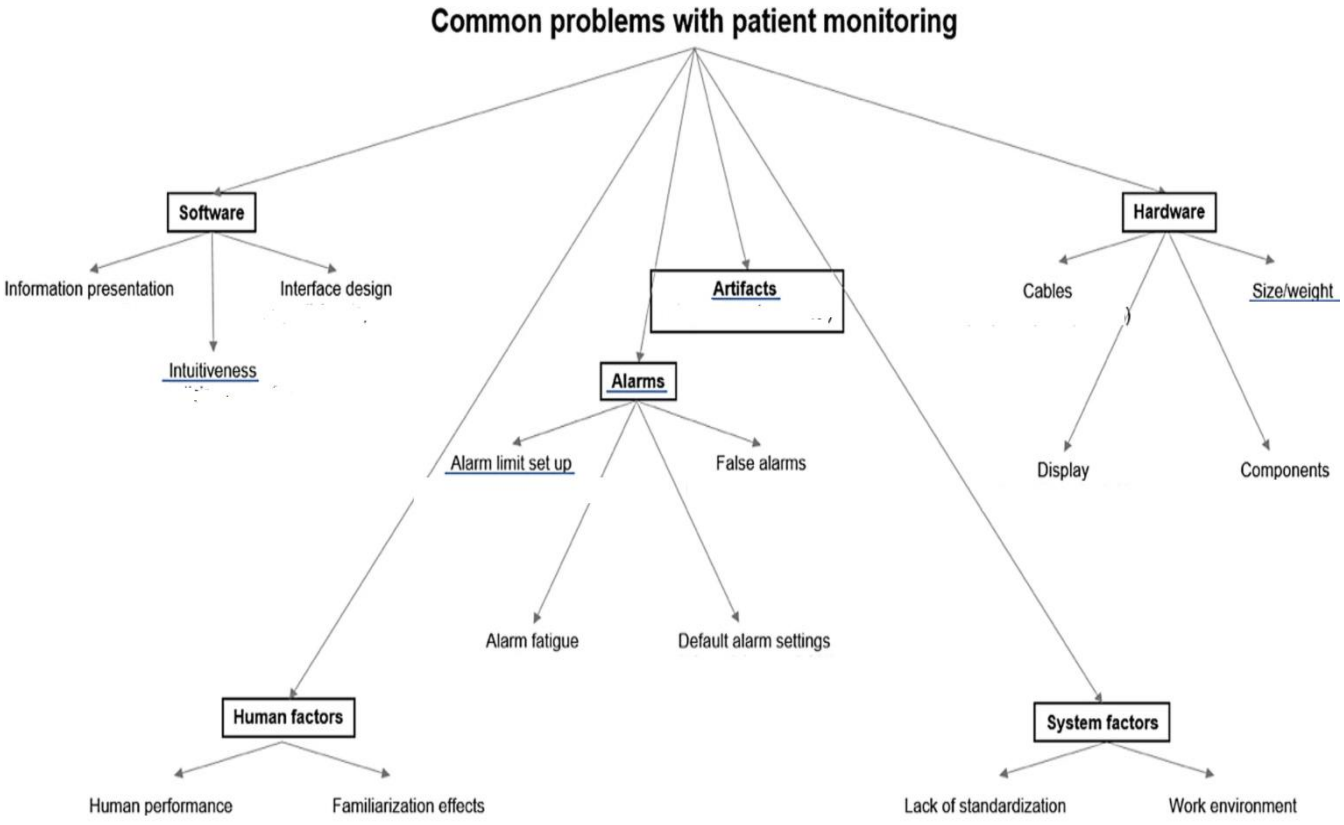
Patient monitors are used to observe, track and document a continuous record of a process, changes, or quantity, including body temperature, pulse rate, respiration rate and blood pressure.

These monitors assist doctors and nurses in observing and tracking the patient's vital signs before, during and after an operation. A properly working patient monitor is vital and therefore, certain steps should be taken to sustain the machine's condition.

Basic checks

- Check the Patient Cable for any visible damage, such as cracks or creases where the wires may be damaged under the protective coating. Also be sure your leads are compatible with the devise you are using.
- Check the date on the Electrodes you are using. They have a shelf life, and very often the individual packages should be used within 7-10 days of opening. The gel has a use by date also, as it can harden.
- Check the Blood Pressure Cuff & Hose for leakage. They are often wrapped up quickly and stuffed next to the monitor which can kink the hose causing cracks, or small tears in the cuff itself. A leaking cuff will give a false reading.
- Check the electrode clips to be sure they are attached firmly. A loose spring action will not clamp itself tightly against the electrode.

- Check SpO2 Sensors to be sure they are fitting the patients' finger correctly. Too loose, or too tight will give an incorrect reading. The tip of the finger should be in contact with the Sensor. Nail polish can be an interference to a correct reading, and cold fingers may not give a reading at all.
- Checking the filter of your patient monitor is important because the build up of debris, dust or other particles could damage and drastically shorten the life of the monitor. Cleaning the filter weekly is necessary to ensure it is free of debris.
- Calibrate the monitor



3.6 Troubleshooting Anesthesia Machine

Function

The anaesthetic machine (or anaesthesia machine in America) is used by anaesthesiologists and nurse anaesthetists to support the administration of anaesthesia. The most common type of anaesthetic machine is the continuous-flow anaesthetic machine, which

is designed to provide an accurate and continuous supply of medical gases (such as oxygen and nitrous oxide), mixed with an accurate concentration of anaesthetic vapour (such as halothane or isoflurane), and deliver this to the patient at a safe pressure and flow. Modern machines incorporate a ventilator, suction unit, and patient monitoring devices.

How it works

Oxygen (O2), nitrous oxide (N2O) and sometimes air sources are connected to the machine. Through gas flowmeters (or rotameters), a controlled mixture of these gases along with anaesthetic vapour passes through a vaporizer and is delivered to the patient. Sometimes a ventilator is also connected with the machine for re-breathing thus making it a closed circuit. With ventilators or a re-breathing patient circuit, soda lime canisters are used to absorb the exhaled carbon dioxide and fresh gases are added to the circuit for reuse. Pressure gauges are installed on the anaesthesia machine to monitor gas pressure. Generally, 25% (or 21%) oxygen is always kept in the circuit (delivered to patient) as a safety feature. The device which ensures this minimum oxygen in the circuit is called a hypoxic guard. Some basic machines do not have this feature, but have a nitrous lock which stops the delivery of N2O in absence of O2 pressure. Machines give various alarms to alert operators.

Troubleshooting

Anaesthesia Machines Fault	Possible Cause	Solution
1. Equipment is not running	No power at mains socket Electrical cable fault	Check power switch is on. Replace fuse with correct voltage and current rating if blown. Check mains power is present at socket using equipment known to be working. Contact electrician for rewiring if power not present. Refer to electrician for repair

2. No gas output	No O2 pressure in cylinder / gas supply. Check pressure gauges for gas pressure (about 4 bar or 4 kg/cm2)	Restore gas supply or replace gas cylinders. Replace O2 cylinder and/or N2O cylinder in case of low pressure.
3. O2 failure alarm not working	Alarm battery is low. Alarm device is not working	Call biomedical technician to fix the problem.
4. Machine has leaks	Poor seal (commonly occurring around tubing connections, flow valves and O2 / N2O yokes) Cylinders not seated in yokes properly	Clean leaking seal or gasket, replace if broken. If leaks remain, call technician for repair. Refit cylinders in yokes and retest. If leaks remain, call technician for repair.
5. Flowmeter fault	Over tightening of the needle valve or sticking of the float / ball	Refer to biomedical technician
6. Electrical shocks	Wiring fault	Refer to electrician immediately

Daily	
Cleaning	Remove any dust / dirt with dry cloth Remove water and waste matter from inside
Audio-Visual checks	If any leak is audible, check with soapy solution Check all seals, connectors, adapters and parts are tight Check all moving parts move freely, all holes are unblocked
Function checks	Report any faults to technician immediately After use, depressurize system and replace all caps / covers

Weekly	
Cleaning	Clean inside and outside with damp cloth and dry off
Audio-Visual checks	Check connections for leakage with soap solution and dry off Check all fittings for proper assembly Replace soda lime if it has turned blue Replace any deteriorated hoses and tubing If seal, plug, cable or socket are damaged, replace
Function checks	When next used, check pressure gauges rise When next used, check there are no leaks

3.7 Testing and troubleshooting dialyzers/ dialysis machines

The main faults in dialysis machines can be classified into two main parts:

- **Mechanical faults.**
- **Electrical faults.**

• Mechanical faults can be divided into three common types:

Conductivity faults

Some causes of conductivity faults are:

Machine pumps malfunction which is due to long period of operation i.e. the preparation of the dialysis solution takes about four hours per session.

Bad solution and this can be caused by the improper acid concentration.

Temperature and conductivity transducers suffer from faults that occur when temperature and conductivity transducers are not calibrated.

Pressure faults.

Common causes are: Filters and valves; sometimes the filters are stuck by wastes and valves failure can be due to high electric current.

- Leakage; this is due to overheat
- Pumps when the pressure of pumps is not calibrated pressure fault can occur.
- Pressure transducers if are not calibrated or the calibration is not proper

Pumps faults.

Pumps faults causes can be classified into:

Brush defect due to longer brush operation.

- Gear erosion; this can happen because of longer brush operation.
- Pumps stuck as a result of bad solution or no proper disinfection of machine after dialysis sessions.
- Over heat which leads to tubes detaching and leakage into pumps and so pump defect occurs.
- Belt defect in blood pumps caused by long operation period or calibration procedures are not made
- The electrical faults on the other hand can be divided into two common types:

Electrical faults

Causes of power faults can be:

High current which is common fault in power and it is due to instability of the electric current from the main electricity supply.

High temperature; that is when the word temperature is above 29°C a power fault may occur.

- Fluid spills in the machine which could make a short circuit and a power fault occur.
- Software defects due to: Mobile telephone electromagnetic waves. The installed software is not matched with the machine

Generally the faults can be overcome by considering the following:

The dialysis room's temperature must not exceed 27°C.

- The inside and outside of the machine must be cleaned and sterilized perfectly and periodically

.• Disposable parts of machine have to be changed after each 5000 hours of work.

- Dialysis machines have to be exposed to calibration processes to check their efficiency.

- Only original patient sets recommended to each machine have to be used i.e. universal patient sets must not be used.

- The operators must be aware of how to deal with the machine and the outcomes of using the machine in careless way.

3.8 Surgical Tools

SCALPEL Used for initial incision and cutting tissue. Consists of a blade and a handle. Surgeons often refer to the instrument by its blade number.

SCISSORS Used for cutting tissue, suture, or for dissection. Scissors can be straight or curved, and may be used for cutting heavy or finer structures

FORCEPS Also known as nonlocking forceps, grasping forceps, thumb forceps, or pick-ups. Used for grasping tissue or objects. Can be toothed (serrated) or nontoothed at the tip.

CLAMPS Also called locking forceps, these are ratcheted instruments used to hold tissue or objects, or provide hemostasis. Can be traumatic or atraumatic.

NEEDLES & SUTURE Needles come in many shapes and cutting edges for various applications. Suture can be absorbable, non absorbable, and is available in different sizes.

RETRACTORS In varying forms, retractors are used to hold an incision open, hold back tissues or other objects to maintain a clear surgical field, or reach other structures. They can either be hand-held or self-retaining via a ratcheting mechanism.

SUCTION Suction tips, combined with a suction source, help to remove debris and fluid from the surgical field. It can also be used to clear surgical smoke

STAPLERS AND CLIPS - Used for reanastomosis of viscera, vessel ligation, and excision of specimens. Can be one-time use, reloadable, manual, or electronically powered. Staples come in multiple sizes.

LAPAROSCOPIC INSTRUMENTS Many instruments are similar to those used in open surgery, adapted to fit through narrow ports placed through the skin. Laparoscopic work is then conducted via the ports

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DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – IV – MEDICAL EQUIPMENT MAINTENANCE AND TROUBLESHOOTING – SBMA3001

4.1 Troubleshooting X-ray machines

Functions

X-Ray machines are used for imaging bones and hard tissues and diagnosing fractures, joint defects, choked lungs etc. Sometimes contrast agents are also used to highlight any defects in the abdomen under X-rays.

Working

X-rays are high energy electromagnetic waves. The transformer produces a high voltage that directs electrons onto a target in the machine head. X-rays are produced by the target and are directed into beams by a collimator towards the human body. Soft body tissue absorbs less X-rays, i.e., passes more of the radiation, whereas bone and other solids prevent most of the X-rays from going through. A photographic film or electronic sensor displays how much X ray has passed through, forming an image of the interior of the body. Bone appears nearly white, because few X-rays strike the corresponding part of the film, leaving it largely unexposed; soft tissue allows much more radiation to pass through, darkening the film in those places.

Troubleshooting

X-Ray Machines Fault	Possible Cause	Solution
1. X-Ray unit does not switch on.	Mains power not connected	Check the machine is plugged into the mains socket and that all switches are on. Replace fuse with correct voltage and current if blown. Check mains power is present at socket using equipment known to be working. Contact electrician for rewiring if power not present.
2. X-Ray machine not exposing, even when power is on.	Safety interlock is on Exposure switch cable problem Internal error	Check safety locks, all switches Check for any loose connection Refer to biomedical technician

3. Poor X-Ray image quality	X-Ray tube problem	Refer to biomedical technician / medical physicist
4. The table does not move.	Table motor or cable problem. Safety switch or fuse problem Control circuit problem	Check all cable connections Check relevant fuse or switch Refer to biomedical technician
5. Electrical shocks	Wiring fault	Refer to biomedical technician immediately

Daily	
Cleaning	Clean dust from the unit with a dry cloth Remove any tape, paper or foreign body from equipment
Visual checks	Check all parts are present and connected Check cables are not twisted and remove from service if any damage is visible
Function checks	Switch on power and check all indicators function

Weekly	
Cleaning	Clean all dust and dirt from the X-Ray machine and room
Visual checks	If any plug, cable or socket is damaged, refer to biomedical technician Check all knobs, switches and wheels operate properly Check lead aprons for any defects Check table, cassette holder and grids for smooth movement
Function check	If machine has not been in use, wear lead apron and check whether exposure indicator lights on switch operation Check collimator bulb, replace with correct type if needed

4.2 Troubleshooting of ECG recorders

Function

ECG machines are used to monitor the electrical activity of the heart and display it on a small screen or record it on a piece of paper. The recordings are used to diagnose the condition of the heart muscle and its nerve system.

Working

The electrical activity is picked up by means of electrodes placed on the skin. The signal is amplified, processed if necessary and then ECG tracings displayed and printed. Some ECG machines also provide preliminary interpretation of ECG recordings. There are 12 different types of recording displayed depending upon the points from where the recordings are taken. Care must be taken to make the electrode sites clean of dirt before applying electrode jelly. Most problems occur with the patient cables or electrodes.

Troubleshooting

ECG Machines Fault	Possible Cause	Solution
1. ECG traces have artifacts or base line drift	Improper grounding	Try with battery power only. If the recording improves then problem is with grounding. Check the grounding Power the machine from another outlet with proper electrical ground
2. ECG traces have artefacts in one or more traces, but not in all traces	Improper electrode connection with patient or problem with the ECG cable	Check the patient cable continuity with continuity tester. Replace cable if found faulty Check the electrodes expiration date Check patient skin preparation Check limb electrodes and chest electrodes for damage, replace if necessary
3. Paper feed not advancing	Incorrect paper loading	Use instructions to reload paper

4. Printing not clear or not uniform	Printing head problem	Adjust the printing head temperature or position Clean the printing head with head cleaner. If no improvement, replace the printing head. Check the paper roller and replace if not smooth
5. The machine shuts down after a few minutes while on battery power.	Problem with battery or charging circuit	Recharge the unit overnight If there is no improvement then replace the battery If still no improvement, refer to technician

Daily

Cleaning	Clean off dust with dry cloth and replace dust cover
Visual checks	Check that battery charge indicator, power indicator and patient cable connector indicators are working
Function checks	Check the calibration of machine before use using 1mV pulse Check the baseline of the ECG recording is steady Check the printing is clear

Weekly

Cleaning	Clean the printing head
Visual checks	Check all cables are not bent, knotted or damaged Replace any damaged electrical plugs, sockets or cables Check all knobs, switches and indicators are tightly fitted
Function checks	Check the calibration of recordings with ECG simulator Check battery power can operate the equipment

4.3 Troubleshooting of incubator

Function

An infant incubator is a closed chamber in which a controlled environment is provided to the premature or critically ill baby. The user can select the appropriate temperature, humidity and oxygen level suitable for the baby.

How it works

The general principle is that air is processed before it reaches baby. An electric fan draws room air through a bacterial filter which removes dust and bacteria. The filtered air flows over an electric heating element. The filtered and heated air then passes over a water tank where it is moistened. It then flows on to the incubator canopy. The incubator canopy is slightly pressurised. This allows expired carbon dioxide to pass back into the room via the vent holes and most of the air to be re-circulated. It also prevents unfiltered air entering the system.

Troubleshooting

Incubators (Infant) Fault	Possible Cause	Solution
1. Incubator is not running	No power from mains socket Electrical cable fault	Check power switch is on. Replace fuse with correct voltage and current if blown. Check mains power is present at socket using equipment known to be working. Contact electrician for rewiring if power not present. Try cable on another piece of equipment. Contact electrician for repair if required.
2. Fuse keeps blowing	Power supply or cable fault	Refer to electrician
3. Alarms not working	Alarm battery dead	Replace the battery and recheck. Send for repair if problem remains.
4. Temperature not properly controlled	Temperature probe and sensor not working Incubator placed in direct sunlight or near a draught / fan. Fan or air duct problem	Check the temperature probes and sensor connections. Replace the temperature probe and sensor and recheck. Move incubator if placed near heat or draught Call technician if fan not working. Unblock air duct if obstructed.

5. Incubator not heating even when the heater lamp is on.	Heating element problem	If accessible, replace heating element. Otherwise refer to technician for repair
6. Electrical shocks	Wiring fault	Refer to electrician immediately

Daily	
Cleaning	Wipe dust off exterior and cover equipment after checks Remove any tape, paper or foreign body from equipment
Visual checks	Check all fittings and accessories are mounted correctly
Function checks	Drain off the water tray. Run machine for 30 minutes to dry the tray. Refill tray with sterile water just before re-use.

Weekly	
Cleaning	Unplug, clean outside with damp cloth and dry off Remove any dirt from wheels Wash (or replace) the air filters, dry thoroughly for reuse
Visual checks	Check mains plug screws are tight Check mains cable has no bare wire and is not damaged Check doors, cable and tray. Repair if damaged
Function checks	Check all controls operate correctly Check the readings of thermometer and oxygen sensors change when breathed upon Check any batteries are working properly.

4.4 Troubleshooting of baby warmer

#	**Text Box**	**Comments**
1	Begin: Infant warmer	Begin diagnostic process for infant warmer.
2	Does warmer power on?	Lights, displays, and sounds are all indications that the device has powered on.
3	Troubleshoot power supply (separate flowchart)	Most infant warmers have AC-DC power supplies. See Flowchart for Power Supply and BTA skills on Power Supply.
4	Does unit heat when switched on?	Does the device produce heat when the warmer is switched on?
5	Does power reach the heating element?	If no heat is produced, use a multimeter to test if the proper voltage is reaching the heating element.
6	Repair any open circuits or bad connections.	If power does not reach the heating element, there might be an open circuit, bad connection, or broken wire. See BTA skills on Electrical Connections.
7	Replace switch, relay, or triac.	A switch, relay, or triac may be used to control current flow to the heating element. Ensure it is working properly. See BTA skills on Electrical Switches.
8	Is heating element resistive?	Infant warmers typically use a resistive element or a bulb to create heat. Check which one is used in this device.
9	Replace bulb.	If a bulb is used and the proper voltage is reaching the bulb, it must be replaced. See BTA skills on Electrical Lighting.

10	Replace heating element.	If a resistive element is used and the proper voltage is reaching the resistor, the element must be replaced. See BTA skills on Electrical Heating Element.
11	Is the warmer designed to use a temperature probe?	If the warmer heats, it's necessary to check the temperature control methods of the device. Is a temperature probe (thermometer) used, either on the skin of the infant or in the air?
12	Is temperature > 38 degrees C?	If there is no thermometer, the temperature must be measured at patient level to ensure it stays at the desired level (typically between 34 and 38 degrees C).
13	Is temperature < 34 degrees C?	If the temperature is below 38 degrees C, confirm that is above the minimum temperature (34 degrees C).
14	Increase temperature.	Increase the temperature if it is below 34 degrees C. This might be accomplished by using control knobs to increase heat output, moving the heating element closer to the patient, and/or reducing ventilation.
15	Decrease temperature.	Decrease the temperature if it is above 38 degrees C. This might be accomplished by using the control knob to decrease output of the heating element, moving the element farther from the patient, and/or increasing ventilation.
16	Is probe present?	Confirm that the probe is present. Missing or damaged temperature probes are a common problem. Some warmers may have a manual mode to set a fixed heat output if the temperature probe is missing.

17	Is probe thermistor?	If there is a temperature probe present, it will be either a thermistor or a thermocouple. Attempt to verify which it is.
18	Replace probe or improvise thermocouple.	If the probe is a thermocouple, it works by providing a voltage source that varies in response to the input temperature. A battery and voltage divider might be able to be used to improvise the voltage output at a particular level to convert the infant warmer to manual mode.
19	Replace probe or improvise thermistor	If the probe is a thermistor, it works by providing a resistance that varies in response to the input temperature. A potentiometer or resistor might be able to be used to improvise the resistance at a particular level to convert the infant warmer to manual mode.
20	Does warmer maintain temp within 1 degree C?	If the probe is present, test the temperature output at various temperature levels to ensure the device can maintain the selected temperature within 1 degree C.
21	Replace or correct probe.	If the device does not maintain a temperature close to the input, the probe must be replaced or corrected.
22	Go to begin.	Begin the diagnostic process again to determine if corrective measures have repaired the device.
23	Go to begin.	Begin the diagnostic process again to determine if corrective measures have repaired the device.
24	Infant warmer is working properly.	The infant warmer maintains the appropriate temperature. The repair was successful.
25	Is temperature between 34 and 38 degrees?	Does the warmer maintain an appropriate temperature (between 34 and 38 degrees C) when operating in manual mode (without a temperature probe)?

Preventive Maintenance

Check for signs of physical damage or abuse especially concerning the heater(s) elements.
Check for evidence of fluid spills

Check for secure mounting

Check casters/brakes/mounting

Check AC plug/cord/receptacle

Check strain relief at both ends of cord

Check controls/switches

Check caution/operation labels present & legible

Check filters. Clean/replace as needed

Check power-on sequence

Test all audible & visual alarms and indicators

Clean interior/exterior as required

Test HI Temp Alarm

Measure temperature at a minimum of 2 set temperatures. Check high temperature alarm. Measure chassis ground resistance

Measure chassis leakage current

Check battery

Check that the unit is clean and disinfected prior to use.

Clean skin temp sensor

Check for corrosion and tightness of the heating element connections.

4.4 Troubleshooting of infusion pumps

#	Text Box	Comments
1	Begin: IV infusion pump (syringe)	Start the diagnostic process for a work order on an Infusion pump (syringe).
2	Device turns on?	Displays, lights, and sounds are all indications the machine has turned on.
3	Troubleshoot power supply (separate flowchart).	Syringe pumps generally have an AC-DC power supply. See flowchart on Power Supply and BTA skills on Power Supply.
4	Test or replace battery if necessary.	Old batteries are a common problem with syringe pump batteries. See BTA skills for Batteries.
5	Device runs on battery only (no AC)?	Check if the machine will run on battery when power is unplugged. This is a safety feature on nearly all syringe pumps.
6	Pump creates correct flow rate?	Measure the flow rate using a container of known-volume to collect the fluid and a stopwatch. For small flow rates, it may be necessary to use a precision scale to measure the fluid output. Flow rate is volume divided by time.
7	Is flow rate zero?	Check if the machine will generate any output of fluid.
8	Is flow rate too high?	Compare the measured flow rate to the amount programmed in the machine.
9	Confirm clutch is not slipping.	Low flow can be caused by a clutch slipping on the lead screw. Repair slip if necessary.
10	Clean and lubricate lead screw as necessary.	See BTA skills on Cleaning and Lubrication.

11	Confirm syringe is loaded properly.	Incorrect flow rate can be caused by improperly loaded syringe.
12	Confirm cables to and from sensors and motor are seated properly.	See BTA skills on Electric Connections.
13	Replace/calibrate sensors as necessary: syringe position sensor, and syringe size sensor (if applicable).	Faulty sensors can cause faults in controlling the flow rate.
14	Is flow rate correct?	Measure the flow rate using a container of known volume to collect the fluid and a stopwatch. For small flow rates, it may be necessary to use a precision scale to measure the fluid output.
15	There may be a fault with microprocessor.	If corrective measures don't resolve the incorrect flow rate, a problem with the microprocessor or computing software is possible.
16	Consider replacing/disposing.	If the problem lies with the microprocessor, the machine may need to be disposed.
17	Confirm syringe is loaded properly.	Incorrect flow rate can be caused by improperly loaded syringe.

18	Confirm proper menu settings and options are in use.	User error may be a problem if machine is reported for lack of flow.
19	Clean and lubricate lead screw as necessary.	See BTA skills on Cleaning and Lubrication.
20	Is flow rate zero?	Check if the machine will generate any output of fluid.
21	Repair or replace stepper motor.	If corrective measures don't start fluid output, there may be a problem with the motor that drives the syringe. See BTA skills on Motors.
22	Flow ceases when syringe pump is off?	Verify that the flow ends when the pump is turned off or the control panel is used to end the flow.
23	Confirm syringe is loaded properly.	An incorrectly loaded syringe could leak fluid when flow is turned off by controls.
24	Correct leaks in tubing.	See BTA skills on Plumbing Leaks.
25	Confirm syringe plunger will not move freely without motor.	If plunger moves independently of machine controls, check mechanical connections. See BTA skills on Mechanical Attachment.
26	Does high pressure alarm sound when tube is pinched after syringe?	If the output tube is occluded, the machine should emit a high pressure alarm.
27	Is machine always silent?	Investigate if machine makes noises due to any other inputs or alarms.
28	Replace/calibrate force sensor on syringe plunger.	High pressure alarm is not sounding. Check the force sensor that measures the force applied to the syringe plunger.
29	Ensure force sensor cables are properly connected and seated.	See BTA skills on Electric Connections and Connectors.

30	Replace speaker.	Machine is not in silent mode, but it does not make noise. Replace the speaker.
31	Go to begin.	Restart the diagnostic process to see if the corrective measures have repaired the machine.
32	Go to begin.	Restart the diagnostic process to see if the corrective measures have repaired the machine.
33	IV pump is working properly.	Return the machine to service via the appropriate clinical personnel.
34	Verify machine not in silent mode.	Silent mode may be preventing the alarm. Turn off silent mode and check alarm again.

Preventative Maintenance

- Examine plug and line cord.
- Examine internal cables and connectors.
- Verify software and menu settings are appropriate for clinical application.
- Examine controls and switches for proper function.
- Verify battery chargers and indicators are working
- Check suggested replacement date for the battery to see if the date is passed or approaching.
- Confirm lights, indicators, and displays are working.
- Verify flow stops when device is turned off.
- If device includes a feature that requires the IV set to be closed before it is disconnected (either automatically or manually), verify that this mechanism is operating properly.
- Calibrate machine for flow rate.
- Replace battery if necessary.
- Check for unusual noise or vibration.
- Run self-test, if equipped.
- Lubricate lead screw, gears, and other moving parts as required.
- Measure chassis leakage current.
- Measure ground resistance.

Test audible and visual alarms and indicators.

4.5 Annual maintenance

- AMC is an annual contract for maintenance.

A manufacturer provides the service on its own or with the assistance of service providers through AMC. The contract is usually for a period of 1 year and, according to the mutual understanding of both parties, can be extended for up to three years or five years.

Generally service providers only provide business support and pay for each portion under AMC separately. In some situations, however, few parts are replaced by service engineer during the visit while minimal parts are replaced in the AMC contract.

- CMC stands for comprehensive maintenance contract.

  It includes the company or service provider's prompt service.

  The contract is typically for a term of 1 year and, according to the mutual understanding of both parties, can be extended for up to three years or five years. This requires defective components fixes and replacements. Getting the agreements offers the advantages that are available at reduced costs such as consumables (which are not part of the contract).

  CMC is more costly than AMC because it also requires spares costs.

AMC and CMC Management

1. The specialized and lifesaving critical equipment will require AMC- Annual Maintenance Contract without spares and CMC- Comprehensive Maintenance Contract with all the spares included.

2. The AMC and CMC will be monitored centrally. It will be initiated by the Divisional Biomedical Engineer based on the assessment as to whether to go in for CMC or for AMC. The Divisional Biomedical Engineer will initiate the process at least 30 days in advance of the date of expiry of the warranty period.

3. The procurement division will procure the equipment with either 2 years warranty and five years CMC (For equipment costing less than 1 Crore) OR with 5 Years warranty and 5 years CMC (for equipment costing more than one crore). In both the cases the post warranty AMC/CMC rates are approved and the supplier will have to sign contract based on approved rates only. Post warranty the rates can't be modified by the vendor unless there is a clause to do so.

4. The Divisional Biomedical Engineer will examine the AMC/ CMC rates with respect to the approved rates and will send the contract for formal approval to the GM-Equipment.

5. GM- Equipment will examine the same and will sign the contract and send the same back to the Divisional Engineer.

S. No	Activity	Responsibility	Record
1	Health facility In charge / end users to report any Equipment under Warranty / AMC requires repair	Facility In charge & End users	Call log
2	Service provider to notify respective Vendor for any repair / service	Service provider	Call centre/call log/letter/email
3	The copy of such letter and email will be submitted to Health facility In Charge	Service provider	Call log/letter/email
4	Service provider to notify respective vendor one month prior to expiry of warranty	Service provider	Call log/letter/email
5	Medical equipment under AMC will be added to service provider contract after the expiry of such AMC to the inventory asset base	Service provider	Dash board
6	Service provider updates all service done in Dashboard	Service provider	Dash board

4.6 Contract requirements, vendor services

The vendor shall provide the following services to keep the equipment in good working condition.

The replacement of all the spares is included under the AMC.

Replacement of defective parts will be at the vendor's cost with original spares of the brand/make of the computer and peripherals as far as possible.

In the event of non-availability of the spare parts, equivalent or higher configuration components should be substituted with the company's consent.

Faulty parts removed from the system belong to vendor. However, the company can retain the same and use at its own sole discretion to maintain the equipment subject to the payment of its value to the vendor

The vendor shall maintain adequate spare machine and other spares at the site to facilitate any temporary replacement.

The Vendor shall maintain the equipment's as per the manufacture's guidelines and shall use standard and genuine components for replacements.

Complaint can be registered either telephonically or by e-mail by respective branch/Office and proper record of the complaints to be maintained by the AMC Vendor

A logbook shall be maintained in which the vendor shall record all the complaints made and parts taken out of branches/office for repair. The vendor shall submit copy of consolidated complaint reports furnishing the details

All the complaints received shall be attended by them in following manner.

a. Minor faults immediately with telephonic support.

b. Major faults which require visit to branch within 48 hrs.

Repair and servicing of equipment shall be carried out at customer sites, in case the equipment is required to be transported to the vendor's/manufacture's service workshop for repairs, the same shall be undertaken at the risk and cost of the vendor.

The contract shall be on comprehensive basis, inclusive of repairs and replacement of spare without any extra payments.

The AMC Vendor shall carry out Preventive Maintenance (PM) on quarterly basis and shall plan, as per schedule of quantities, such that maintenance is carried out in each equipment at least once in three months. A separate logbook should be maintained to record the preventive maintenance carried out on each equipment.

The vendor shall make AMC services available on all days as and when requested by the Company.

This AMC does not include:

a) Electrical work external to the equipment or maintenance of accessories, attachments, machines or other devices not covered under this agreement.

b) Damage resulting from accidents, fire, lightning or transportation. The cost of repairs or replacements due to these factors will include charges for labour as well as charges for parts, which is payable to the AMC vendor apart from AMC charges.

c) Any work external to the equipment such as maintenance of non-AMC attachment, accessories etc.

4.7 **Quality and Safety standards**

Medical devices are subject to strict general controls and procedural regulations. The development and use of standards is vital to ensuring the safety and efficacy of medical devices. Numerous regulatory agencies and standards organizations collaborate to establish the accepted standards for medical equipment. Standard-setting activities include the development of performance characteristics, characterization and testing methodologies, manufacturing practices, product standards, scientific protocols, compliance criteria, ingredient specifications, labeling, or other technical or policy criteria.

International Organization for Standardization (ISO): a non-governmental organization that develops and publishes international standards on a wide range of subject, including medical equipment. For the consumer, ISO International Standards ensure that products and services are safe, reliable and of good quality. For business, they are strategic tools that reduce costs by minimizing waste and errors, and increasing productivity. These standards are very relevant for medical devices and encompass virtually every aspect of device design and implementation – from device inspection requirements to guidelines for medical device labels.

International Electrotechnical Commission (IEC): a non-governmental organization that prepares and publishes International Standards for all electrical, electronic and related technologies. It utilizes over 10,000 experts from industry, commerce, government, test and research labs, and academia and consumer groups. When appropriate, IEC cooperates with ISO to ensure that International Standards are congruent.

In general, ISO concentrates on controls for materials and processes, and IEC concentrates on the manufacturing and testing of products.

ASTM International: a globally recognized leader in the development and delivery of international voluntary consensus standards. ASTM standards encompass virtually all medical devices and services imaginable – and all aspects relevant to medical devices, such as materials and biological components. ASTM standards encompass product areas including anesthesia, biocompatibility, cardiovascular, dental, orthopedics, plastic surgery, general surgery, general Taylor, A. Page 3 hospital devices (such as medical gloves), materials, neurosurgery, obstetrics and gynecology, sterility in medical devices, and tissue engineering.

- ISO 13485 - standard for medical device quality management systems
- ISO 14971 - standard for medical device risk management
- ISO 9001 - standard for business quality management systems
- ISO 62304 - standard for software used in medical devices, and ISO 62304:2006 is the most current version.
- ISO 10993 - standard for biological evaluation of medical devices.
- ISO 15223 - standard for symbols to be used with medical device labels, labeling, and information to be supplied.
- ISO 11135 - standard for ethylene oxide sterilization of medical devices
- ISO 11137 - standard for sterilization of medical devices using radiation.
- ISO 11607 - standard for sterilized product packaging for medical devices.
- IEC 60601 - standard applies to the safety and essential performance of medical electrical equipment.

Benefits of ISO Compliance and Certification

Although compliance with ISO standards isn't always mandatory, and certification may not be required, there are many benefits to conforming to the applicable standards, including:

Better Quality Management Systems

Certification forces you to make process improvements, which ultimately adds value to your business.

Fewer Audit Findings And Inspection Deficiencies

FDA auditors and notified body reviewers will have fewer questions and find fewer issues if you are in ISO compliance for quality and risk management.

Patient Safety

This is the primary goal for both regulators and manufacturers. Conforming to ISO standards helps reduce quality issues and protect patients.

Credibility

ISO compliance demonstrates that your business conforms to internationally recognized standards, which lends credibility to your brand among regulators, patients, and healthcare providers.

More Efficient Regulatory Processes

When you comply with standards, FDA and notified bodies know you have properly tested products and processes, which helps streamline approvals, audits, and inspections.

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

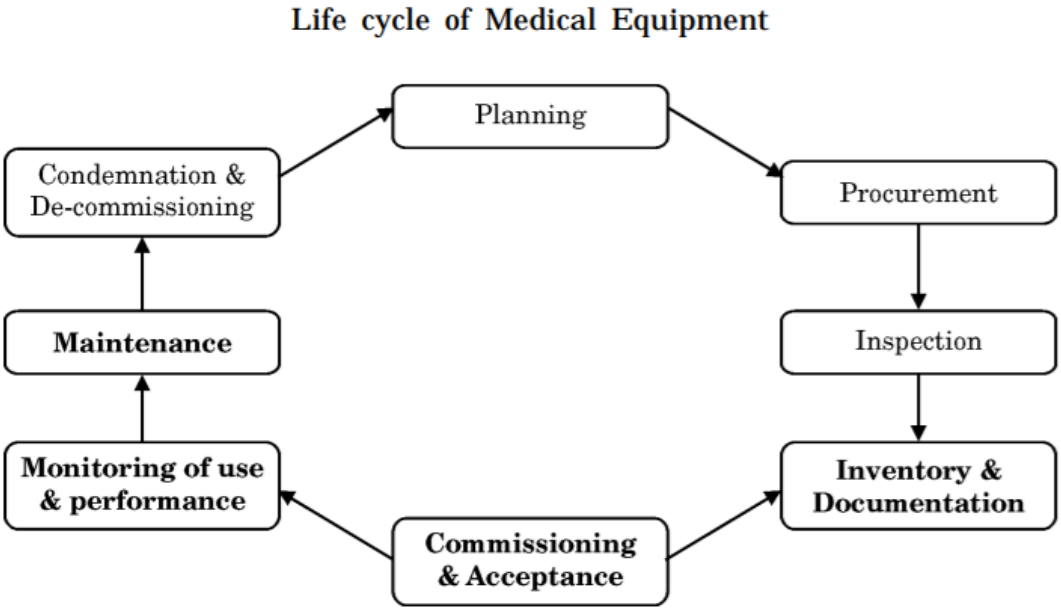
DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – V – MEDICAL EQUIPMENT MAINTENANCE AND TROUBLESHOOTING – SBMA3001

5.1 Life cycle management of medical equipment

The effective management of medical devices throughout the medical device life cycle is a crucial process that provides value for the manufacturer and the end user. As medical devices transition through each stage of their life cycle, they are subject to new types of processes, testing and regulatory requirements.

An equipment life cycle are every medical devices entire life-span from its manufacture, purchase and planning, installation and acceptance inspection, to its every day use, as well as daily maintenance, to its final turn in disposal and retirement.



Lifecycle of medical equipment in four main phases:

1. Planning and assessment
2. Set-up
3. Use and maintenance
4. Disposal

Planning and assessment

The planning phase is critical to the success of the donation, and should be considered as part of the lifecycle of medical equipment. Actions required during this phase include:

- Assessing what is needed, and what is already available at the healthcare facility – considering the environment, the equipment users and the patients.
- Budgeting for both equipment purchase and other costs across the entire lifecycle.
- Deciding exactly what to buy, and assessing whether equipment available on the market is suitable; of good quality; and meets the needs identified.
- For large or complex donations, drawing up tenders or donation agreements

Set-up

In the set-up phase, the equipment is delivered to the healthcare facility, and installed. Staff are trained on how to use the equipment.

This can be much more complicated than it initially appears. For example, just for the delivery of the equipment, consider: how will the equipment be transported to the healthcare facility? Is the equipment insured against damage during transport and set-up? Who will be at the facility to receive the equipment and inspect it for damage? Have you agreed a space where the equipment will be stored, and do any modifications need to be made to that space (e.g. power supply, temperature control)? It is likely that the healthcare facility will have processes in place for the delivery of medical equipment, but you need to find out what these are.

Training staff on how to use the equipment may require dedicated time and space for the training sessions; educational materials; somebody who is qualified to deliver the training; as well as consideration of how to motivate staff to attend.

Use and maintenance

The **use and maintenance phase** of the equipment lifecycle is the time when the equipment is put to use. This includes ongoing training of healthcare staff, including new staff, on how to use the equipment, as well as monitoring of compliance with safety procedures.

However, need to understand what happens between uses of the equipment: cleaning and sterilisation, replacement of single-use parts, disposal of contaminated materials or used parts, and storage of the equipment.

Some equipment will need a consistent supply of electricity, water, or medical gases. Some equipment might need specific storage conditions.

If part of the equipment breaks, trained personnel will need to identify the problem, and be able to access spare parts at affordable prices.

Disposal

The **decommissioning and disposal phase** is fairly self-explanatory.

However, consider who will decide when the equipment needs to be replaced, and whether there are any specific requirements for safe disposal of e.g. sharps, contaminated materials, or confidential data.

All of these issues may be easily surmountable; and different types of equipment will obviously have very different requirements. However it is important to map out the entire lifecycle of a piece of equipment, to ensure you are not forgetting something vital to the success of the donation.

By Managing The Full Lifecycle With Medical Equipment Capital Planning Software, Healthcare Delivery Organizations Can:

- Improve patient care through streamlined processes, efficiencies and cost reduction.

- Quickly generate and update accurate equipment budgets.
- Collaborate and centralize processes around capital equipment decisions.
- Reduce expensive change orders and project completion delays.
- Prioritize and control capital and replacement expenditures for immediate and long-term budgets.

5.2 Cost of medical equipment

Supply costs (including medical devices) are one of the greatest expenses for healthcare facilities, after labor and administrative expenses. In total, supply budgets equal approximately 25-33 percent of the medical and surgical operating expenses

The Medical Device industry is highly capital intensive with a long gestation period and requires development and induction of new technologies. It also requires continuous training of health providers to adapt to new technologies The products and services driving this growth include hospitals, medical devices, clinical trials, telemedicine, medical tourism, health insurance, and medical equipment.

The Indian medical device market is estimated at $10 billion and is an attractive export sector. India imports nearly 80 percent of its medical devices. India remains highly dependent on imports for many types of medical devices, particularly higher end equipment such as cancer diagnostics, medical imaging, ultrasonic scans, and PCR technologies. Healthcare is provided through primary, secondary, and tertiary care hospitals in India. The former two categories are fully managed by the government; tertiary care hospitals are owned and managed by either the government or private companies, and the private sector's contribution to healthcare has been growing at a faster pace than the government's. The medical infrastructure market is growing at an estimated 15 percent annually.

Medical Devices & Equipment Unit: $ million	2018	2019	2020
Total Market Size	7,300	8,974	10,360
Total Local Production	606	2,390	4,473
Total Exports	3,269	3,477	3,211
Total Imports	9,963	10,061	9,098
Imports from the United States	1,685	1,703	1,319

5.3 Maintenance cost

Medical devices requiring calibration, maintenance, repair, user training, and decommissioning − activities usually managed by clinical engineers. It can be used either alone or in combination with any accessory, consumable, or other piece of medical equipment.

seven ways how hospitals can reduce equipment service and maintenance costs.

Keep an inventory of the medical equipment:

One of the best ways to ensure that hospital equipment service and maintenance costs are reduced is keeping an inventory. Educate the medical staff to maintain the equipment and keep it in good shape for maximum use. There are several cases where it has been seen that the sensors and cable fitted outside the equipment get damaged. This is due to mishandling and should be avoided for the best results.

Reduce the coverage options on your medical equipment:

Another great way to reduce equipment service and maintenance costs is by lowering the coverage option.

Multi-system service agreement:

The multiservice agreement is a perfect way to reduce the maintenance and service cost of hospital equipment. In addition, taking this service agreement costs less per system as it reduces the operational cost by a considerable margin.

Long term service agreement:

Multisystem and long-term service agreements work similarly. Depending on the use of the hospital equipment, you can go for a long-term service agreement. Long term service agreement offers a discounted rate every year if you select their services for multiple years.

Advance payment:

Making advance payments can reduce the service cost by a considerable margin. However, making upfront payments decreases the price, so it is advised to pay in cash if possible, for the best results.

When you spend more initially, the service organizations reduce the overall price, rewarding hospitals. Hospital fowler bed prices can reach several thousand dollars, but paying upfront will indeed reduce the service costs that come in the future.

Make comparisons:

If a service organization is charging higher, it does not mean that they always offer quality services. It is advised to compare several other service organizations and compare their services for the best results. Choose the top service organizations in your location and compare their pricing and services for the best experience.

Medical Equipment Maintenance Policy will provide broad logical framework of decision to be taken for guiding certain actions that are useful in prolonging the active life of equipment so that the equipment provides accurate results in diagnosing, monitoring and treating. The equipment may be useful for medical education and research.

The Policy aims to ensure that whenever medical equipment is used, it is:

- Suitable for its intended purpose
- Properly understood by appropriately trained users
- Maintained in a safe and reliable condition.

MAINTENANCE OF THE EQUIPMENT : Proper maintenance of medical equipment is essential to obtain sustained benefits and to preserve capital investment. Medical equipment must be maintained in working order and periodically calibrated for effectiveness and accuracy of the results.

The Maintenance consists of: a. Planned Preventive Maintenance b. Breakdown Maintenance a. **Planned Preventive Maintenance (PPM)-** Planned Preventive Maintenance involves maintenance performed to extend the life of the equipment and prevent its failure. Planned Preventive Maintenance is usually scheduled at specific intervals and includes specific maintenance activities such as lubrication, calibration, cleaning (e.g. filters) or replacing parts that are expected to wear (e.g. bearings) or which have a finite life (e.g. tubing). The procedures and intervals are usually established by the manufacturer. In special cases the user may change the frequency to accommodate local environmental conditions. Planned Preventive maintenance will be a statutory requirement for most of the medical equipments. It will enhance the efficiency, effectiveness and reliability of medical equipment and must be carried out at appropriate frequency as suggested by the manufacturer/service provider

The record of Planned Preventive Maintenance should be maintained department wise and must include following details:- 1. Reference ID as per inventory 2. Equipment Name 3. Company/Make 4. Serial No. 5. Date of Installation 6. Warranty Period 7. Under AMC/CMC 8. Frequency of Preventive Maintenance/Calibration a. as per manufacturer guidelines b. presently being followed 9. Preventive Maintenance/Calibration Done On 10. Preventive Maintenance/Calibration Due On 11. Expenditure with cost and details 12. Remarks with Functional Status

Breakdown Maintenance Breakdown Maintenance is a task performed to identify, isolate, and rectify a fault so that the out of order equipment, machine, or system can be restored to an operational condition. All medical equipment in use should be free from any fault or defect and all repair work should be carried out to accepted standards by competent person(s). Faulty or defective equipment shall not be used regardless of how minor is the problem and must be reported in the first instance to the manufacturer/supplier/agency hired for maintenance of the equipment as soon as possible.

Department should:

1. Record details of the defect(s). 2. Attach label to the faulty equipment(s). 3. Contact Service engineer of manufacturer/supplier/hired agency by telephone number/fax/email supplied and

keep a record of the same. 4. Ensure that information regarding breakdown is passed to all staff, including any shift changes and head of the institution.

2. All the breakdowns occurring in the department should be maintained on record and must include following details:- 1. Reference ID as per inventory 2. Equipment Name 3. Company/Make 4. Serial No. 5. Date of Installation 6. Warranty period 7. Under AMC/CMC 8. Breakdown Date and Time 9. Breakdown Details (Technical fault or other reasons) 10. Date and Time of Rectification 11. Total Time Taken (Rectification Time – Breakdown Time) 12. Rectification Details with expenditure including cost (if any) 13. Remarks with functional status

5.3 Replacement Analysis

Every equipment reaches end of its economic service life after a repeated use and its cost-benefit ratio decreases exponentially, its reliability dwindles, experiences high downtime which results in high operational and maintenance costs. When equipment is not reparable, the subsequent option is to replace it. Furthermore, medical equipments go obsolete to use and at that time replacement must be considered

Individual Replacement Strategy: Whenever any item fails, it is necessary to replace it immediately. B. Group Replacement Strategy: All items/parts need to be replaced after a particular period even if they are in good working condition. This ends up in replacement practice for the hospitals to become effective, improve health outcomes and supply sustainable health services

A strategy for proactive replacement planning is needed in which financial and clinical leaders come together to make more informed decisions for the organization. By leveraging existing data, replacement planning can help an organization achieve the following objectives:

- Reduce costs associated with parts, maintenance, equipment, and training
- Improve quality and reduce “near-miss” events associated with old or faulty equipment
- Enable leaders to reallocate underutilized assets
- Promote greater staffing flexibility across different sites
- Improve standardization across the enterprise, thereby further reducing costs

A comprehensive replacement planning approach would be a marked departure from the commonly used short-term, reactive strategy of purchasing new equipment when it breaks or when a department head says a purchase is mission-critical.

Factors Necessary for Replacement of Equipment

All equipments hit its their service life and their net present value goes to negative which results in reduced reliability, increased downtime, safety problems, compromised treatment, increased running costs, changing legislations, or simply obsolescence and at this point replacement must be considered. Often times, hospitals respond to healthcare technology replacement requests by causing immediate, unplanned and unbudgeted replacement of expensive technologies. Examples of reactive replacement requests include the following:

When a device fails at a critical time and maintenance is not an option;

When a medical staff claims that present technology is obsolete and need to be replaced;

When repair is undergoing and parts and supports are no longer available;

Equipment replacement techniques take various criteria into consideration while developing equipment replacement plans: technical, financial/cost and safety factors.

1.3.1 Technical Factors

Obsolescence: The existing equipment has good performance; unfortunately, new alternatives are available in the market that provide better results because of technological developments . Obsolescence is usually the rationale why equipment has to be replaced before its estimated economic life expires.

Inadequacy: When the prevailing equipment becomes inadequate to satisfy demand or it is powerless to extend the assembly rate to specified level, then the question of replacement will arise.

Deterioration Due to Aging: Deterioration is a process that usually arises from natural wear induced by¬ usage and passage of time. As a medical equipment gets older, the maintenance and operational costs increase. Those are financial losses for organizations and therefore they tend to replace assets even they are in good conditions. To verify the state of deterioration of an asset, it is necessary to compare the performance of the same machine in different ages, regarding factors such as failure rate, average downtime, average cost per failure and average maintenance cost for a period.

Equipment Downtime: measures the time the device is out of service because of breakdown.
User Errors: These errors happen while identifying the areas where assets have failed.

5.5 Managing equipment service, decision making

Medical equipment plays an important role in healthcare delivery. It ranges from small and simple devices such as sphygmomanometer to complex and big devices such as Magnetic Resonance Imaging (MRI) machines. This ranking is as a result of differences in utilised technologies and intended applications.
It is, therefore, of vital importance that healthcare organisations manage their assets to keep their expenditures under control as well as ensure the quality of healthcare delivery.

Medical Equipment Management (MEM) takes place within the context of human, material, structural, organisational, and financial resources. It is a process which helps hospitals to develop, monitor, and manage their equipment to promote the safe, effective, and economical use and maintenance of equipment. Responsible organisations should setup and regularly review MEM to ensure that a suitable medical device is used in accordance with the manufacturer's instructions, maintained in a safe and reliable condition, and disposed appropriately at the end of its useful life.

A systematic way to manage medical equipment is to study and optimise all phases in the useful life of that equipment.

It consists of nine stages

1. Planning
2. Acquisition
3. Delivery and incoming inspection
4. Inventory and documentation
5. Installation and commissioning
6. User training
7. Monitoring of performance

8. Maintenance
9. Replacement or disposal

1. Planning

Planning process is an important aid in decision-making because it provides essential information for management. In other words, it provides technology vision where healthcare facility should position itself; it can specify the following conditions in order to aid the decision-making process.

• Demonstrated needs and benefits
• Available qualified users
• Confirmed maintenance services and support
• Adequate environment support
• Regulatory compliance

These conditions are simple and should be applied to any routine acquisition of a medical device. Planning is the responsibility of the Medical Technology Advisory Committee (MTAC). The committee includes an administrator, a planning director, and a clinical engineering director. The role of planning is to ensure a balance between clinical and technology sectors of healthcare facilities in addition to meeting the community needs. The procedure of strategic planning of medical equipment includes:

• Performing an initial audit for existing technologies
• Conducting a technology assessment for new and emerging technologies that fit the desired clinical services
• Planning for replacement and selection of new technologies
• Setting priorities for acquisition
• Developing processes to implement equipment acquisition, and monitor ongoing utilisation

2. Acquisition

Healthcare industry is known for its continued innovation and production of new devices and techniques intended to improve the delivery and outcome of patient care. Funding constraint is considered the master key to evaluate incorporation of new technology to healthcare service. Thus, more attention should be given to the acquisition process keeping in mind both healthcare delivery outcomes and funding availability

Needs identification usually starts from users of technology, i.e. the medical staff (physicians and nurses).Indeed, the need to acquire a medical device may be due to one or a combination of the following reasons:

- Provide a new service
- Improve service efficiency
- Improve clinical outcomes
- Improve cost benefits
- Meet specific standards
- Reduce a risk.

In general, tendering process takes place to purchase medical equipment based on the required specifications. In tendering, all vendors are allowed to bid under a competitive and fair evaluation. Moreover, it gives a good opportunity for hospitals to select the best possible medical equipment. It is worthy to mention that technical specifications should include general requirements such as the warranty, technical services, technical documents, and any other necessary requirements for equipment operation.

In the evaluation process, the purchased medical equipment should be evaluated from three different angles: technical, clinical, and financial. The purpose of technical and financial evaluations is to check the proposed technology, and to ensure the performance of the devices meets the desired outcomes. On the other hand, financial evaluation considers only the costs of the proposed technology. Both technical and clinical evaluations are carried out using either scoring or accept/reject approaches, whereas financial evaluation regards the lowest price among accepted vendors.

After making the selection, an award must be issued to acquire the device. A purchase contract document is prepared by the purchasing department and it must cover all terms and conditions that have been agreed upon by the vendor and the hospital.

3. Delivery and incoming inspection

Clinical engineering department ensures an incoming inspection on equipment includes verification of accessories, manuals, and electrical safety and operation in accordance with all applicable policies. Incoming equipment should be carefully checked for possible shipment damage and compliance with specifications in the purchase order. One role of clinical engineer is to ensure an incoming inspection on medical equipment by verifying the following:

- Accessories existence
- Manuals existence
- Electrical safety
- Compliance with specifications
- Possible shipment damage

4. Inventory and documentation

Medical device inventory and documentation is an assistive stage in the life cycle. It provides information to support medical equipment management in different stages. Upon completion of the incoming inspection, a device record file should be created and it should be active throughout the useful life span of the device. Each device is identified and tracked by a unique number called equipment record number. The device record file should contain the following data:

- An Equipment Control Number (ECN)
- A generic description of the equipment
- The equipment manufacturer, model, and serial number
- The owner department and the location of the equipment
- The purchase order number and date
- The equipment’s acquisition cost
- The supplier’s name, address, and telephone number

• The warranty conditions and expiration date
• An abbreviated description of the inspection and preventive maintenance requirements and intervals
• An abbreviated service history
• Information regarding any applicable service contract
• The location of the equipment’s user and service manuals.

5. Installation and commissioning

Installation and commissioning can be carried out by in-house technical staff if they are familiar with a given item of equipment. If the installation and commissioning are needed from the suppliers, in-house technical staff should monitor this process. In general, installation process should be compatible with standard policies for medical equipment installation.

6. User Training

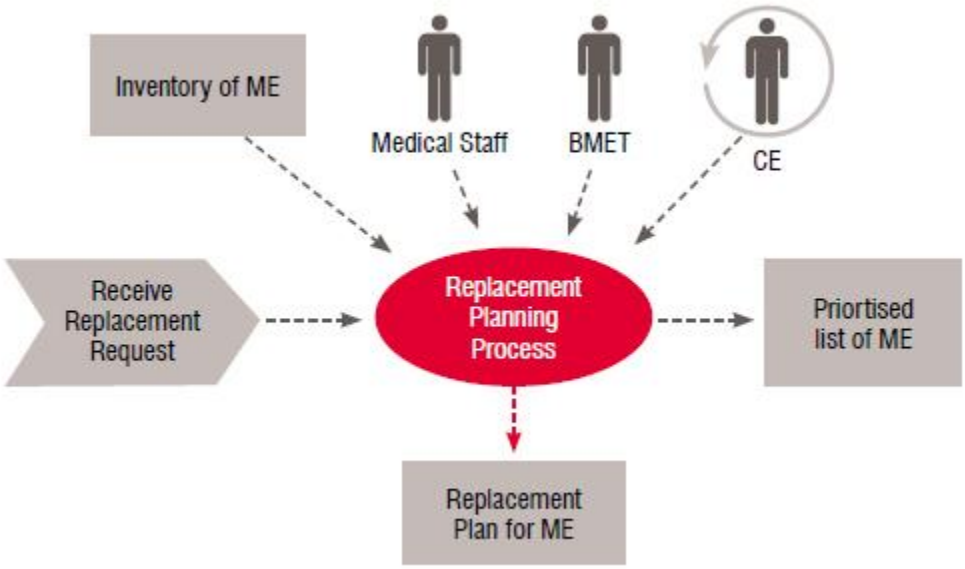
To reduce the possibility of equipment malfunction following service or repair, all personnel involved in maintaining and servicing equipment must be trained to appropriate standards for the work they are carrying out. Operator error is a leading cause of device malfunctioning, especially in developing countries. Incorrect usage of medical equipment will also greatly increase maintenance problems. Therefore, training of users should be regularly monitored from the vendor to ensure an appropriate skill level that is required for equipment operation. In fact, training should include all of the user staff as needed, such as clinical and technical staff. In addition, it should cover all aspects of medical equipment usage.

7. Monitoring of use

One common mistake in MEM is to believe that the warranty period is covered by the supplier, so no in-house technical attention is necessary. In-house technical staff should become the link between user and supplier and should observe any supplier's technical staff. This also will provide a learning opportunity for the in-house technical personnel. This performance should be also documented in the service history of the device by in-house technical staff.

8. Maintenance

Equipment maintenance involves all activities related to providing an adequate level of service and limiting downtime of medical devices. Maintenance or service activity is required in order to ensure the devices are kept functioning within the limits imposed by the test criteria and to return devices to the required level of functioning after breakage or other failure. The primary goal of maintenance activity is to reduce, or, if possible, to eliminate the need of repairs.



9. Replacement

Replacement is the last stage of medical equipment's life cycle. All medical devices reach the point in their life where the cost-benefit ratio goes to the negative because of decreased reliability, increased downtime, safety issues, compromised care, increased operating costs, changing regulations, or simply obsolescence. A synopsis diagram that illustrates the replacement process in terms of participants, inputs, and output is shown in Figure 3.

Disposal of equipment must follow safety procedures in order to protect people and the environment. The ideal healthcare technology replacement planning system should be facilitywide, and cover all clinical equipment employing accurate objective data for analysis. Moreover, it should be futuristic and include strategic planning relating to clinical marketplace

trends and the hospital's strategic initiatives relating to technology. The plan should encompass factors relating to cost-benefit analysis, safety, expected life span, standardisation, and clinical benefits. In application, decontamination requirements should be regarded prior to disposal. Furthermore, many benefits can be obtained by utilising scrapped equipment as listed below:

- Use spare parts with similar equipment
- Replace with new ones with the same vendors
- Donate them to charity clinics after operation verification
- Dummies in internal training
- Use in research labs
- Save them for museums.