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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – I – Therapeutic Instrumentation – SBMA1601

UNIT-1

INSTRUMENTS FOR CARDIOLOGY

1.1 CARDIAC PACEMAKERS

1.1.1 NEED FOR PACEMAKERS

Rhythmic beating of heart is due to the triggering pulsed generated at the SA node. If the SA node ceases to function, or if pulses do not reach the heart muscles, the normal heart action gets disturbed.

An external electrical stimulation can regulate the heart rate. These pulses are given by an electronic instrument called pacemaker. A pacemaker is a small device that's placed in the chest or abdomen to help control abnormal heart rhythms. This device uses electrical pulses to prompt the heart to beat at a normal rate.

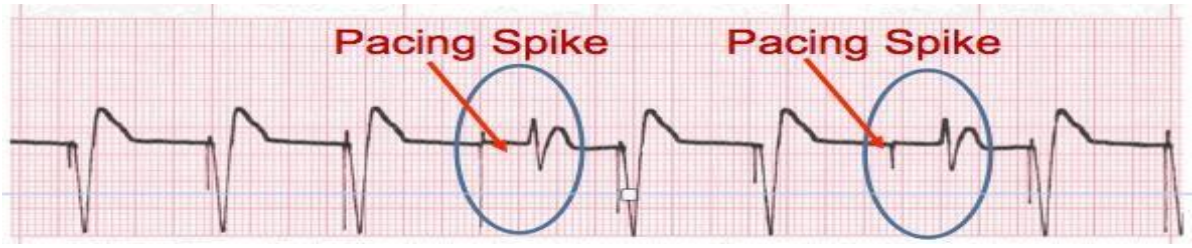

Fig 1.1 Pacing ECG

Pacemakers are used to treat arrhythmias. Arrhythmias are problems with the rate or rhythm of the heartbeat. During an arrhythmia, the heart can beat too fast, too slow, or with an irregular rhythm.

Pacemakers have 2 parts:
All artificial cardiac pacemakers have a pulse generator (a device that gives off an electrical impulse at prescribed intervals), electrical leads (which transmit the impulse to the myocardium),and a battery (usually made of lithium iodide) encased in titanium and implanted surgically in a subcutaneous pocket (usually in the chest). A small incision (cut) is made, most often on the left side of the chest below the collarbone. The pacemaker generator is then placed under the skin at this location.

The battery most commonly used in permanent pacers has a lifespan of five to nine years.

Types of pacemakers – External pacemakers and internal pacemakers

1.2.1 EXTERNAL PACEMAKERS

External pacemakers are a temporary means of pacing a patient's heart during a medical emergency. It is accomplished by delivering pulses of electric current through the patient's chest,which stimulates the

heart to contract. The most common indication is an abnormally slow heart rate.

Fig 1.2 External pacemaker

During external pacing, pads are placed on the patient's chest, either in the anterior/lateral position or the anterior/posterior position. The anterior/posterior position is preferred as it minimizes transthoracic electrical impedance by "sandwiching" the heart between the two pads. The pads are then attached to a monitor/defibrillator, a heart rate is selected, and current (measured in milliamps) is increased until electrical capture (characterized by a wide QRS complex with tall, broad T wave on the ECG) is obtained, with a corresponding pulse.

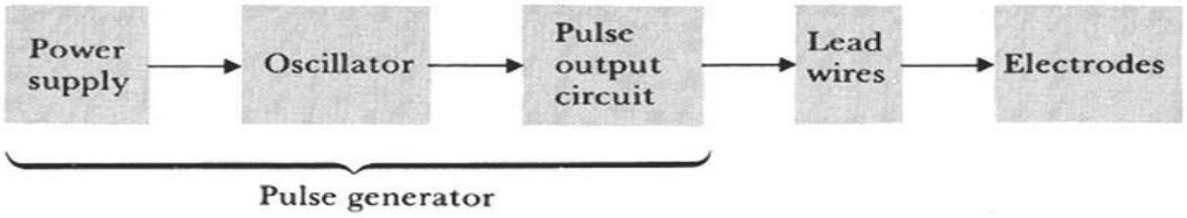

Fig 1.3 Block diagram of external pacemaker

1.3.1 IMPALNTABLE PACEMAKERS

An internal pacemaker is one in which the electrodes into the heart, the electronic circuitry and the power supply are implanted (internally) within the body.

Pacemakers may function continuously and stimulate the heart at a fixed rate or at an increased rate during exercise. A pacemaker can also be programmed to detect too long a pause between heartbeats and then stimulate the heart.

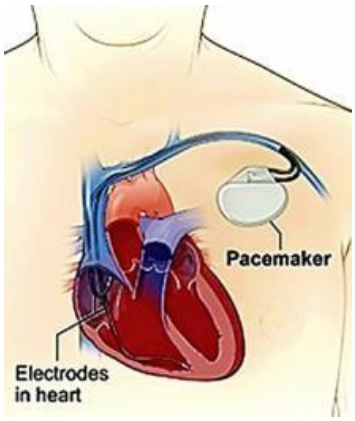

Fig 1.4 pacemaker placement

Types of pacemakers

1. Fixed rate pacemakers
2. Demand pacemakers
3. R wave triggered pacemakers
4. R wave inhibited pacemakers
5. Atrial triggered pacemakers
6. Single chamber pacemakers
7. Dual chamber pacemakers

Pulse generators

The pulse generator is internal in permanent pacemakers (subcutaneously or submuscularly) and external in temporary pacing.

It can be set to a fixed-rate (asynchronous) or demand (synchronous) mode.

In the fixed-rate mode, there is a small risk of producing dangerous dysrhythmias if the impulse coincides with the vulnerable period of the T wave.

On-demand pacemakers detect spontaneous ventricular activity and the output of the pacemaker is either suppressed or discharged in order to make the impulse fall within the safe period of the QRS complex.

Demand pacemaker generator stimulus is inhibited by a signal derived from the heart's electrical activation (depolarization), thus minimizing the risk of pacemaker-induced fibrillation.

Most pacemakers are programmable, and many are rate responsive.

Ventricular synchronous demand pacemakers

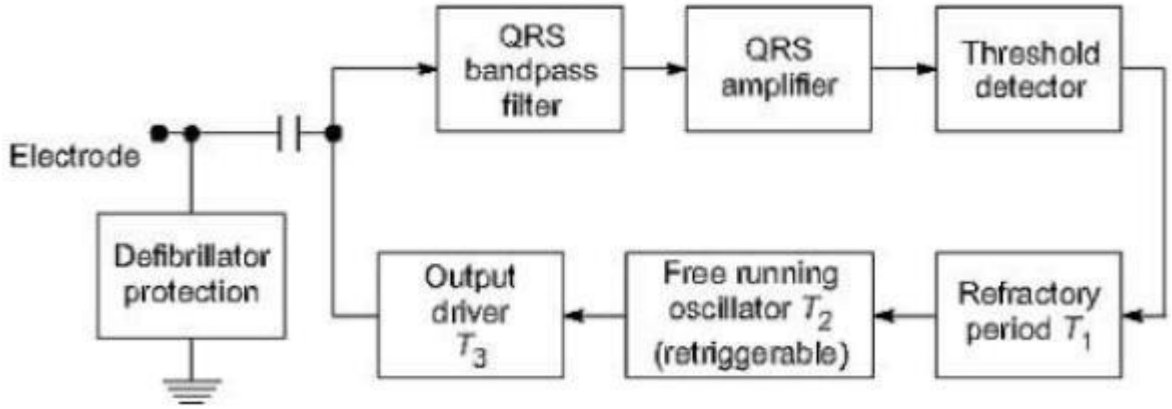

Fig 1.5 Ventricular synchronous demand pacemakersFixed-rate pacemaker

A pacemaker that stimulates the heart at a predetermined rate.

Programmable pacemaker

An electronic permanent pacemaker in which one or more settings can be changed electronically.

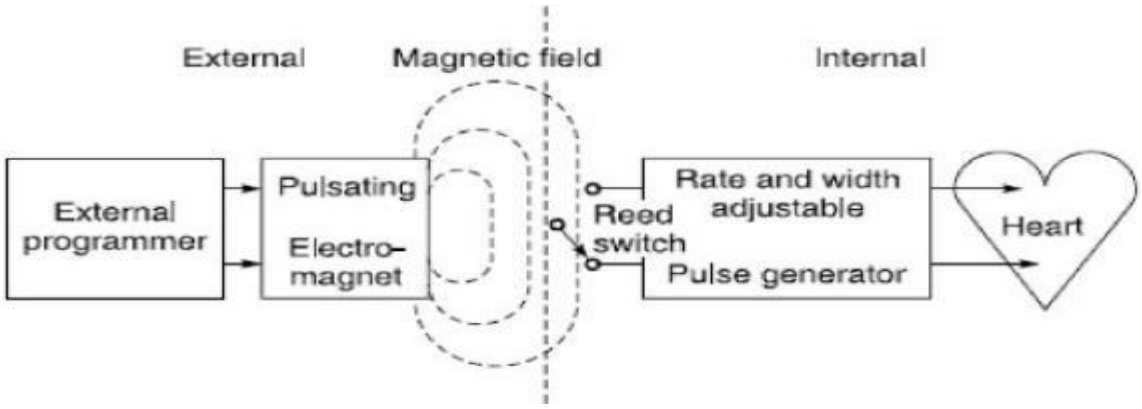

Fig 1.6 programmable pacemakers

Rate-responsive pacemaker

An electronic pacemaker that senses changes in the body's need for adjustment of the cardiac rateas can occur in sleeping, waking, sitting, walking, or running. The device alters cardiac rate by sensing body motion, changes in breathing, or slight changes in blood temperature, which improves the quality of life for active patients. It is also called a rate-adaptive pacemaker.

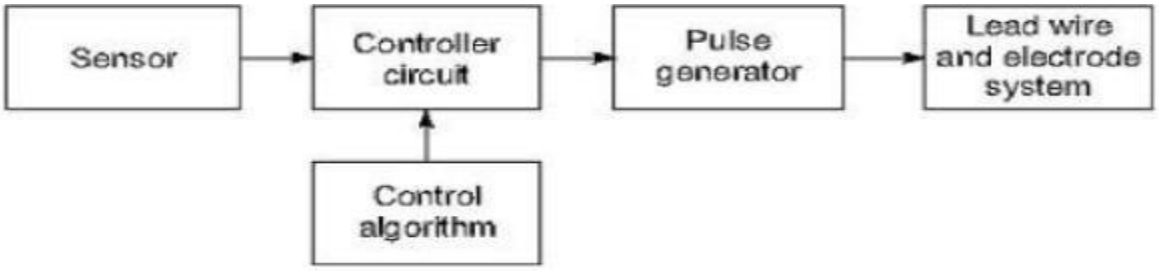

Fig 1.7 Rate-responsive pacemaker

1.4.1 RECENT DEVELOPMENTS IN PACEMAKER

1. A new pacemaker that can be implanted into the heart without the necessity for surgery to test its safety and efficacy in fragile patients who require permanent pacing for normal functioning ofthe heart.

The device, the Nanostim from St. Jude Medical, which only measures 6mm in diameter and 42mm in length, can be implanted into either side of the heart using a catheter inserted via theleg arteries, similar to how stents are currently placed. Moreover, unlike traditional pacemakers, the device does not need an external generator or wires to function. Instead, a small battery with an estimated lifetime of 15 years is built into the device.

2. His bundle pacing is a new treatment option for patients with heart failure. It helps to implant pacemakers that provide greater longevity. The pacemaker lead is put on directly on the His bundle, which is the junction between the upper and lower chambers of the heart. This replicates the physiological functioning of the heart as the heart's natural electrical impulses travel in normal human hearts.

3. Pacemakers could soon be powered by energy from the beating heart, finally ending the need for a battery. A prototype of a battery-free cardiac pacemaker has been developed by a Swiss researcher based on an automatic wristwatch. The technology harvests energy from the motion ofthe heart with the help of 200-year-old principles used to power self-winding watches.

4. About the size of calcium pills, this new one was the Medtronic Micra, the world’s smallest pacemaker. In clinical trials at the time of Mary Lou’s procedure, Micra was approved for use in the United States on April 6, 2016. Revolutionary not only for its size, Micra is implanted insidethe

heart. Small tines then attach it to the heart wall.

1.5.1 PACEMAKER ANALYSER

The microprocessor-based analyzer enables measurement and display of pacing pulse rate, heightand width as well as A-V interval, refractory period, R, S and T wave sensitivity, long term stability, and susceptibility to 50/60 Hz interference**.**

The External Pacemaker Analyzer is an advanced microprocessor-based, compact, high performance external pacemaker tester designed for accurate testing of all types of external pacemakers, including invasive and transthoracic. The device is menu-driven and simple to operate. All functions are set from a 2-line, 16-character LCD display and a keypad with 8 tactilekeys. It provides superior accuracy and performance.

- Pacing system analysers are useful in the operating room or catheterization laboratory during pacemaker surgical procedures.
- Analyser can help to determine optimum voltage and pulse width thresholds
- Likewise, the R-wave amplitude of the heart sensed by the implanted electrode is displayed thus helping to determine the sensitivity threshold.
- The analysing system has two independent functions:
- A synchronous pulse generator with variable rate, pulse duration and output voltage—These parameters help the physician to determine the stimulation threshold.
- A digital measuring system helps to test the operation of the pulse generator as well as the lead. The system provides a digital read-out of the pulse amplitude, pulse rate and pulse width available at the output of the pulse generator.

- This series of test capabilities is useful when verifying the proper operation of a pulse generator to be implanted and when troubleshooting for a suspected malfunction in an implanted system.

1.2 CARDIAC DEFIBRILLATOR

1.2.1 NEED FOR DEFIBRILLATOR

Cardiac arrest is when someone’s heart stops pumping blood around the body and they stop breathing normally.

The most common cause of a cardiac arrest is a abnormal heart rhythm called ventricular fibrillation (VF). Ventricular fibrillation happens when the electrical activity of the heart becomes so chaotic that the heart stops pumping and quivers or 'fibrillates' instead.

Defibrillator is the machine used to deliver the shock. The electrodes are placed at the sternum and apex.

During defibrillation and cardioversion, electrical current travels from the negative to the positive electrode by traversing myocardium. It causes all of the heart cells to contract simultaneously. This interrupts and terminates abnormal electrical rhythm. This, in turn, allows the sinus node to resume normal pacemaker activity.

1.2.2 DC DEFIBRILLATOR

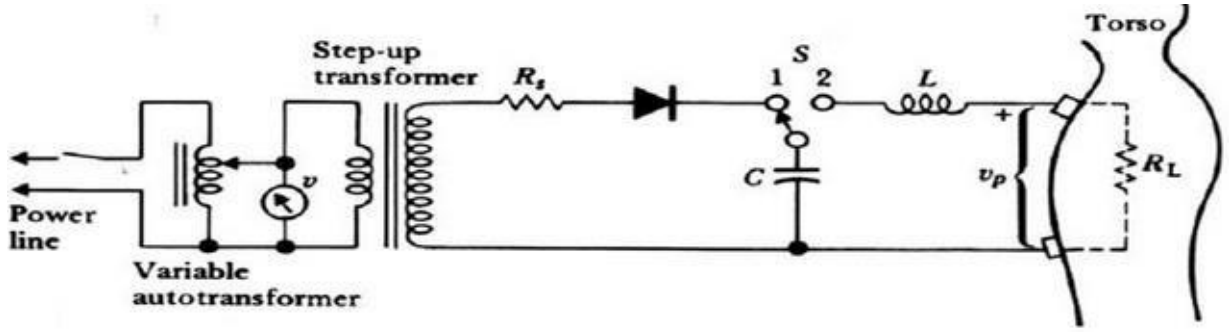

Fig 1.8 Circuit of dc defibrillator

A Variable auto transformer forms the primary of a high voltage transformer. The output voltage transformer is rectified by a diode rectifier and is connected to vacuum type high voltage change over switch. In position 1, the switch is connected to one end of an oil filled micro farad capacitor. In this position, the capacitor charge to a voltage set by the positioning of the auto transformer. When the shock is delivered to the patient, a foot switch or a push button mounted on the handle of the electrode is operated. The high voltage switch change over to position 2 and the capacitor is discharged across the heart through the electrode.

The inductor in the circuit slows down the discharge from capacitor by induced counter voltage. This gives the output pulse a physiologically favorable shape. The disadvantage of using inductor is that any practical inductor will have its own resistance and dissipates part of the energy during the discharge process. The shape of waveform that appears across electrodes will depend upon the value of the capacitor and inductor used in the circuit.

Using this design, external defibrillation uses:

–50 to 100 Joules of energy when electrodes are applied directly to the heart

–Up to 400 Joules when applied externally.

Capacitor is discharged through the subject by turning on a series silicon-controlled rectifier. When sufficient energy has been delivered to the subject, a shunt silicon-controlled rectifier short-circuits the capacitor and terminates the pulse, eliminating a long discharge tail of the waveform.

Output control can be obtained by varying, voltage on the capacitor and Duration of discharge.

1.2.3 IMPLANTABLE DEFIBRILLATORS

An AID is a battery-powered device placed under the skin that keeps track of the heart rate. Thinwires connect the AID to your heart. If an abnormal heart rhythm is detected the device will deliver an electric shock to restore a normal heartbeat if your heart is beating chaotically and much too fast.

AIDs have been very useful in preventing sudden death in patients with known, sustained ventricular tachycardia or fibrillation.

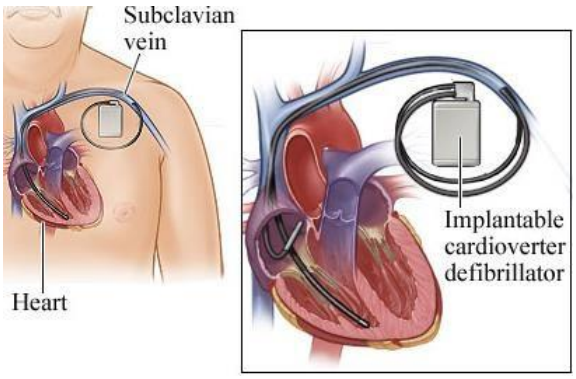

Fig 1.9 Defibrillator placement

The AID has two parts: the lead(s) and a pulse generator. The lead(s) are made up of wires and sensors that monitor the heart rhythm and deliver energy used for pacing and/or defibrillation(see below for definitions). The generator houses the battery and a tiny computer. Energy is stored in the battery until it is needed. The computer receives information from the leads to determine how the heart is beating.

A battery-powered pulse generator is implanted in a pouch under the skin of the chest or abdomen, often just below the collarbone. The generator is about the size of a pocket watch. Wires or leads run from the pulse generator to positions on the surface of or inside the heart and can be installed through blood vessels.

It knows when the heartbeat is not normal and tries to return the heartbeat to normal. If the AID has a pacemaker feature when the heartbeat is too slow, it works as a pacemaker and sends tiny electric signals to your heart. When the heartbeat is too fast or chaotic, it gives defibrillation shocks to stop the abnormal rhythm.

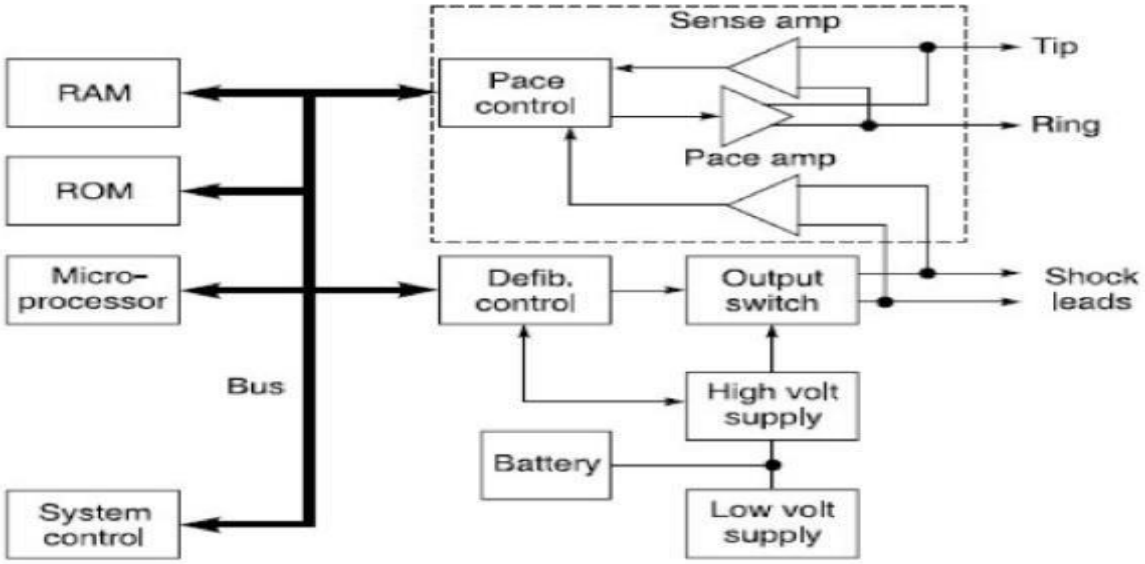

Fig 1.10 Pulse generator

1.2.4 PACER CARDIO VERTER DEFIBRILLATOR

- Tachyarrhythmias generally develop into ventricular fibrillation.
- Extreme brady arrhythmias require pacing.
- Hence, it is logical to have a multi-function defibrillator, capable of external pacing as a standard feature.
- An implantable defibrillator with high-output pacing function after defibrillation.
- Composed of five battery-powered units: sensing circuit, high voltage converter, switching circuit, defibrillation control circuit, and pacing control circuit.
- Heartbeat signal, which is detected by a catheter type heartbeat sensor, is amplified for heartbeat monitoring.
- Absence of a heartbeat for 3.5 s causes the fibrillation detecting circuit to deliver the turn-on signal which then switches on the high voltage converter.
- These are used for patients having extreme brady arrhythmias. A multifunction defibrillator withexternal pacing.
- This has high output pacing function after defibrillator.
- It has 5 battery powered units-sensing circuit, high voltage convertor, switching circuit, defib control circuit and pacing control circuit.
- At a predetermined voltage level (800 V), the thyristor switch allows the capacitor to discharge its current through the right ventricular electrode.
- After defibrillation, high-output demand pacing is activated by using the residual energy in the output-capacitor.

- The pacing rate and pulse width are controlled by the pacing control circuit, and the heartbeat signal is used for demand function.

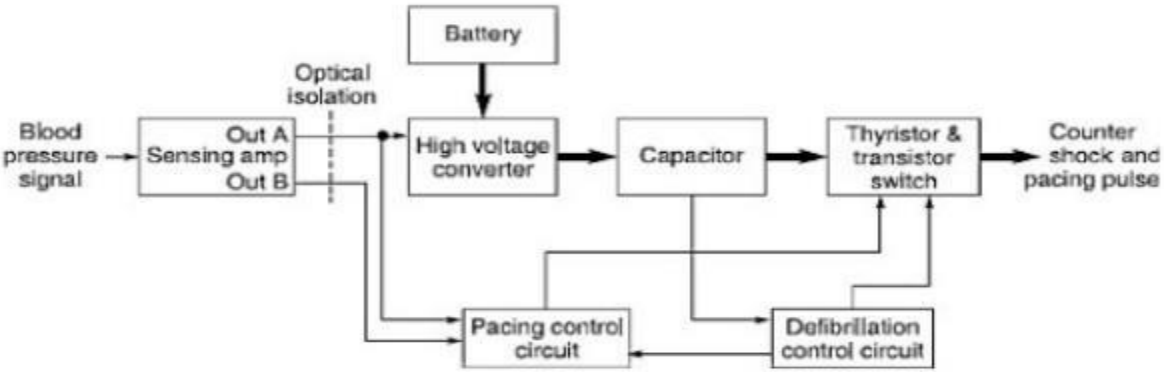

Fig 1.11 Pacer cardioverter defibrillator

- Absence of heart beat for a specific time causes the circuit to deliver signals to the HV convertorand the capacitor discharges its current through the electrode.
- After defibrillation, high output demand pacing activated.Uses LSVO cells and has a life of 4-years.

1.2.5 DEFIBRILLATOR ANALYSIS

- Automatic and semi-automatic defibrillators recognize patient waveforms and provide a discharge energy pulse.
- It measures the energy content in the discharge pulse.
- The pulse is applied across a load and voltage developed is given to a squaring circuit.
- The analyzers measure precisely the pulse energy and verifies and calibrates the output energyof all defibrillators.

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UNIT – II – Therapeutic Instrumentation – SBMA1601

UNIT-2

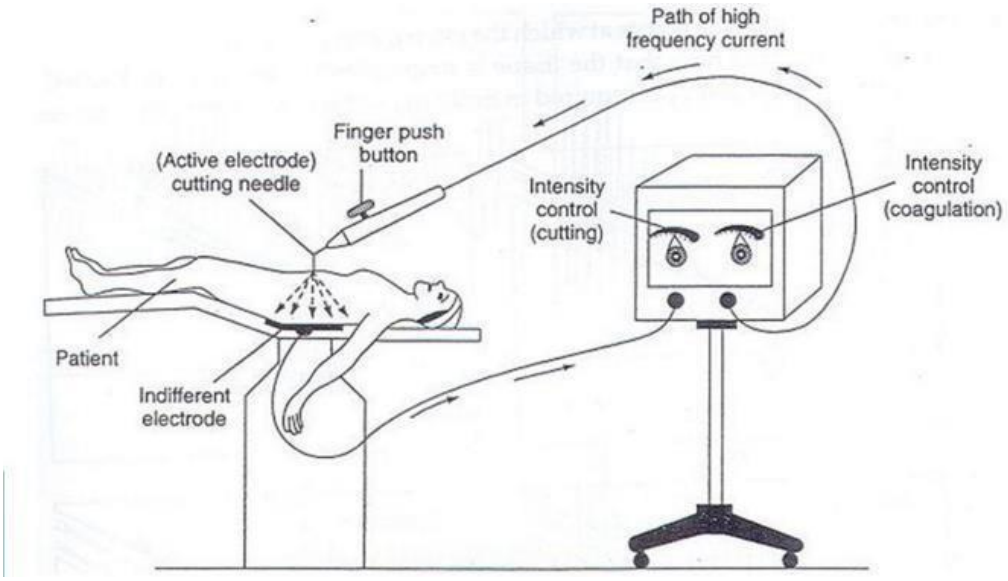
INSTRUMENTS FOR SURGERY AND TREATMENT

2.1 PRINCIPLE OF SURGICAL DIATHERMY

Surgical diathermy is the machine of high frequency currents, used in operating rooms for surgical purposes involving cutting and coagulation.

When high frequency current flows through the sharp edge of the point of a needle into the tissuethere is a high concentration at this point. The cells which are immediately under the electrodeare torn apart by the by the boiling of cell fluid. This type of tissue separation forms the basis of electro-surgical cutting.

Electrosurgical generators typically operate at frequencies between 400,000 Hz and 2.5 MHz, although some generators produce currents with frequencies as high as 3.5 MHz.

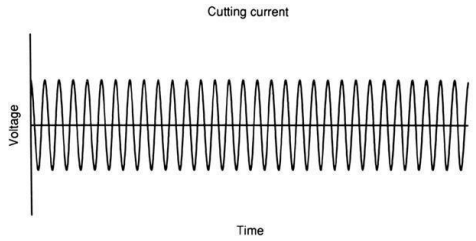


2.1.1 Types of currents

Cutting current

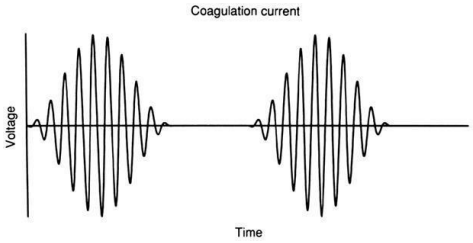
Cutting current uses a pure, non-modulated sinusoidal waveform. This waveform achieves a higher average power when compared with any other alternating waveform of equal peak voltage, allowing the voltage to be limited when compared with coagulation current. The high average power creates a

higher current density than is allowed by other waveforms, facilitating a smooth cutting action without extensive thermal damage.



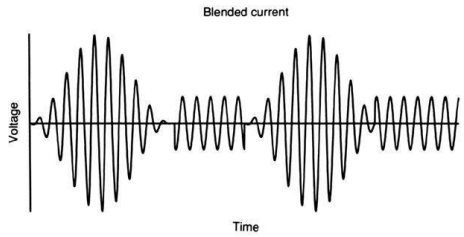
Coagulation current

Coagulation current is characterized by extensive wave modulation, which produces intermittent bursts of damped sine waves of high peak voltages. These peak voltages result in high tissue temperatures, and hence significant thermal destruction, making this type of current particularly suited for the coagulation of bleeding vessels.



Blended currents

Blended currents allow the surgeon to cleanly divide tissue while maintaining a variable degree of hemostasis, depending on the amount of coagulating current used. Blended currents are created by modulating a second, lower frequency, higher amplitude sine wave with the sine wave from the cutting generator, producing a higher peak-to-peak voltage. The new waveform is then delivered in intermittent bursts at a rate determined by the settings of the electrosurgical generator (*i.e.*, Blend 1) .



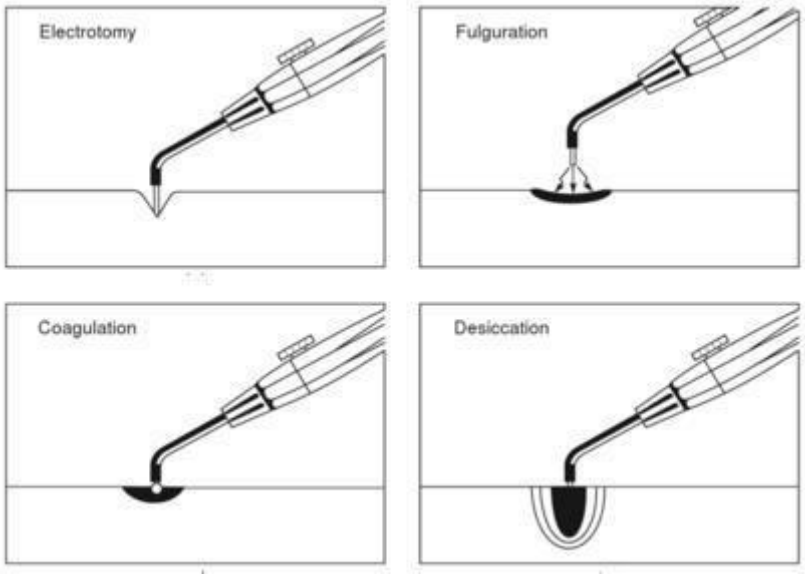
2.1.2 Methods used in ESU's

Fulguration

Fulguration results from the action of electrical arcs striking the tissue at widely divergent locations, producing a high localized instantaneous current density, but a low average current density.

Desiccation

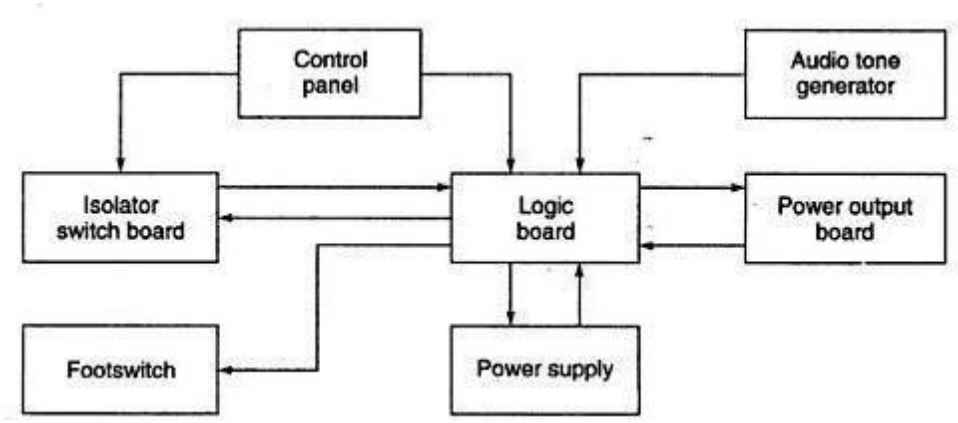
Desiccation is produced by low current and relatively higher voltage applied over a broad area, producing a low current density.



Coagulation

Coagulation occurs at higher current densities than are used in desiccation, resulting in higher tissue temperatures. The tissue fluids boil away and the proteins become denatured, forming a white coagulum similar to that produced when an egg white is boiled. There is loss of cellular definition as all tissue structures fuse into a formless, homogenous mass with a hyalinized appearance.

2.2 SURGICAL DIATHERMY MACHINE



- Logic board: The heart of the system id logic and control part which produces the basis signal and provides various timing signal for the cutting, coagulation and haemostasis modes of operation.
- Power output: The 250 kHz signal used for cutting is given to power output stage.
- Audio tone generator: in order to facilitate identification of each mode of operation, the machine incorporates an audio tone generator. The tone signals are derived from the counter at 1 kHz (coagulation), 500 Hz (cutting) and 250 Hz (haemostasis).
- Isolator switch: The isolator: The isolator switch provides isolated switching control b/w the active hand switch and the rest of the unit.
- Footswitch: Besides basic function circuit, logic circuits are used to receive external control signals and to operate the isolating relays, give visual indications and determine the alarm conditions.
- The logic circuits receive information from the foot-switch, finger switch and alarm sensing points.
- Solid state generators produce the coagulation waveform by using transistors and solid state components to produce high voltage bursts of current. Spark gap generators produce damped, high voltage bursts of current by discharge of air-spaced plates. Spark gap systems are incapable of producing undamped, cutting current. Cutting and coagulating currents are produced from twoindependent generators contained within the ESU.

2.3 SAFETY ASPECTS IN ELECTRO SURGICAL DIATHERMY UNITS

Complications of electrosurgery can be categorized as: the potential for the explosion of combustible gases, either anesthetics or bowel gas, interference with pacemakers and monitors, neuromuscular stimulation including ventricular fibrillation, accidental burns, and the potential for the transmission of infection.

Burns

Burns to the patient's skin can occur in a variety of ways. The most common mechanism is the alternate site burn, which results from a high current density either at a poorly applied ground electrode, at the site of monitoring devices such as ECG electrodes or temperature probes, or at the sight of accidental contact with a grounded metal object. All electrosurgical burns are visible at the time of occurrence.
Most modern electrosurgical generators are isolated from earth ground, and have fault monitors that will disable the machine and sound an alarm if the ground electrode circuit is not intact.

Explosion

Explosive anesthetic gases posed the greatest explosion risk in the operating room. If they are used, the surgeon should be so informed, and use of the ESU avoided. Of greater concern is bowel gas, which frequently contains a mixture of methane and hydrogen which, when mixed with oxygen, even in low concentrations, are highly explosive. This is a real hazard when operating around the large bowel, or when performing anorectal surgery.

Nitrous oxide supports combustion, as well as pure oxygen. Many gynecologists use nitrous oxide as a laparoscopic distention medium to avoid the peritoneal irritation caused by carbon dioxide. If electrosurgery is to be used during a laparoscopic operation, the use of nitrous oxide to distend the abdomen should be avoided.

Pacemaker interference

Most modern cardiac pacemakers are resistant to interference by extraneous electromagnetic signals, several incidences of asystole and cardiac arrest have been reported when electrosurgery is used in patients with pacemakers. In these units, the electrosurgical signal may block the pacer's inhibition amplifier allowing an R-on-T phenomenon to occur, leading to ventricular fibrillation.

2.4 PHYSIOTHERAPY AND ELECTROTHERAPY EQUIPMENT

2.5 HIGH FREQUENCY HEAT THERAPY

The Diathermy energy field passes through softer surface tissues and turns to heat when reachingmore dense tissues. The heat increases circulation and helps to speed the healing process.

Heat speeds up healing by increasing blood flow to the injury. Diathermy is a deep tissue heat treatment. The temperature of the injured tissues is raised by high frequency current, ultrasonic waves, or microwave radiation. Like surface heating, deep heat is used to:

* reduce pain,

* relieve muscle spasm,

* decrease soft-tissue contractures,

* resolve inflammation, and

* promote healing.

2.6 SHORT WAVE DIATHERMY

- The term ‘diathermy’ means ‘through heating’ or producing deep heating directly in the tissues of the body.

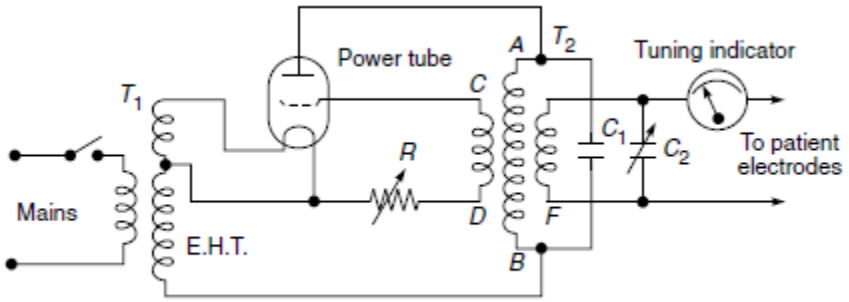
- Externally applied sources of heat like hot towels, infrared lamps and electric heating pads often produce discomfort and skin burns long before adequate heat has penetrated to the deeper tissues.
- But with the diathermy technique, the subject's body becomes a part of the electrical circuit and the heat is produced within the body and not transferred through the skin (Yang and Wang, 1979).
- Another advantage of diathermy is that the treatment can be controlled precisely. The amount of heat can be closely adjusted by means of circuit parameters.
- Careful placement of the electrodes permits localization of the heat to the region that has to be treated.
- The heating of the tissues is carried out by high frequency alternating current which generally has a frequency of 27.12 MHz and a wavelength of 11 m.
- Currents of such high frequencies do not stimulate motor or sensory nerves, nor do they produce any muscle contraction.
- The method consists in applying the output of a radio frequency (RF) oscillator to a pair of electrodes which are positioned on the body over the region to be treated.
- The RF energy heats the tissues and promotes healing of injured tissues and inflammations.

Circuit Description:

- The short wave diathermy machine consists of two main circuits:
    - An oscillating circuit, which produces a high frequency current and
    - A patient circuit, which is connected to the oscillating circuit and through which the electrical energy is transferred to the patient.
- The diathermy machines employed single-ended or push-pull power oscillators operating from unfiltered or partially filtered power supplies.
- They usually made use of a valve circuit, a typical example of which is shown in Fig. 29.2. Transformer Tl, the primary of which can be energized from the mains supply, is a step-up transformer for providing EHT (extra high tension) for the anode of the triode valve.
- A second winding can provide heating current for the cathode of the triode valve.
- The tank (resonance) circuit is formed by the coil AB in parallel with the condenser Cl. The positive feedback is generated by coil CD.
- There is another coil EF and a variable condenser C2 which form the patient's resonator circuit due to its coupling with the oscillator coil AB.
- The anode supply of such a circuit is around 4000 V. The conduction in the triode takes place during the positive half-cycle and the high frequency is generated only during this period.
- The supply voltage is rectified before supplying to the anode of the oscillator valve.
- In order to ensure that the oscillator circuit and the patient's resonator circuit are tuned with each other, an ammeter is placed in series with the circuit.

- The variable condenser C2 is adjusted to achieve a maximum reading on the meter, the needle swinging back on either side of the tuned position. The maximum power delivered by these machines is 500 W.
- A thermal delay is normally incorporated in the anode supply which prevents the passage of current through this circuit until the filament of the valve attains adequate temperature.
- The patient circuit is then switched on followed by a steady increase of current through the patient.
- A mains filter is incorporated in the primary circuit to suppress interference produced by the diathermy unit itself.
- There are several ways of regulating the intensity of current supplied to the patient from a short-wave diathermy machine. This can be done by either
    - controlling the anode voltage, or
    - controlling the filament heating current, or
    - adjusting the grid bias by change of grid leak resistance*R*1, or
    - adjusting the position of the resonator coil with respect to the oscillator coil.

  However, the best way of finely regulating the current is by adjusting the grid bias, by putting a variable resistance as the grid leak resistance.



➤ **Fig. 29.2** ***Simplified circuit diagram of a short-wave diathermy unit***

Application Technique of Short-wave Therapy:

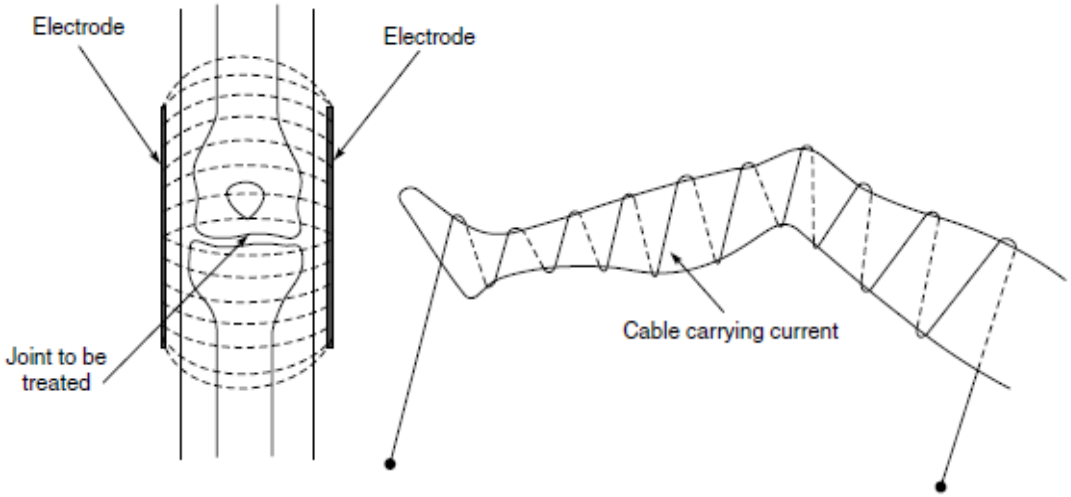
The two most common forms of application include

- the capacitor plate method and
- the inductive method (Fig. 29.4).

- In the capacitor plate method, the output of the short-wave diathermy machine is connected to metal electrodes which are positioned on the body over the region to be treated.
- These electrodes are called ‘PADS’ in the terminology of the diathermy. These pads or electrodes do not directly come into contact with the skin.
- Usually layers of towels are interposed between the metal and the surface of the body. The pads are placed so that the portion of the body to be treated is sandwiched between them. This

arrangement is called the 'Condenser Method' (Fig. 29.4(a)) wherein the metal pads act as two plates while the body tissues between the pads as 'dielectric' of the capacitor.

- When the radio frequency output is applied to the pads, the dielectric losses of the capacitor manifest themselves as heat in the intervening tissues.
- Figure 29.4a shows the use of air-spaced condenser electrodes for short-wave diathermy treatment.
- The inductive method, the output of the diathermy machine may be connected to a flexible cable instead of pads. This cable is coiled around the arm (Fig. 29.4(b)) or knee or any other portion of the patient's body where plate electrodes are inconvenient to use.
- When RF current is passed through such a cable, an electrostatic field is set up between its ends and a magnetic field around its centre.
- Deep heating in the tissue results from electrostatic action whereas the heating of the superficial tissues is obtained by eddy currents set up by a magnetic effect. This technique is known as 'inductothermy'.
- Although most short-wave diathermy machines have an output power control, yet there is no
- indication of the amount of converted and absorbed heat within the body tissues. Therefore, the intensity of treatment is dependent on the subjective sensation of warmth felt by the patient.



➤ **Fig. 29.4** *Method of applying electrodes in short-wave diathermy treatment*
(a) *condenser method*
(b) *inductive method*

2.7 MICROWAVE DIATHERMY

- Microwave diathermy consists in irradiating the tissues of the patient's body with very short wireless waves having frequency in the microwave region.

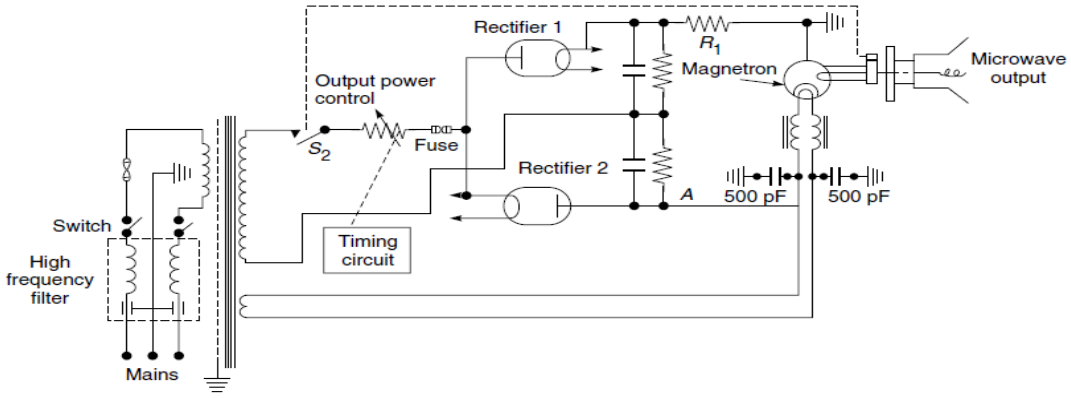
- Microwaves are a form of electromagnetic radiation with a frequency range of 300-30,000 MHz and wavelengths varying from 10 mm to 1 m.
- In the electromagnetic spectrum, microwaves lie between short waves and infrared waves. The most commonly used microwave frequency for therapeutic heating is 2450 MHz corresponding to a wavelength of 12.25 cm.
- The heating effect is produced by the absorption of the microwaves in the region of the body under treatment.
- Microwave diathermy provides one of the most valuable sources of therapeutic heat available to the physician.
- The technique of application of microwave diathermy is very simple. Unlike the short-wave diathermy where pads are used to bring in the patient as a part of the circuit, the microwaves are transmitted from an emitter, and are directed towards the portion of the body to be treated.
- Thus, no tuning is necessary for individual treatments. These waves pass through the intervening air space and are absorbed by the surface of the body producing the heating effect.

Production of Microwaves:

- Microwaves are produced by high-frequency currents and have the same frequency as the currents which produce them.
- A special type of device called ‘magnetron’ is used for the production of high frequency currents of high power.
- The magnetron consists of a cylindrical cathode surrounded by an anode structure that contains cavities opening into the cathode-anode space by means of slots.
- The efficiency of a magnetron is usually 40 to 60%. The heat produced at the anode must be removed which is usually done by using water or air as a means of cooling.

***Schematic Diagram of a Microwave Diathermy Unit*:** The essential parts of a microwave diathermy unit are shown in Fig. 29.5.

- The mains supply voltage is applied to an interference suppression filter. This filter helps to bypass the high frequency pick-up generated by the magnetron.
- A fan motor is directly connected to the mains supply. The fan is used to cool the magnetron.



➤ **Fig. 29.5** *Simplified circuit diagram of a microwave diathermy machine*

The Delay Circuit:

It is necessary for the magnetron to warm up for 3 to 4 minutes before power may be derived from it. A delay circuit is incorporated in the apparatus which connects the anode supply to the magnetron only after this time elapses. The arrangement is such that a lamp lights up after 4 minutes indicating that the apparatus is ready for use.

The Magnetron Circuit:

- The magnetron filament heating voltage is obtained directly from a separate secondary winding of the transformer.
- The filament cathode circuit contains interference suppression filters. The anode supply to the magnetron can be either DC or AC.
- A DC voltage is obtained by a full wave rectifier followed by a voltage doubler circuit.
- A high wattage variable resistance is connected in series which controls the current applied to the anode of the magnetron.
- When using AC, the voltage is applied to the anode of the magnetron through a series connected thyratron so that the AC voltages of both tubes are equal in phase.
- By shifting the phase of the control grid voltage with respect to the phase of the anode voltage, the amount of current through the magnetron can be determined and thus the output power can be varied.
- The phase shift can be achieved by using a capacitor resistor network.

Safety Circuits:

- There are chances of the magnetron being damaged due to an excessive flow of current. It is thus protected by inserting a fuse (500 mA) in the anode supply circuit of the magnetron.
- The protection of both the patient and the radiator is ensured by the automatic selection of the control range depending on the type of the radiator used.

- The considerable interference produced by the apparatus necessitates the use of large self inductance coils in the primary supply in such a way that no magnetization occurs.
- Excessive dosage can cause skin burns. The skin should be dry as these waves are rapidly absorbed by water. The duration of irradiation generally ranges from 10 to 25 minutes.

2.8 ULTRASONIC WAVE DIATHERMY

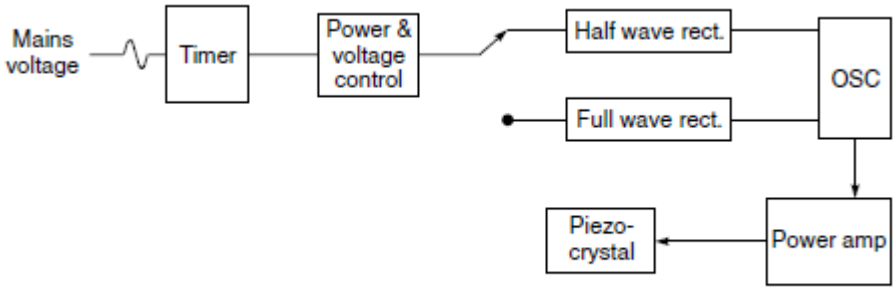
- Ultrasonics is used for therapeutic purposes in the same manner as a short-wave diathermy machine is used. The heating effect in this case is produced because of the ultrasonic energy absorption property of the tissues.
- The property of specific heat distribution in tissue and the additional effect of a mechanical component have given rise to a number of special therapeutic applications of ultrasonics.
- The effect of ultrasonics on the tissues is thus a high speed vibration of micro-massage. Massage as a modality in physical medicine has been used in the treatment of soft tissue lesions for centuries.
- Ultrasonic energy enables this massage to be carried out, firstly to a greater depth than is possible manually and secondly at times (in acute injuries) when pressure cannot be exerted by hand because of intolerable pain caused to the patient.
- The thermal effects of ultrasound are dependent on the amount of energy absorbed, the length of time of the ultrasound application and the frequency of the ultrasound generator.
- The electrical power required in most of the applications is usually less than 3 W/cm2 of the transducer area that is in contact with the part of the body to be treated.

- ***Ultrasonic generators*** are constructed on the piezo-electric effect. A high-frequency alternating current (e.g., 0.75-3.0 MHz) is applied to a crystal whose acoustic vibration causes the mechanical vibration of a transducer head, which itself is located directly in front of the crystal.
- These mechanical vibrations then pass through a metal cap and into the body tissue through a coupling medium. The therapeutic ultrasonic intensity varies from 0.5 to 3.0 W/cm2. Applicators range from 70 to 130 mm in diameter.
- The larger the diameter of the applicator, the smaller would be the angle of divergence of the beam and the less the degree of penetration.

***Circuit Description*:**

- The heart of the system is a timed oscillator which produces the electrical oscillations of the required frequency. The oscillator output is given to a power amplifier which drives the piezo-electric crystal to generate ultrasound waves.

- Power amplification is achieved by replacing the transistor in typical LC tuned Colpitt oscillator by four power transistors placed in a bridge configuration.
- The delivery of ultrasound power to the patient is to be done for a given time. This is controlled by incorporating a timer to switch on the circuit.
- The timer can be a mechanical spring-loaded type or an electronic one, allowing time settings from 0 to 30 minutes.



➤ **Fig. 29.6** *Block diagram of an ultrasonic therapy unit*

- The output of the oscillator can be controlled by either of the following two methods:
    - Using a transformer with a primary winding having multi-tapped windings and switching the same as per requirement;
    - Controlling the firing angle of a triac placed in the primary circuit of the transformer, and thereby varying the output of the transformer.
- The machine can be operated in either continuous or pulsed mode. A full-wave rectifier comes in the circuit for continuous operation.
- The mains supply is given to the oscillator without any filtering. The supply voltage is therefore at 100 Hz which causes the output 1 MHz to be amplitude modulated by this 100 Hz.
- In pulsed mode, the oscillator supply is provided by the half-wave rectifier and the oscillator gets the supply only for a half cycle. Thus the output 1 MHz is produced only for one half of the cycle and is pulsed.
- The transducer may be barium titanate or lead zirconate titanate crystal, having 5-6 cm2 effective radiating area. In front of the crystal lies a metal face plate which is made to vibrate by the oscillations of the crystal.
- Ultrasonic waves are emitted from this plate. The crystal has a metal electrode pressed against its back surface by a coiled spring.
- Voltage is applied to the crystal via this electrode. The front diaphragm is grounded and provides a return path for the excitation voltage.

Dosage Control: The dosage can be controlled by varying any of the following variables.

• Frequency of ultrasound;

• Intensity of ultrasound; or

• Duration of the exposure.

Application Technique:

- There are several ways for applying ultrasonics to the body. The probe can be put in direct contact with the body through a couplant provided the part to be treated is sufficiently smooth and uninjured.
- In case a long area is to be treated, the probe is moved up and down, and for small areas it is given a circular motion to obtain a uniform distribution of ultrasonic energy.
- If there is a wound or an uneven part (joints etc.), the treatment may be carried out in a water bath. This is to avoid mechanical contact with the tissues which may damage an already injured surface.
- It should be ensured that air bubbles are not present either on the probe or the skin.

2.9 PAIN RELIEF THROUGH ELECTRICAL STIMULATION

- Electrical impulses to block the pathways of the transmission of pain.
- Impulses are produced in a battery powered pulse-generator to which a pair of electrode-tipped wires can be attached.
- Applied to the skin overlying any painful area of the body, these electrodes provide continuous, mild electrical stimulation.
- Signals seem to jam the pain signals travelling along the nerve pathways before they can reach the brain.
- Gate Control Theory - By electrically stimulating sensory nerve receptors, a gate mechanism is closed in a segment of the spinal cord, preventing pain carrying messages from reaching the brain and blocking the perception of pain
- Endorsphin Release Theory - Electrical impulses stimulate the production of endorphin and enkaphalins in the body.
- Natural, morphine-like substances block pain messages from reaching the brain, in a similar fashion to conventional drug therapy, but without the danger of dependence or other side-effects.

2.9.1 TENS

TENS stands for (Transcutaneous Electrical Nerve Stimulation). which are used for nerve related pain conditions (acute and chronic conditions). TENS machines work by sending stimulating pulses across the surface of the skin and along the nerve strands.

The stimulating pulses help prevent pain signals from reaching the brain. Tens devices also help stimulate your body to produce higher levels of its own natural painkillers, called "Endorphins".

TENS is most commonly delivered from small, hand held, battery powered devices. The electrodes are often placed on the area of pain or at a pressure point, creating a circuit of electrical impulses that travels along nerve fibers.

The current intensity (A) (strength) will typically be in the range of 0 - 80 mA, though some machines may provide outputs up to 100mA.

The machine will deliver discrete 'pulses' of electrical energy, and the rate of delivery of these pulses (the pulse rate or frequency (B) will normally be variable from about 1 or 2 pulses per second (pps) up to 200 or 250 pps . To be clinically effective, it is suggested that the TENS machine should cover a range from about 2 – 150 pps (or Hz).

In addition to the stimulation rate, the duration (or width) of each pulse (C) may be varied from about 40 to 250 micro seconds (ms). Usually uses stimulation at a relatively high frequency (80 - 130Hz) and employ a relatively narrow (short duration) pulses.

The type of stimulation delivered by the TENS unit aims to excite (stimulate) the sensory nerves, and by so doing, activate specific natural pain relief mechanisms.

2.10 BLADDER STIMULATOR

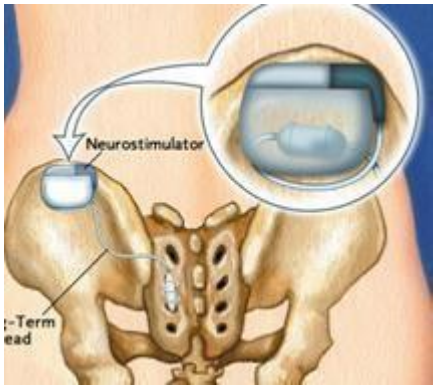
Bladder control problems can be retention and overactive bladder. It prevents a person from controlling when and how much he can urinate and can make simple everyday activities a challenge and social lives very difficult.

Sacral nerve stimulation (SNS) involves the use of a device that can be thought of as a pacemaker for the bladder.

When the bladder begins to fill with urine, a message is sent along the sacral nerves to the brain telling the brain that the bladder is getting full. As the bladder fills, this message to the brain becomes stronger. When the message becomes strong enough, and a person decide to urinate, thebrain sends a

message back to the bladder along the sacral nerves telling the bladder muscle to contract and the pelvic muscles to relax to allow urine to empty from the bladder (urination).

The therapy uses a small implanted medical device to send mild electrical pulses to a nerve located just above the tail bone. These nerves are called sacral nerves. The sacral nerves [specifically S2, S3 and S4] activate or inhibited muscles and organs that contribute to urinary control-the bladder, sphincter and pelvic floor muscles. The electrical stimulation may eliminate or reduce certain bladder control functions in some people. This stimulation may facilitate the communication between the brain and bladder, and may relieve the symptoms of urinary retention or symptoms of overactive bladder, including urinary urge incontinence and significant symptoms of urgency-frequency in some patients.



A neurotransmitter device, implanted under the skin in the upper buttock area, transmits mild electrical impulses through a lead wire close to the sacral nerve. The impulses, in turn, influence the bladder sphincter and pelvic floor muscles providing bladder control.

2.11 CEREBELLAR STIMULATORS

An implanted cerebellar stimulator is a device used to stimulate electrically a patient's cerebellar cortex for the treatment of intractable epilepsy, spasticity, and some movement disorders.

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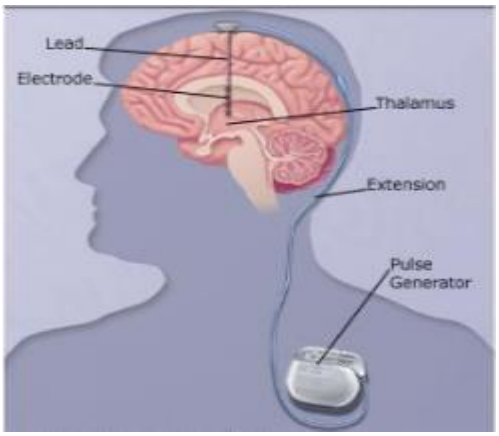

Electrical stimulation of the cerebellum using arrays of electrodes surgically implanted on the anterior surface of the cerebellum has been proposed as one way to treat certain neurological disorders. Leads connected to the electrodes emerge through small openings in the skull and are placed subcutaneously down the neck to a stimulator implanted in a subcutaneous pocket below the clavicle on the anterior chest.

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UNIT-3

EXTRACORPOREAL UNITS

3.1 HAEMODIALYSIS MACHINES

3.1.1 FUNCTION OF KIDNEYS

The kidneys have three basic mechanisms for separating the various components of the blood: filtration, reabsorption, and secretion. These three processes occur in the nephron which is the most basic functional unit of the kidney. Each kidney contains approximately one million of these functional units.

Blood first enters the kidney through the renal artery, which branches into a network of tinyblood vessels called arterioles. These arterioles then carry the blood into the tiny blood vessels of the glomerulus. Filtration occurs in the renal corpuscle.

The tubule functions as a dialysis unit, in which the fluid inside the tubule is the internal solutionand the blood (in capillaries surrounding the tubule) acts as the external solution. Particles may pass through the membrane and return to the blood stream in the process known as reabsorption.

3.1.2 ARTIFICIAL KIDNEY

When the kidneys do not function properly, dialysis must be performed artificially. Without this artificial kidney dialysis, toxic wastes build up in the blood and tissues, and cannot be filtered outby the ailing kidneys. This condition is known as uremia, which means urine in the blood. Eventually this waste build-up leads to death.

The artificial kidney uses cellulose membranes in place of the phospholipid-bilayer membranes used by real kidneys to separate the components of blood. Cellulose is a polymer of glucose molecules that form long, straight chains. Parallel chains form linkages with one another by hydrogen bonding to make strong fibers. These fibers in turn interact to form the strong, sheet- like structure of the membrane.

Hemodialysis uses a cellulose-membrane tube that is immersed in a large volume of dialysate. The blood is pumped through this tubing, and then back into the patient's vein. The membrane has a molecular-weight cut-off that will allow most solutes in the blood to pass out of the tubing but retain the proteins and cells. The dialysate in which the tubing is immersed is a salt solution with ionic concentrations near or slightly lower than the desired concentrations in the blood.

Through diffusion excess substances in the blood are removed from the body. To maintain the blood's concentration of a species, the dialysate is made to have the same concentration of that species as the blood.

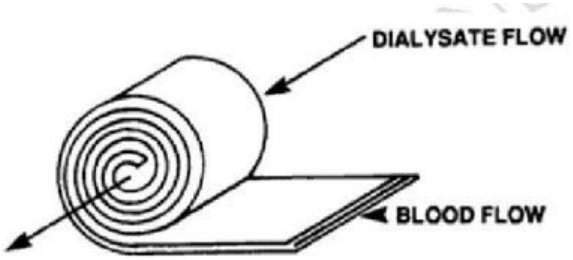
3.1.3 DIALYZERS

The dialyzer is a large canister containing thousands of small fibers through which your blood is passed. Dialysis solution, the cleansing fluid, is pumped around these fibers. The fibers allow wastes and extra fluids to pass from your blood into the solution, which carries them away. The dialyzer is sometimes called an artificial kidney.

Dialyzers, in routine clinical use, may be classified according to three basic design considerations:

(a)Coil (b)Parallel
Plate
(c)Hollow Fibre Type

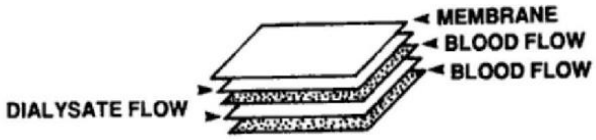
(a) Coil Dialyser



A coil hemodialyzer comprises a tubular membrane placed between flexible support wrapped around a rigid cylindrical core. The coil is immersed in a dialyzing bath. The tubular membrane can be of cellophane or cuprophane.

The coil membrane supports are woven screens or unwoven lattice. Usually, the 'twin-coil' is made with three layers of woven, polyvinyl chloride-coated fibre glass screen separated by four narrow strips of the same material, which are sewn into place with cotton thread.

(b) Parallel flow dialyser

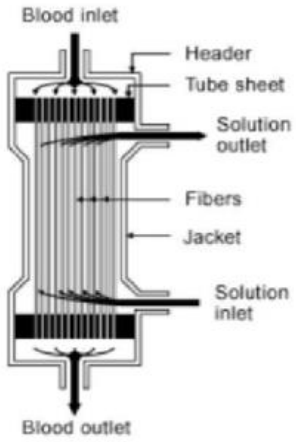


The Parallel Flow Dialyzer has a low internal resistance which allows adequate blood flow through the dialyzer with the patients arterial blood pressure eliminating the need for a blood pump. The dialyzing surface area of parallel flow dialyzer is about 1 cm2. The rigid support used in parallel flow dialyzers permit negative pressure to be created on the dialysate side of the membrane for ultrafiltration.

The KI1L dialyzer has earlier been the most commonly used form of parallel flow dialyzer. It consists of polypropylene boards with dialyzing membranes laid between them. The boards are held firmly with a frame on the top and bottom are fastened by a series of bolts on the side. A rubber gasket runs along the periphery of the board, in a surface, to prevent blood and dialysate leakage. The dialysate enters through a SS port and is distributed to grooves running across the end of the board, both above and below the membrane of each layer. After flowing down longitudinal grooves in the board, it is collected and flowed out at the opposite end of the board.

The KIIL dialyzer is not disposable. It needs to be cleaned and rebuilt after each dialysis operation.

(c) Hollow Fiber Dialyser



The hollow fibre haemodialyzer is the most commonly used haemodialyzer. It consists of about 10,000 hollow de-acetylated cellulose diacetate capillaries. The capillaries are jacketedin a plastic cylinder 18 cm in length and 7 cm in diameter. The capillaries are sealed on each end into a tube sheet with an elastomer. The capillaries range from 200 - 300 mm internal diameter and a wall thickness of 25 * 30 cm.

The blood is introduced and removed from the hemodialyzer through manifold headers. The dialysate is drawn through the jacket under a negative pressure around the outside of the capillaries counter-current to the blood flow. The dialyzers are disposable.

3.1.4 MEMBRANES OF HAEMODIALYSIS

Ideal membrane should possess high permeability to water, organic metabolites and ions. It should have good strength to prevent tearing or bursting.

Dialyzer membranes come with different pore sizes. Those with smaller pore size are called low-flux and those with larger pore sizes are called high-flux.

Cellulose was the first membrane material widely used for hemodialysis. It is a polymer of cellobiose and occurs in natural materials, such as cotton.

Cellulose membranes are hydrogels and can be made very thin (6–15 mm dry thickness) while retaining good mechanical strength. They allow high diffusive transport of small molecules.

Synthetic Membranes

These membranes were made of synthetic polymers.
Synthetic membranes are thick (> 35 □m) with cross-sectional structures that were either homogeneous or asymmetric.

Many synthetic membranes have large pore sizes allowing higher rates of water flux and permitting a higher ultrafiltration capacity as well as a better removal of high molecular weightsolutes than membranes with smaller pore size.

Commonly used membrane is Cupraphan (Cupro-ammonium regenerated cellulose). It hasnatural cellulose, puncture proof and high elasticity.

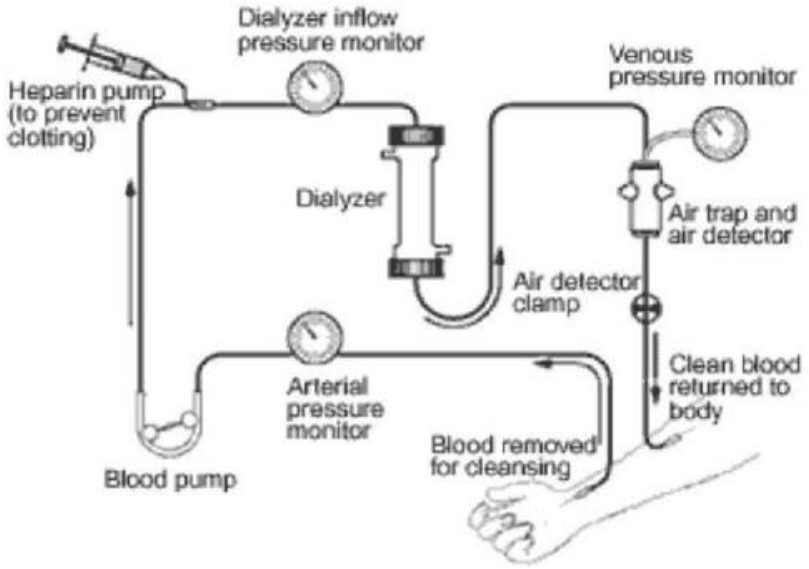
More the 16000 fibers are used.

3.1.5 HAEMODIALYSIS MACHINE

Hemodialysis is a type of dialysis that uses a special filter to cleanse the blood. During hemodialysis treatment, blood is passed from the body through a set of tubes to a filter. The cleansed blood is then returned to the body through another set of tubes.

The machine performs 5 basic functions:

1. Mixes dialysate
2. Monitors the dialysate
3. Pumps blood and administers the anti-coagulants
4. Monitors blood for presence of air
5. Monitors the UF rate



(i) Proportioning Pumps:

A motor driven displacement pump is used to mix water and concentrate (35:1). These are fed into a mixing chamber.

Proportioning pumps mix premade fresh dialysate acid (A) and bicarbonate (B) solution. Acid solutions contain acid/chloride salts including sodium, potassium, calcium, magnesium, andacetate. Bicarbonate solutions are made fresh, since pre-prepared bicarbonate can release CO2 and encourage bacterial growth

(ii) Dialysate temperature control and measurement:

Dialysis is done at body temperature. The Dialysate temperature is monitored and maintained before giving to the dialyser. If it is overheated system should stop the flow to the dialyser. The heaters are switched off if the temperature crosses 43^{o}c. Thermistor senses the temperature and triac controls the

power to the heater.

(iii) Conductivity Measurement:

The conductivity of the Dialysate has to be monitored continuously. It is done using a conductingcell. It is maintained at 1%. The effluent motor is switched off if there is change in conductivity.

(iv) Dialysate pressure control and measurement:

A negative pressure on the Dialysate is caused by the effluent pump. A valve limits the max negative pressure available. The pressure is measured using a strain gauge transducer connected downstream of the Dialysate return site. The gauge gives the Dialysate pressure and venous pressure

(v) Dialyzer and Dialysate:

The dialyzer is the key part of a dialysis machine where the cleaning of the blood takes place. The blood compartment of the dialyzer contains a membrane that does the filtering of wastes from the blood, using the dialysate solution.

The dialysate, also known as the bath, is made up of purified water, bicarbonate and a solution referred to as acid. This acidified fluid also contains minerals and electrolytes. Although the

dialysate never actually mixes with the blood, it pulls the impurities from the blood through a membrane filter. Once the blood is thoroughly cleansed, it is then pumped back into the body. Only about a pint of blood is in the machine at any one time.

(vi) Blood Leak Detector:

A leak developing in the membrane separating the blood from the dialysate in an artificial kidney machine requires immediate corrective action.

Leakage of blood into the dialysate circuit is detected by the blood leak monitor, which is usually located downstream from dialyzer. Infrared or photoelectric cells detect decreases in light from source. Red blood cells scatter light and trigger alarm, which deactivates the blood pump

(vii) Blood Pumps:

Peristaltic pumps are commonly used for driving the various higher volume fluids in the machine: blood, dialysate, water, and saline. This type of pump is very convenient because it does not touch the fluids directly. Instead, a section of flexible tubing runs through the pump mechanism where it is compressed by rollers to push the fluid forward. These pumps require a significant amount of power and are driven by either DC or AC motors with variable speed control.

(viii) Sensors:

Dialysis machines require many different types of sensors to monitor various parameters. Blood pressure at various points in the extracorporeal circuit, dialysate pressure, temperature, O2saturation, motor speed, dialyzer membrane pressure gradient, and air are all monitored for proper values during dialysis.

(ix) Heparin Pump:

Because blood has a tendency to clot when moving through the tubes, a syringe is attached to the dialysis machine tubing. This syringe contains a drug called Heparin, and this is pumped into the blood during the treatment. It is what prevents the blood from clotting.

(x) Cleaning system:

Between patient sessions, any reused components must be sterilized. One approach is to heat water or saline to a high sterilizing temperature and then run it through the machine, both through the extracorporeal circuit and through the dialysate circuit.

(xi) Microcontrollers:

Because of the large number of input signals to be monitored and the large number of pumpsand other mechanisms to be controlled, many of these functions are performed with dedicated microcontrollers for that portion of the system. Controlling the overall system will be a main processor capable of running a full operating system and GUI. Communication between the controllers is required to send data, commands, and alerts.

(xii) Alarms:

Alarms are installed on a dialysis machine, in order to protect the patient from any errors in functioning. The things that are monitored with alarms include:

Blood pressure within the machine, Blood pressure of the patient, Blood flow, Temperature, Dialysate mixture

Each hemodialysis treatment normally takes four to five hours. Usually, a person needs three treatments a week. However, certain people may need more frequent treatments or longertreatments.

3.1.6 PORTABLE KIDNEY MACHINE

Peritoneal dialysis does not use an artificial membrane, but rather uses the lining of the patient's abdominal cavity, known as the peritoneum, as a dialysis membrane. Fluid is injected into the abdominal cavity, and solutions diffuse from the blood into this fluid. After several hours, the fluid is removed with a needle and replaced with new fluid. The patient is free to perform normalactivities between fluid changings.

In Peritoneal dialysis, a sterile solution containing minerals and glucose is run through a tubeinto the peritoneal cavity, where the peritoneal membrane acts as a semipermeable membrane. The dialysate (1-3 L of prescribed solution) is left in the peritoneal cavity for a period of time to

absorb waste products, and then it is drained out through the tube and discarded. This cycle is repeated 4-5 times during the day. Peritoneal dialysis treatment is used at home under the routinesupervision of a dialysis facility. The types of chronic peritoneal dialysis are determined by various schedules:

CAPD- CAPD is a manual form of peritoneal dialysis, with no machine. During CAPD, the dialysate solution stays in the peritoneal cavity for about 4 to 6 hours. After this time, thesolution is drained out of the cavity. The cavity is then is then refilled with fresh solution. This isthe most commonly used form of peritoneal dialysis and employs 4-6 exchanges per day.

CCPD, also known as Automated Peritoneal Dialysis (APD), is a form of peritoneal dialysis using a cycler at night. During CCPD, a machine automatically fills and drains the dialysate fromthe peritoneal cavity. This process takes about 10 to 12 hours; therefore CCPD is performed at night. The cycler automatically makes 4-6 exchanges per day.

3.2 LITHOTRIPTERS

3.2.1 THE STONE DISEASE PROBLEM

A kidney stone is a hard mass developed from crystals that separate from the urine within the urinary tract.

Small stones can be as tiny as a grain of sand and may remain in the kidneys without causing any symptoms. Pain can occur as stones get bigger.

Kidney stones may contain various combinations of chemicals. The most common type of stone contains calcium in combination with either oxalate or phosphate.

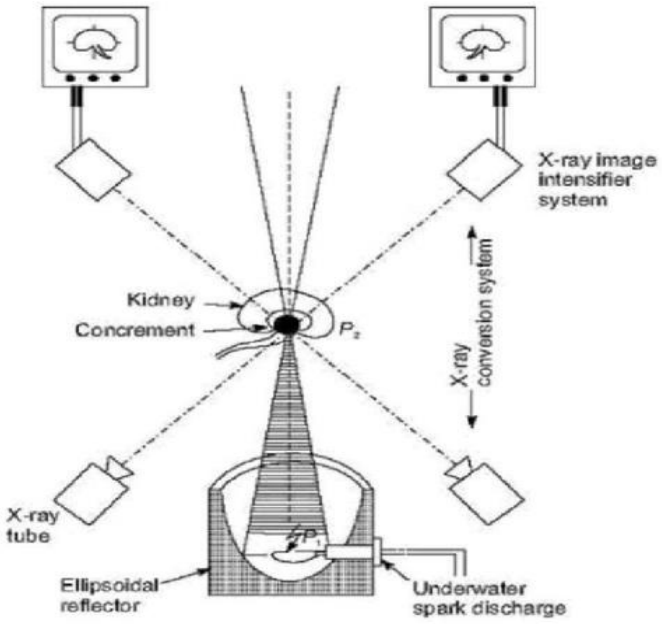
Kidney stones are classified by the substance that forms them. The main types of kidney stones are: Calcium stones, Struvite stones, Uric acid stones, Cystine stones

3.2.2 FIRST LITHOTRIPTER MACHINE

Lithotripsy is the use of high-energy shock waves to fragment and disintegrate kidney stones.The shock wave, created by using a high-voltage spark or an electromagnetic impulse outside of the body, is focused on the stone. The shock wave shatters the stone, allowing the fragments to pass through the urinary system. Since the shock wave is generated outside the body, the procedure is termed extracorporeal shock wave lithotripsy (ESWL). The name is derived fromthe roots of two Greek words, litho , meaning stone, and trip , meaning to break.

ESWL is used when a kidney stone is too large to pass on its own, or when a stone becomes stuck in a ureter (a tube that carries urine from the kidney to the bladder) and will not pass.

The original lithotripsy machines were commonly referred to as “stone baths” because thepatient was placed on a supportive frame called a gantry and partially immersed in a tub of waterwhich had been deionized to eliminate air bubbles.



The gantry was positioned such that the patient’s stone was within the crosshairs of an aiming system (at the so-called F2 focal point) and electromechanical shock waves generated under water at the F1 point by a spark gap generator traveled through the body to fragment the stone.

Ultrasound or fluoroscopy is utilized during the treatment to monitor the fragmentation process. Once the stone or stones have been fragmented, the particles flush through the urinary tract and are eliminated.

3.2.3 MODERN LITHOTRIPTER MACHINE

The major components are

1. Focussed shock wave source
2. Acoustic coupling
3. Imaging
4. Patient table
5. Triggering and monitoring

1. Focussed shock wave source:

The shock waves are generated by an emitter outside the body and transmitted as pulsed waves through a fluid coupling medium.

There are three categories of shockwave generators:

a) Plasma explosion method/ Ellipsoidal reflector-

A capacitor is discharged across 2 opposing electrodes paced in a bath tub. A conducting channelis formed between the electrodes and expands with supersonic velocity. The shock wave is focused by a ellipsoidal reflector.

b) Electromagnetic/ Acoustic lens

The electromagnetic assembly produces an electric field in the coils, and the eddy currents produces a magnetic field.

c) Piezoceramic system/ self focusing source

This operated by driving several thousands of piezoceramic elements mounted on a spherical dish, thus giving self-focusing waves. The wave field is focused with a lens. High voltage is generated by capacitors.

2. Acoustic Coupling

A medium is used for coupling shock waves to the human body to minimize the presence of air and give undisturbed propagation of acoustic pulses.

An open bath provides with warm water or oil gives optimal coupling.

3. Imaging

Imaging for stone localization can be done with ultrasound, fluoroscopy or the combination of both.

4. Patient Table

The shock wave sources are arranged below the structure supporting the patient. The table is motorized. The table has an opening that permits the lumbar area to be exposed to oil filled membrane.

5. Triggering and Monitoring

Monitoring of heat is done as a preventive measure when anesthesia is given.

The triggering of shock waves is gated to the respiratory cycle for efficient treatment. It is done so because the kidney is displaced during respiration.

About 1-2 thousand shock waves are needed to crush the stones. The complete treatment takes about 45 to 60 minutes.

3.2.4 EXTRACORPOREAL SHOCKWAVE THERAPY

Extracorporeal Shockwave Therapy or ESWT is a treatment used in physical therapy, orthopedics, urology and cardiology. Extracorporeal means that the shockwaves are generated externally to the body and transmitted from a pad through the skin.
Extracorporeal Shockwave Therapy is used to treat a growing number of tendon, joint and muscle conditions.

ESWT is also used to promote bone healing and treat bone necrosis. It is an effective alternative to surgical treatment of non-healing fractures. ESWT is used for wound healing and has shown positive results in short-term and long-term outcomes in diabetic patients suffering from foot ulcers.

The kinetic energy of the projectile, created by compressed air, is transferred to the transmitter atthe end of the applicator and further into the tissue.

Energy levels are between 0.03-0.5 $MJ/mm^{2.}$ 1500-2000 shock waves are applied to the highest point of pain.

3.3 HEART-LUNG MACHINE

- During open heart surgery for installation of valve prosthesis or correction of congenital mal formation the heart cannot maintain the circulation. It is then necessary to provide extra-corporeal circulation with a special machine called **heart lung machine**
- This is also used to provide circulatory assistance to support a faulty heart. While doing open heart surgery, it is necessary to bypass the heart to enable the surgeon to work in a bloodless field under direct vision.
- The heart lung machine replaces the functions of heart and lungs thereby providing the rest of the body with a continuous supply of oxygenated blood while the heart is stopped.
  Mechanical Functions of the heart

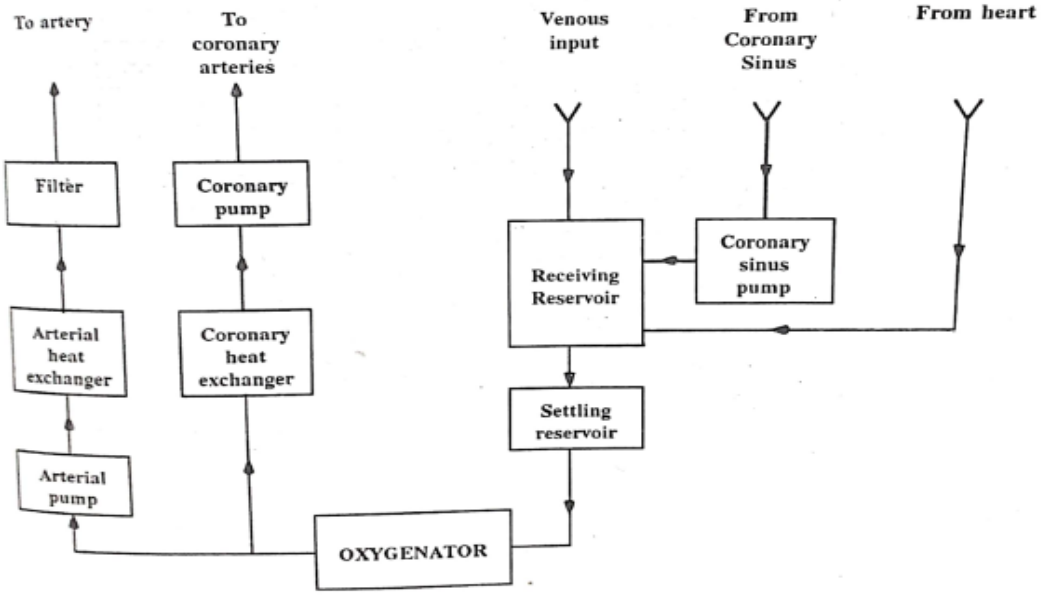
- In an intact heart, venous or oxygenated blood is returned to the right side of the heartat a pressure of 0 to 5 mm Hg and oxygen saturation below 75%
- From the right side of the heart, the blood is pumped into lungs through pulmonaryarteries
- In the lungs the blood is oxygenated to about 95 to 98% saturation and then it is goingto the left atrium of the heart which acts as a receiving chamber.
- From there the blood flows into the left ventricle through the mitral valve. The leftventricle is called the more powerful chamber all the heart
- The ventricle ejects the blood into the aorta with peak pressures ranging from 100 to150 mm Hg
- Since the contraction of the lett ventricle is rhythmic, the resultant flow in the aorta is pulsatile, reaching a systolic peak pressure of about 90 to 140 mmHg with 120 mm Hg as the mean and a low point or diastole of about 60 to 90 mm Hg with 80 mm Hg as the mean. Systole is the period of contraction of the ventricular muscles during thattime blood is pumped into the pulmonary artery and the aorta. Diastole is the period of dilation of the heart chambers as they till with blood.
- The heart pumps about 5 litres of blood per minute. At any time, the veins contain 75 to 80 percent of the blood volume and arteries contain 20 to 25 percent of blood volume
- All the arteries, (except pulmonary artery) carry pure blood from heart to different parts of the body. Similarly all the veins (except pulmonary vein) carry the impure blood from different parts of the body to the heart.

Model of the heart lung machine

- Two cannulas are inserted into the right side of the heart to collect the returning venous blood as shown in figure.
- Using heart lung machine, extracorporeal circulation can be possible and in which thelungs and heart are replaced by the oxygenator and blood pump respectively. The collected venous blood is

directed into a receiving reservoir of heart lung machine by gravity drainage.

- The accumulated blood in the operating Field is collected and passed into the receiving reservoir by suction devices. From here the blood in passed into the settling reservoir or debubbling chamber and then it is passed into oxygenator.



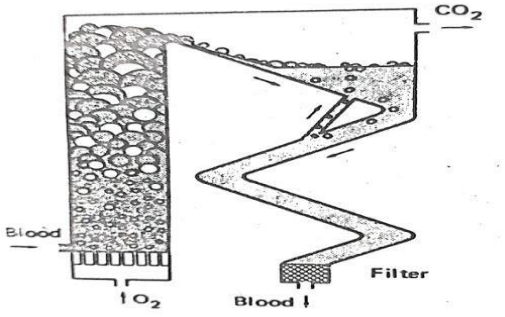
- In the oxygenator the blood is exposed to an atmosphere rich in oxygen. From the oxygenator a pump raises the pressure of the blood to the mean arterial pressure from which it flows into an arterial beat exchanger.
- Arterial beat exchanger is necessary during hypothermic or low temperature operationwhich is allowed for two reasons:
  - First is to reduce body metabolism and therefore to reduce oxygen consumption during the operation thereby operation time can be increased
  - Secondly the brain damage due to oxygen starvation is reduced. It is well known that the brain is the most sensitive to oxygen starvation and easily damaged by oxygen starvation.
- Between 37°C and 30°C, brain consumption of oxygen is reduced approximately 7% for each degree ^{0}C lowering of body temperature.
- Without hyperthermia the operation time is limited to 10 minutes. Beyond this time ventricular fibrillation can occur.
- With hyperthermia the operation time can be extended to few hours. Anyway increase, operation time may lead to hemolysis or breakdown of the red blood cells.
- In the heat exchanger the blood is maintained at the Human body temperature 37^{o}C. From the arterial heat exchanger, the blood passes through a filter to prevent the possibility of particles or bubbles returning to the body.
- Systemic circulation is maintained by returning this arterial oxygenated blood to a major artery.
- In addition to ensure that the coronary arteries and the heart itself are properly perfused with blood

during aortic valve surgery, individual cannulas are inserted into each of the coronary arteries and blood is pumped through them.

Oxygenators

- In the oxygenators a mixture of oxygen and 2 to 5% of CO_2 is usually employed toavoid respiratory alkalosis.
- Every oxygenator should oxygenate Upto 5 litres/min of blood.
- The amount of blood necessary for filling the entire extracorporeal circuit is called thepriming volume.
- For an ideal oxygenator the following conditions are required:
    - Lower priming volume
    - Minimum trauma to blood
    - Simple, safe and reliable operation
    - Ensured sterilization
    - No microembolus formation and
    - Short preparation time There are four types of oxygenators or artificial lungs.

1. **Bubble oxygenators**



(a) BUBBLE OXYGENATOR

Principle

- By bubbling the oxygen through a large column of blood and then making the flow to blood through a slanting path, the carbon dioxide is removed from the blood

Working

- There are two major components. In one component, oxygen is bubbled through the blood in a finely dispersed form.

Features

In the other component called gas separating component, gaseous exchange istaking place.

- Meanwhile the bubbles and foam are removed. The existence of bubbles inblood causes air emboli.
- To remove bubbles, beads, sponges, meshes and fabrics coated withdefoaming agent like silicon is used.
- The surface tension of bubbles is reduced by the silicon and hence it causesthe bubbles to break. There are also permanent and disposable oxygenators.
- The oxygenation is effective because of the large surface area. But large surface area leads to pronounced foaming and damage to the red cells. Therefore, these are suitable only for short operations.
- It is the simplest among the different oxygenators.
- Due to the mechanical stress introduced by the bubbles, trauma produced in it is the highest.
- In the case of disposable unit, except the long preparation time and expensive material cost, we can get cleanliness, sterility, simplicity and inexpensive manpower cost.
- But in the case of permanent unit, except the difficulty in cleaning and expensive manpower cost, we can get shorter preparation time and inexpensive material cost.

2. Film Oxygenators

Principle

- Here the thin film of blood is spread on a rotating disc or metal screen and an cryogen mixture flows over this thin layer of blood.

Working

- There are several types in this oxygenator.

Foam oxygenator

- Blood is poured over the top of the blood foam. The oxygen mixture is bubbled through the blood in the opposite direction. The blood is spreading over the surface of the bubble in a thin film form and effectively it is exposed to oxygen. The filmed blood is oxygenated while falling down. Defoaming is done afterwards.

Screen oxygenator

- A thin film of blood over a screen (stationary or rotating) is exposed to oxygen for oxygenation. This causes fewer traumas to blood. Disposable units are also available in this type.

Blood film over sponge

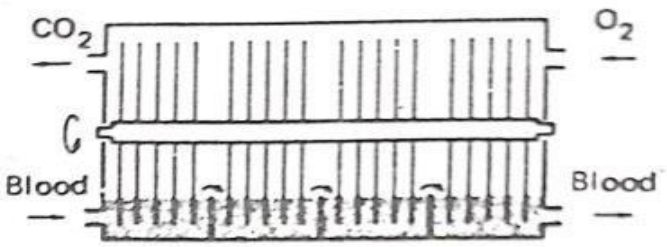
- A small volume of sponges saturated with blood provides a large surface area for blood oxygenation if oxygen is simultaneously distributed in the sponge. It is called artificial alveoli.

Rotating disc film oxygenator

- A horizontal cylinder in which a number of discs are mounted on a central axis. In thefigure rotating discs are shown as vertical lines.
- A blood level is maintained at the bottom of the cylinder so that only outer edge ofeach disc is immersed in the blood.
- Rotation of the central axis of the cylinder causes a thin blood film to form on theperiphery of the discs.
- After a short exposure to oxygen which is filled in the oxygenator housing, the bloodis washed off from the discs.
- At the same time a new blood film is formed on the same discs. This new film is alsowashed off at the text revolution.
- Since the cylinder is rotated at 120 r.p.m., the exposure time of the blood film with theoxygen atmosphere is only 0.5 second.

Features

- These are difficult to clean
- Traumas produced in these are very small.
- Effective oxygenation can be done.



(b) FILM OXYGENATOR
(Disc type oxygenator)

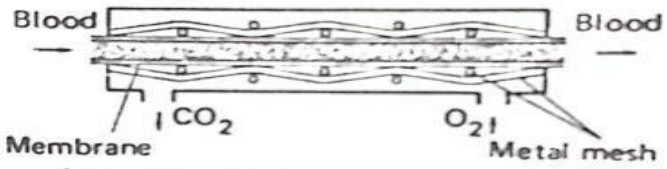
Membrane oxygenators

Principle

- Effective oxygenation is obtained when oxygen and blood are running in opposite directions through a thin porous membrane.

Working

- The blood flows on one side of a membrane permeable to gas and oxygen flows on the other side of it.
- The membrane is made of microporous polyethylene which has higher permeabilityfor oxygen. Silicone rubber is also rarely used.
- Here the carbon dioxide transport is limited by the permeability of the membrane.
- Further the oxygen transport is also limited by the thickness of the blood layer.



(c) MEMBRANE OXYGENATOR

Features

- These are so expensive and hence these are not commonly used.
- Trauma produced in these oxygenators is very small when we compare it with others.
- This is due to the advantage that the blood does not come into direct contact with theoxygen mixture. Therefore, bubbles and foam do not form.
- These are very difficult to clean.

Liquid – liquid oxygenators

Principle

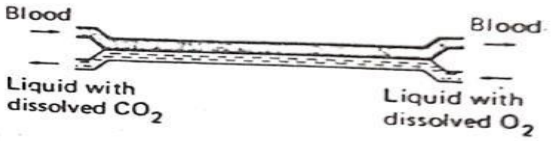
- The oxygen dissolved fluoridised organic fluid and blood are flowing in the oppositedirections and oxygenation of the blood takes place.

Working

- Fluoridized organic liquid is the working liquid which readily dissolves oxygen and carbon dioxide which then diffuse to and from the blood respectively.
- Even though the blood is in direct contact with the working liquid, it is entirely a different chemical compound with respect to the blood constituents and so there is no chemical reaction between them.
- During their opposite flow through a small tube, gaseous exchange takes place.

Features

- No trauma is produced
- Effective oxygenation can beobtained



(d) LIQUID–LIQUID OXYGENATOR

Blood pumps

Various types of blood pumps are available. An ideal blood pump should satisfy the following characteristics.

i. It is able to pump the blood upto 6 litres/minute regardless of the outflow linepressure. It should deliver the blood with appropriate pressure.
ii. Pumping action should not cause any damage to the cellular and noncellularcomponents of the blood.
iii. The pump must be easy to clean and sterilize.
iv. All the parts in contact should have a smooth and continuous surface and nodead space or area where the blood can collect and clot. The clotting of the blood creates unnecessary turbulence and foaming.
v. The calibration of the pump flow should be exact.
vi. In an emergency, this pump should be able to operate manually.
vii. To reduce hemolysis, the blood pump should provide a flow that minimizeturbulence and also the blood cells should not be subjected to unnecessary mechanical stress.

Blood pumps can be classified into two types:Pulsatile pumps and Non-Pulsatile pumps

Pulsatile pumps

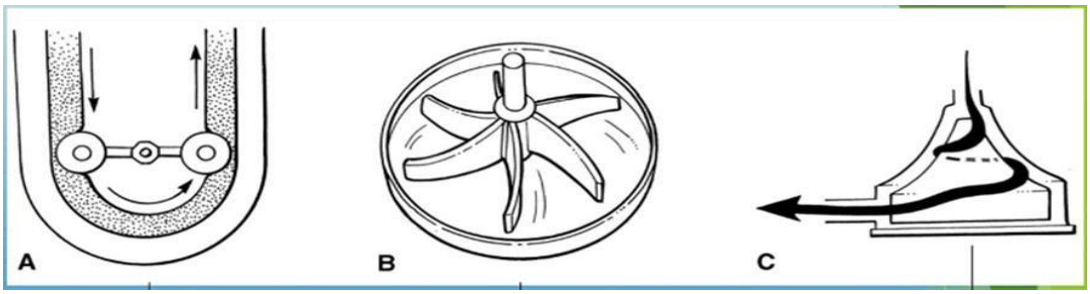
- Reciprocating positive displacement pump creates pulsatile flow.
- For effective action such pumps are provided with inflow and outflow valves.
- A diaphragm pump similar to artificial heart is a pulsatile pump. The diaphragm is activated by the pneumatic system.
- Ventricular pump, in which a balloon is inserted in the aorta via the femoral artery in the groin and is filled during diastole and emptied during systole by sending compressed air using timing circuit
- Pneumatic system is also a disposable pulsatile pump.
- In any pulsatile pump, there are two chambers inner chamber and outer rigid chamber.When the pumping fluid is injected inside the outer rigid chamber, the inner chamber is compressed and the blood in it is ejected out through the outflow valve.
- When the pumping medium is withdrawn, the inner chamber returns to the original shape and refills the blood in the chamber through the inflow valve.

Nonpulsatile pump

- Non pulsatile blood flow can be generated by squeezing a tube filled with bloodby a roller.
- The most commonly used nonpulsatile pump is a roller pump.
- In the clearance between the pump housing and the roller, a tube carrying theblood is positioned.
- Because it has the tendency to move forward as the roller passes over it, anattachment to stop this movement is provided.
- The tube has also a tendency to escape laterally which must be prevented on mostpumps by mounting a guide rod on the central axis of the pump.
- The clearance between the pump housing and the roller is controlled automaticallyto avoid high pressure on the blood in the pump. Since this pump is producing hemoloysis, the maximum time that extracorporeal circulation can be permitted is limited.

Pumps

- Centrifugal pumps consist of plastic cones, which when rotated rapidly, propel blood by centrifugal force.
- Forward blood flow, varies with the speed of rotation and the after load of the arterial line.
- Centrifugal blood pumps generate up to 900 mm Hg of forward pressure, but only 400 to 500 mm Hg of negative pressure. Hence, less gaseous micro emboli. Centrifugal pumps produce pulse less blood flow



A-Impeller Pump **B**-Roller Pump **C**-Centrifugal Pump

Five pump assemblies :

- A centrifugal or roller head pump can be used in the arterial position for extracorporeal circulation of the blood.
- Left ventricular blood return is accomplished by roller pump, drawing blood awayfrom the heart.
- Surgical suction created by the roller pump removes accumulated fluid from thegeneral surgical field.
- The cardioplegia delivery pump.
- Emergency Backup of the arterial pump in case of mechanical failure.

Venous Reservoirs: Reservoirs may be rigid (hard) plastic canisters ("open" types) or soft, collapsible plastic bags ("closed" types). Venous bubble trap present, provides a convenient place to add drugs, fluids, or blood, and adds storage capacity for the perfusion system.

SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – IV – Therapeutic Instrumentation – SBMA1601

UNIT-4

PULMONARY ASSIST INSTRUMENTS

4. ANAESTHESIA MACHINE

4.1 NEED FOR ANAESTHESIA MACHINE

It has 2 functions

1. Ensures patient does not feel pain and minimizes discomfort
2. Provides surgeon with favourable condition to work.

4.2 ANAESTHESIA MACHINE

A machine used to deliver a precisely known but variable gas mixture including anaesthetics andlife sustaining gases to the respiratory system.
A variable concentration of oxygen, nitrous oxide and anaesthestic vapor like ether is obtainedfrom the machine and made to flow through the breathing circuit to the patient.

Gas Supply System

Gases are provided to the machine from a central supply or using small storage cylinders.

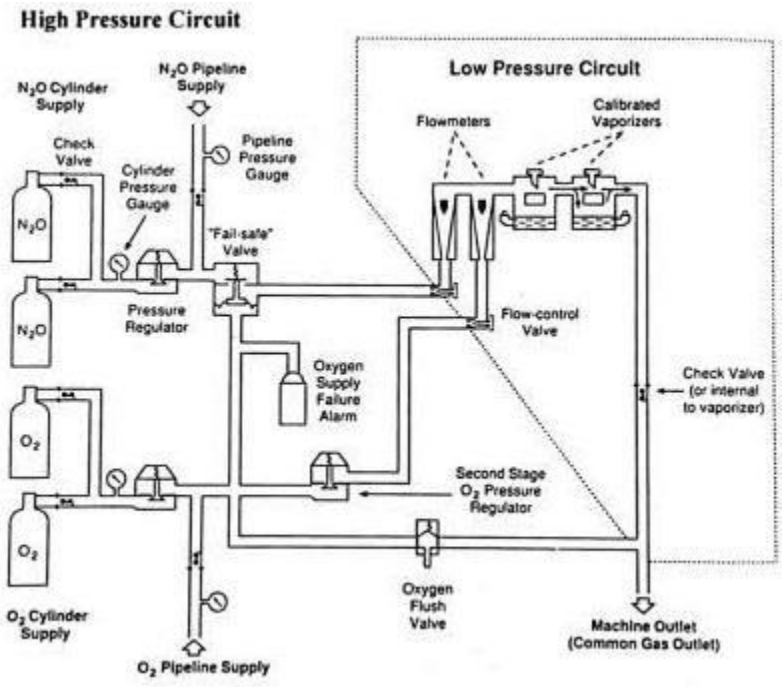
Centralized supply-

It consists of bulk or centralized storage for main and reserve supply, control equipments like valves and pressure regulators, distribution pipeline and supply outlets.
The oxygen-nitrous oxide gases are regulated and maintained at 275-345 K Pa. Gases are supplied to the operating room through color coded hoses for each gas.
Each inlet is also provided with a non-interchangeable connector. They incorporate a specializedmale and female end for each gas.
Gas Cylinder –

Cylinders are attached to the yoke of the anaesthesia machine. It can be used as a reserve during emergency situations.

Yoke – The machines are provided with one or two yokes which are exclusive for each cylinder.

Two pins located in the yoke must fit into the corresponding holes in the tank neck.



***Pressure Regulator* –** These reduce cylinder gas pressures to 275 KPa before it flows into the machine. It has non return valves which prevents the flow into empty cylinder or back into the central piping system.

***Pressure Gauge System* –** This indicates the contents of the gases in the cylinder. For oxygen itis 0-150 kg/cm2. An indicator would give reading and if the falls below the standard values, the cylinder has to be replaced.

***Fail Safe System* –** This system makes sure that the nitrous oxide doesn't flow into the machine unless an oxygen supply pressure exists in the machine. It has a master pressure regulator valve located in the oxygen supply line. Oxygen –N2O ratios vary from 75:25 to 70:30.

4.2.1 Flow Delivery Units

Gas proportioning and gas mixing is used to accomplish delivery and control gas mixture.

***Gas Proportioning* –** The delivered concentration of each gas is a function of a pre determined precisely controlled ratio of proportionality which is independent of the total gas flow. The mass delivery is 7:3 irrespective of the total flow rate.

***Gas Mixing* –** The flow rate of each constituent is independently controlled and measured by a delivery unit consisting of a needle valve and a rotameter.

4.2.2 Vapour Delivery Unit

The liquids that possess anaesthetic properties are too strong to be used as pure vapors. They are diluted in a carrier gas.

Vapourizer is the device that allows the vapourization of liquid agent and the carrier gas. They have two designs- flowmeter controlled and concentration calibrated.

The vapors are picked from the vapourizer by the carrier gas by bubbling through the liquid or passing over the liquid.

The liquid temperature has to be maintained by using a water bath made of copper.

4.2.3 Patient Breathing System

It delivers the anesthetics and respiratory gases to and from the patient. It describes the mode of operation and the apparatus by which inhalation agents are delivered to the patient.

4.2.4 Humidifiers

The air or anaesthetic agents have to be humidified to prevent secretion of mucus or making the passage dry.

The humidification measures used are heated air way humidifiers, nebulizers and heat and moisture exchangers.

In Heated airway humidifiers, air passes over the surface of heated water and vaporization takes place.

Nebulizers supply moisture in form of droplets.

Heat and moisture exchangers conserve the patient's own heat and moisture.

4.2.5 Ventilators

The ventilator provides a positive force for transporting the respiratory and anaesthetic gases into the patient.

They are located in d machine or as an accessory unit. The output is connected to the patient breathing circuit.

4.2.6 Patient Circuit

It consists of a rubber tube, a tube fitting, a rebreathing bag, a valve and a mask.

4.3 ELECTRONICS IN THE ANAESTHESIA MACHINE

The use of microprocessors allows integrating control and safety function and protects the patient from gas supply failure, electrical supply failure, disconnections, etc.

All abnormal conditions cause an alarm to ring.

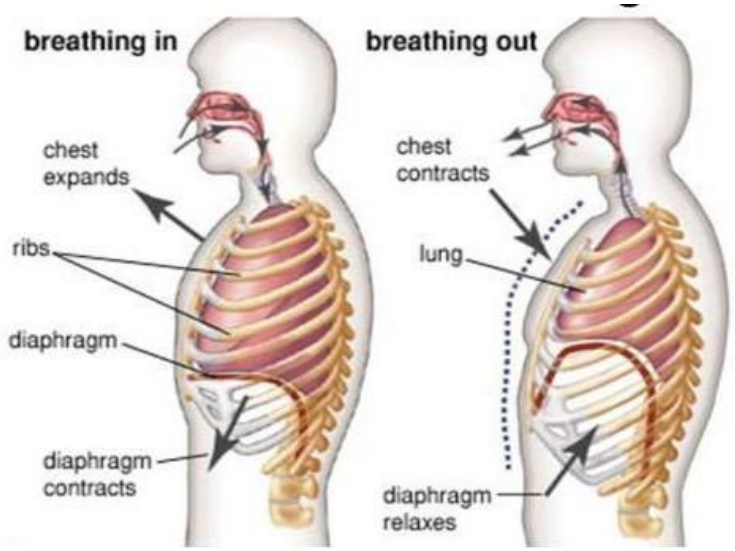
4.4 MECHANICS OF RESPIRATION

Every pulmonary cycle consists of the following phases: intake of breath (inspiration) and exhalation (expiration).

When we inhale, the intercostal muscles (between the ribs) and diaphragm contract to expand the chest cavity. The diaphragm flattens and moves downwards and the intercostal muscles move the rib cage upwards and out.

This increase in size decreases the internal air pressure and so air from the outside (at a now higher pressure that inside the thorax) rushes into the lungs to equalize the pressures.

When we exhale the diaphragm and intercostal muscles relax and return to their resting positions. This reduces the size of the thoracic cavity, thereby increasing the pressure and forcing air out of the lungs.



Only at the optimal course of pulmonary cycles, a sufficient extraction of CO_2 from the blood and its saturation by oxygen are provided.

There are two ways how the lungs can be shrunk or stretched:

1. The activity of the diaphragm
2. The activity of the intercostal muscles

4.5 ARTIFICIAL VENTILATION

For reduced breathing or respiratory failures, mechanical devices are used. These devices supply enough oxygen and eliminate the right amount of CO_2 and maintain the desired arterial partial pressure

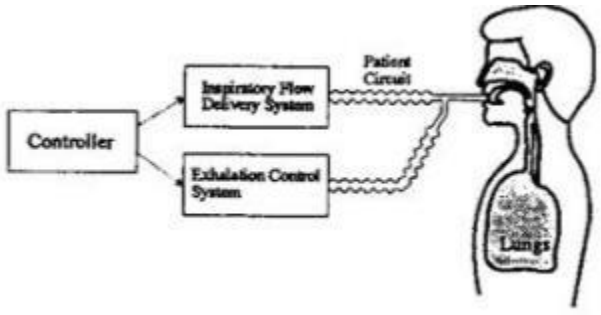
of O2 and CO2.

The aids are mask, breathing valves and self-filling bags.

The masks are held firmly over the patient's mouth and nose. The breathing valve guides the airto the patient and removes the unwanted air. The bag acts as a pump and is squeezed by hand.

4.6 VENTILATORS

These are used when artificial ventilation is to be used for a long time. The
main function is to ventilate the lungs close to the natural process.
Negative pressure ventilators generate a negative pressure inside the lungs or around the patient's thoracic cage. This pressure moves the thoracic wall outwards, expanding the intra thoracic volume and dropping the pressure inside the lungs, giving a pressure gradient between the atmosphere and lungs which causes the flow of air into the lungs. These are not commonly used.



Positive pressure ventilators generate inspiratory flow by applying a positive pressure. They operate in mandatory or spontaneous mode.

4.7 TYPES OF VENTILATORS

Anaesthesia ventilators- Small and simple equipments used to assist during operations.

Intensive care ventilators- They are complicated and are used over a range of parameters. They incorporate patient triggering facility.

4.7.1 VENTILATOR TERMS

IMV (intermittent mandatory ventilation): a breath sequence in which spontaneous breaths are permitted between mandatory breaths.

- **Tidal volume**
  The volume of gas/air delivered with each breath.
- **Inspiratory and expiratory times**
  The total time required for one complete respiratory cycle. Typically, patients are comfortable with

an expiratory time two to three times longer than the inspiratory time.

- **Inspiratory reserve volume – IRV**
  This term means the maximal volume of air that can be inhaled after completion of resting inspiration. 3000ml
- **Expiratory reserve volume – ERV**
  It is the maximal volume of air which can be exhaled after the completion of the resting expiration. 1100ml
- **Residual volume – RV**
  Residual volume is the volume of air that remains in the lungs after a maximum forced expiration, thus the amount of air remaining in the maximally contracted lungs. For an adult 70 kg man is about 1200 ml.
- **Functional residual capacity – FRC**
  Functional residual capacity is the amount of air that remains in the lungs after completed resting exhalation and is equal to the sum of expiratory reserve volume and residual volume of the lungs.
  FRC = ERV + RV
  For an adult 70 kg man is thus about 2300 ml.
- **Vital capacity – VC**
  The maximal volume of air that can be exhaled after the completion of the maximal forced inspiration. In other words, it is the volume of air that the lungs are able to expel by maximum exhalation after maximal strenuous inspiration. It therefore represents a sum of inspiratoryreserve volume, tidal volume and expiratory reserve volume.
  VC = IRV + VT + ERV
  For an adult 70 kg man comprises about 4600 ml.
- **Total lung capacity – TLC**
  Total lung capacity is the maximal volume of air that can be held in the lungs after maximal forced inspiration. It can also be said that this is the maximal volume which can somebody's lungs achieve. It is the sum of all four volumes described above, i.e. residual volume, expiratory reserve, tidal and inspiratory reserve volume. More often is expressed as the sum of vitalcapacity and residual volume of the lungs.
  TLC = RV + ERV + VT + IRV = VC + RV
  For an adult 70 kg man this value reaches about 5800 ml.
- **Lung compliance:** a measure of the ease of expansion of the lungs and thorax, determined by pulmonary volumeand elasticity.
- **Minute Volume**
  Respiratory minute volume is the volume of gas inhaled (inhaled minute volume) or exhaled (exhaled minute volume) from a person's lungs per minute.

- **Airway resistance**
  The ease with which air flows through the respiratory passage.
- **Respiration rate**
  The number of breaths per minute.
- **Synchronized Intermittent-Mandatory Ventilation (SIMV)**
  A combination of machine ventilation and spontaneous breathing.
- **Peak airway pressure**
  Peak inspiratory pressure (PIP) is the highest level of pressure applied to the lungs during inhalation

4.8 CLASSIFICATION OF VENTILATORS

4.8.1 Based on the method of initiating the inspiratory phase

- ***Controller***
  It operates independent of the patient's inspiratory effort.
- ***Assistor***
  It augments the inspiration of the patient by operating in response to the patient's inspiratory effort.
- ***Assistor/Controller***
  It combines both the assistor and controller functions.

4.8.2 Based on power transmission

Direct power transmission

Delivers gas directly from the source to the patient.

Indirect power transmission

It separates the patient and power systems.

4.8.3 Based on Pressure pattern

Positive atmosphere

It produces a positive pressure in the patient's lungs during inspiration. The patient breathes spontaneously.

Positive – Negative

It produces a positive pressure in the patient's lungs during inspiration and the atm. Pressure lowers during the expiratory phase.

Positive-Positive

It produces a positive pressure in the patient's lungs during inspiration with the end expiratory pressure greater than atmospheric pressure.

4.8.4 Based on the type of safety limit

Volume limited

The ventilator in which the pre-determined volume cannot be exceeded during inspiration

Pressure limited

The ventilator in which the pre-determined pressure cannot be exceeded during inspiration.

Time limited

The ventilator in which the pre-determined phase time cannot be exceeded during inspiration

4.8.5 Based on source of power

Pneumatic

Powered by compressed gas

Electric

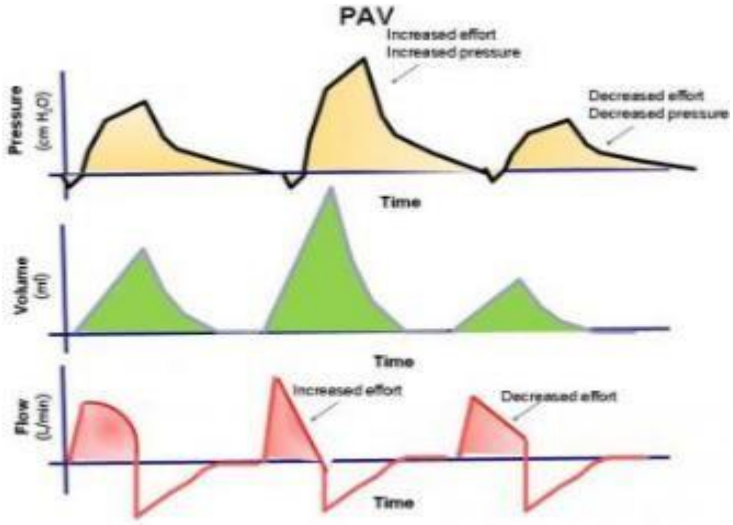
Powered by electrical device like motors

4.8.6 Based on cycling control

The cycling control determines the change from inspiratory phase to expiratory phase and vice versa.

4.9 PRESSURE VOLUME FLOW DIAGRAMS

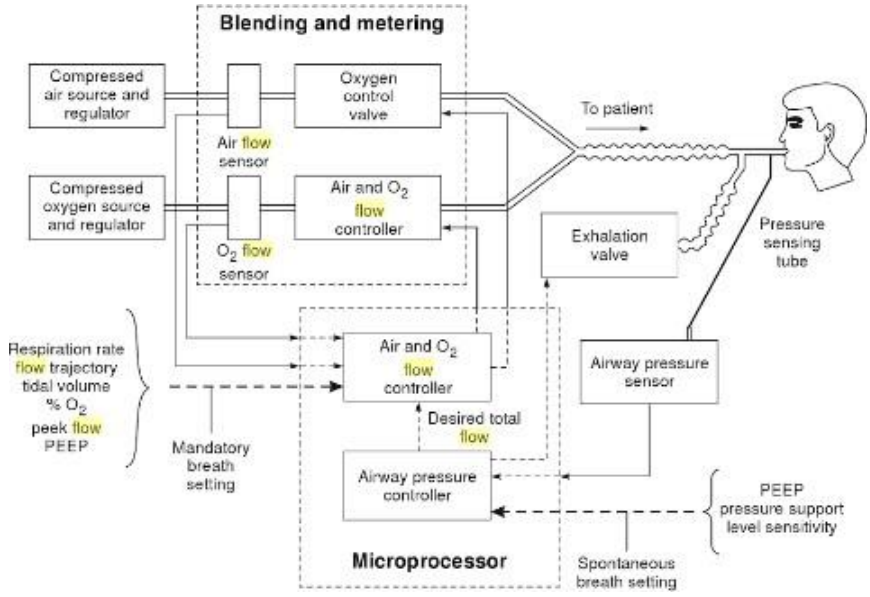
- Pressure-time, flow-time and volume-time diagrams are needed to understand the performance ofventilators.
- The ventilated system comprises the patient circuit, airways and the alveoli having its own compliance.
- At the start of the inspiratory phase, a gas volume is given to the system which results in an pressure in the patient circuit and a flow through the airway. During this phase, the airway pressure and alveolar pressure increase gradually with airway pressure greater than alveolar pressure.
- The equal pressure of patient circuit and alveoli informs the end of the inspiratory phase and beginning of the expiratory volume.



- The expiratory flow is the difference between alveolar pressure and pressure in the patientcircuit.
- A pause time or time delay should be provided between the cycling of the ventilator and thechange from inspiratory to expiratory flow.

4.10 MODERN VENTILATORS

A ventilator is an electromechanical (or, possibly, completely mechanical) device designed to provide all or part of the effort required to move gas into and out of a person's lungs.



It has two interconnected systems – Pneumatic flow system and electronic control system.

Pneumatic flow system –

- This device ensures proper level of o2 in inspiratory air.
- O2 and medical grade air enters into the ventilator at 3.5 bar pressure through built in 0.1 microfilter.
- These gases enter the mixer and the 8 liters reservoir.
- An electronically entered flow value proportions the gas flow from reservoir tank to patientbreathing circuit.
- As the gases leave the ventilator, they pass by an O2 analyser, a safety ambient air inlet valveand back up mechanical pressure valve.
- The ambient valve provides the patient the ability to breathe room air when the machine fails orpressure in patient circuit decreases.
- A bi directional flow sensor in the breathing circuit measured the gas flow. The exhaled gases flow through the electronically controlled exhalation valve.
- The microprocessor controls each valve to deliver the desired inspiratory air and O2 for spontaneous and mandatory ventilation.

Electronic Control System

- It uses one or more microprocessors and software to perform monitoring and control functions.
- The parameters include setting of respiration rate, flow waveform, tidal volume, peak flow andPEEP.
- The PEEP controls the exhalation flow.
- These parameters are used to compute desired inspiratory flow.
- The system consists of monitors for pressure flow and O2 flow sensors. These are connected to electronic processing circuits and values are displayed.
- The pressure sensors are strain gauges.
- Fuel cell type sensors are used to measure fraction of O2.Thermistors are used to measure temperature.
- Ventilators need regular maintenance and calibration.

4.11 HIGH FREQUENCY VENTILATORS

- High frequency ventilation is a type of mechanical ventilation which utilizes a respiratory rate greater than 4 times the normal value.

- High frequency ventilation reduces ventilator-associated lung injury (VALI), especially in the context of ARDS and acute lung injury. This is commonly referred to as lung protective ventilation.
- High frequency ventilation may be used alone, or in combination with conventional mechanical ventilation.
- There are three distinguishing characteristics of high-frequency oscillatory ventilation: the frequency range from 5 to 50 Hz (300 to 3000 bpm); active inspiration and active expiration; tidal volumes about the size of the dead space volume.
- There are four basic types of HFV: high frequency jet ventilation, high frequency oscillatory ventilation, high frequency percussive ventilation, and high frequency positive pressure ventilation. Among these, high frequency oscillatory ventilation is the mode that is used most often.
- HFV provides adequate alveolar ventilation and oxygenation without high inspiratory pressure.
- Babylog 8000 uses oscillating diaphragm mechanism which is computer controlled. It determines the shape of pressure swings and I: E ratio.
- HFV's are microprocessor controlled.

4.12 HUMIDIFIERS, NEBULISERS AND ASPIRATORS

- **Humidifiers** replace humidity in the upper air passages which has been lost due to intubation. It should be close to 100%. It prevents damage to the lungs and air passages. It is done by heat vapourization or bubbling air through a jar of water. The main task of a humidifier is to replace humidity in the upper air passages which has been lost by intubation.
- The humidity should be as close to 100% as possible.
- It is done either by heat vapourization (stream) or by bubbling an air stream through a jar of water.
- **Nebulizers** are used when any medication has to be administered as an aerosol. The water or medication is picked by high velocity jet of oxygen which causes droplets to be formed which are then given to the patient. Ultrasound nebulizers are also used. To provide water or some type of medication suspended in the inspired air as an aerosol
- The water or medication is picked up by a high velocity jet of air/oxygen and made to impact against one or more baffles to break the substance into controlled-sized droplets which are then applied to the patient via a respirator.
- High intensity ultrasound energy which vibrates the substance (water or medication) to produce a high volume of minute particles
- **Aspirators** are used along with ventilators to remove mucus and other fluids from the airways. Suction devices are also used. A part of a ventilator to remove mucus and other fluids from the airways. Consist of a vacuum pump, a vacuum regulator and gauge, a collection canister, and

sometimes a bacterial filter. Plastic tubing is used to continuously draw fluid into the collection canister.

SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – V – Therapeutic Instrumentation – SBMA1601

UNIT 5

DRUG DELIVERY AND NEONATAL SYSTEMS

5.1 INFUSION PUMPS

Infusion pump delivers measured amounts of fluids or medications into the bloodstream over a period of time.

• They supply a controlled amount of drugs very slowly into the bloodstream over a period of time.

5.1.1 Techniques for the pumping action

• One method is peristaltic rollers on a drum squeeze the fluid tubing in a controlled manner to force the fluid down the tubing.

• A second method is obtained by using a cassette (or chamber) that fills with fluid & is then emptied out by the pumping mechanism in a controlled manner

5.1.2 WORKING

- The Infusion Pump uses a combination of these two techniques described as quasi
- A three-chambered cassette is employed with the pumping mechanism operating on these three chambers in turn.
- The user can set the rate of fluid delivery in millilitres per hour (ml/hr) together with the volume of fluid that should be delivered in millilitres (ml).
- The pump will not deliver fluid beyond a certain delivery pressure to prevent harm to the patient.
- This is achieved by monitoring the pressure in the giving set & ensuring that it does not exceed a certain level.
- If the pressure is exceeded, pumping is stopped & an alarm sounded to alert the user. This alarm is called an occlusion alarm flow).
- Monitoring of the function of the pump occurs continuously & alarm sound will prevent any possible danger to the patient such as failure of delivering fluid in the manner expected.
- The Infusion Pump has battery back-up so that it can continue operating even when mains failure occurs

5.1.3 TYPES OF INFUSION

• The user interface of pumps usually requests details on the type of infusion from the technician or nurse that sets them up:

- Continuous Infusion.
- Intermittent Infusion.

• Patient Controlled Infusion.

• Total Parenteral Nutrition.

CONTINUOUS INFUSION

• Consists of small pulses of infusion, usually between 20 nanoliters and 100 microliters depending on the pump's design.

• The rate of pulses depending on the programmed infusion speed.

INTERMITTENT INFUSION

• Has a "high" infusion rate.

• Alternating with a low programmable infusion rate to keep the cannula open.

• The timings are programmable.

PATIENT CONTROLLED

• Is infusion on-demand, usually with a pre-programmed ceiling to avoid intoxication.

• The rate is controlled by a pressure pad or button that can be activated by the patient.

• It is the method of choice for patient analgesia.

• Total parenteral nutrition usually requires an infusion curve similar to normal mealtimes.

5.2 TYPES OF PUMPS

• There are two basic classes of pumps.

• Large volume pumps can pump nutrient solutions large enough to feed a patient.

• Small-volume pumps infuse hormones, such as insulin, or other medicines, such as opiates .

Large-volume pumps

• Uses peristaltic pump.

• They use computer-controlled rollers compressing a silicone which the medicine flows.

• Another common form is a set of fingers that press on the tube in sequence.

Small-volume pumps

• Small-volume pumps use a computer-controlled motor turning a screw that pushes the plunger on a syringe.

• Some of the smallest infusion pumps use osmotic power.

• Basically, a bag of salt solution absorbs water through a membrane, swelling its volume.

• The bag presses medicine out.

• The rate is precisely controlled by the salt concentrations and pump volume.

• Osmotic pumps are usually recharged with a syringe.

Procedure:

- Perform patient assessment and record vital signs
- Assess patient meets criteria for the protocol.
- Ensure there are no contraindications to use any protocol.

- Hospital staff will draw up the medication or IV fluid to be infused and ensure the infusion pump is functioning properly.
- Prior to transport, the EMS personnel will confirm:
- The physician's written and signed order for the infusion
- The infusion pump has enough medication for the expected transport time
- The infusion tubing is properly connected to a three-way stop clock on the patient's intravenous line
- At some facilities, heparin can be infused via a syringe pump without being piggybacked into a running intravenous line
- The rate of infusion pump delivery has to be checked
- The volume of infusion already administered has to be checked
- If an alarm is displayed during transport, the attendant should attempt to correct the problem.
- If the problem is corrected, the alarm display message will disappear.
- If the problem cannot be remedied, the attendant should press the start / stop button to turn the infusion off.

5.2.1 MAINTENANCE OF INFUSION PUMP

• Always place pump and supplies on a clean surface.

• Keep food and drinks away from the area around the pump. • Monitor children when in the pump area.

Before touching the pump

– wash hands thoroughly for 15 seconds

– use liquid soap (not bar soap) and rinse – dry with a clean paper towel.

– Change tubing according to pump's Instructions for Use.

– Change batteries or recharge the pump as directed by healthcare provider

5.2.2 CLEANING OF UNIT:

Don't use organic solvents such as alcohol & thinner in cleaning.

- Before starting any cleaning, be sure to turn OFF the power & pull out the AC power cable.
- Power cord failure & cleaning.
- Check for any damage, deformation & chemical solution stuck in the connector unit.
- If any chemical solution has adhered onto the occlusion detector unit or airline detector or if either of them wipes it thoroughly with cotton swab softly.

Infusion pumps must be portable, since patients need to be mobile both within the hospital and at home. The devices must be battery powered, relatively small, and relatively lightweight. Designers, therefore, require solutions that minimize size and power consumption. Examples include the use of switching voltage regulators instead of linear regulators, even in low-energy power supplies, and the use of higher frequency switching supplies to minimize the size of external components.

5.3 INFUSION PUMP COMPONENTS

Pump Mechanism

Traditionally, stepper motors have been used in the pump mechanism to provide a precise flow rate. With angular-position sensors or Hall-effect sensors, it is possible to use DC motors instead. In these designs, the motors drive actuators (cams and fingers) to milk the tubing in precisely known fluid volumes per revolution of the mechanism.

Motor loading varies as the mechanism rotates. Motor load is affected by the position of the pump mechanism, fluid viscosity, and flow rate. To reduce power consumption, motor drive circuits can include motorload sensor signals that feed into a closed-loop control system to adjust the motor drive voltage. A variety of current-sense amplifiers, operational amplifiers, comparators, and filters are used to implement these closed-loop control systems.

Power Supplies

To maximize battery life, system designers use switch-mode voltage regulators for any significant power level. Switch-mode converters should run as fast as possible to minimize size and weight. Low-dropout linear regulators (LDOs) are used only in the very lowest power circuitry where their low efficiency can be tolerated, or where the output voltage of the LDO is not much lower than the input voltage, which keeps the efficiency high.

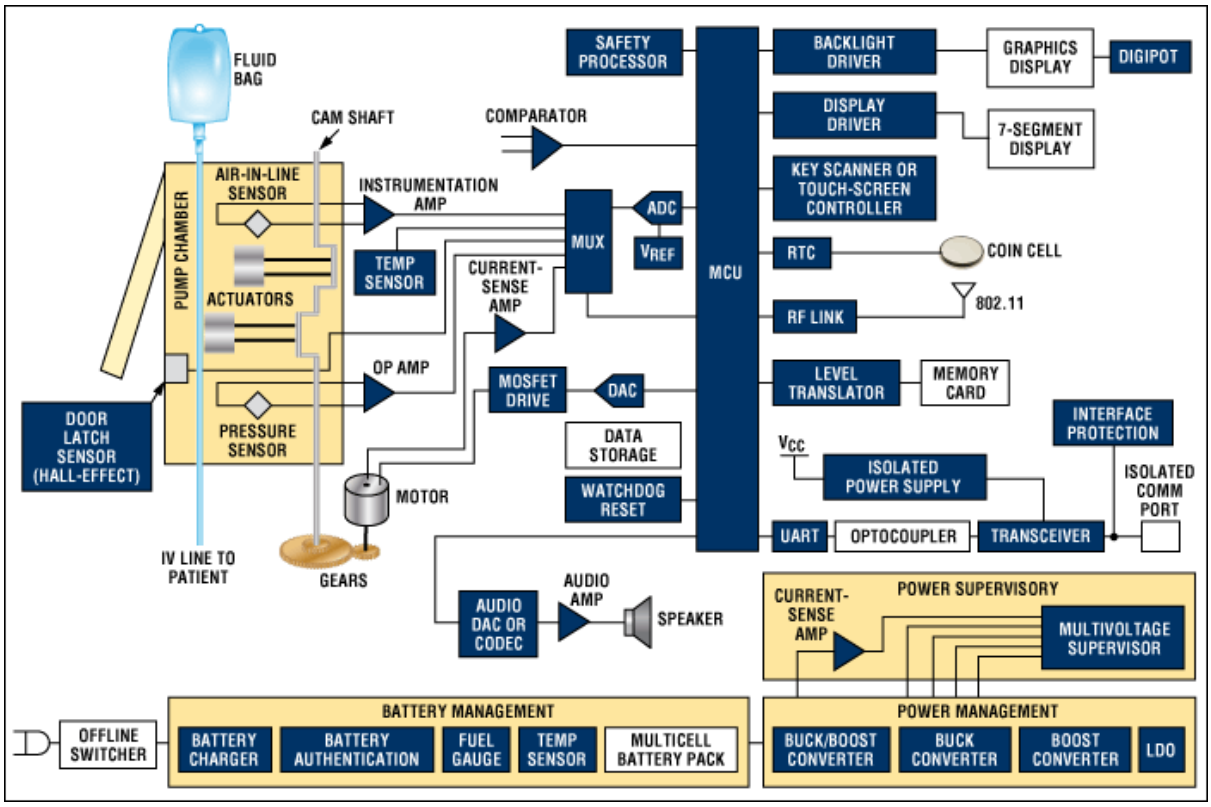
The use of fairly sophisticated processors places requirements on power supplies that can include voltage identification digital (VID) control from the central processing unit (CPU), fast load-step response, and precision low-voltage/high-current outputs. Digital-to-analog converters (DACs) and digital potentiometers are used in these power supplies when on-the-fly programmability is needed but VID control is not built into the regulator controller.

Because these are patient-connected devices and AC-line powered, they must meet UL® and IEC safety requirements. This means that the offline switching power supply must be designed and certified by these organizations for medical applications with patient connection.

Battery Management

Caregivers often need to transport patients while they remain on the IV, so the infusion pump must be able to operate from battery power alone for several hours. The use of rechargeable battery packs is mandatory.

The infusion pump absolutely must not run out of battery power; otherwise, it would stop pumping. Because of this, an accurate battery fuel gauge is required. Coulomb counting is the accepted method today, as voltage-sensing fuel gauges are not nearly accurate enough for this type of patient-connected equipment.



Functional block diagram of an infusion pump.

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User Interface

The user interface is used to program the flow rate and provides a wealth of information. In addition to the infusion rate, hospital units display parameters such as the fluid being infused, patient information, the health of the pumping system, the amount of battery life remaining, and alarm conditions.

On some wearable models intended for home use, the patient is expected to do the programming. These devices benefit from intuitive graphical user interfaces (GUIs) that guide patients through the programming process. These infusion pumps frequently have color displays and touch screens for user inputs. Visible, audible, and haptic responses to user touch inputs help designers improve the user experience. Advanced touch-screen controllers like the MAX11811 offer haptic feedback, touch processing to reduce bus traffic, and autonomous modes for precision gesture detection.

Flow rates can be programmed over a very wide range: 0.01mL/hr to 999mL/hr is typical. Due to a history of medication errors caused by pump programming errors, sophisticated software routines have been implemented in infusion pumps to warn users when unusual or dangerous infusion rates are selected.

Displays/Keyboards

Full-color, high-resolution, backlit liquid-crystal displays (LCDs) are the most common. Some pumps also incorporate auxiliary alphanumeric displays. Display self-test at power-up is an FDA requirement, so designers require drivers with built-in self-test features.

Self-Test and System Monitoring

All infusion pumps must perform power-on self-test (POST) to meet FDA requirements. This includes tests of all critical processors, critical circuitry, indicators, displays, and alarm functionality. Some POST operations can require user observations, but additional circuitry is used for self-checking to reduce the risk of undetected failures.

For example, some models use a safety processor to monitor the performance of the main processor and to generate an alarm if unexpected behavior is detected. Another example of self-test is the simple monitoring of current through light-emitting diodes (LEDs) as they are turned on and off. If currents fall outside the acceptable range, a fault is indicated. Probably the most common self-test is the watchdog timer (WDT). Microprocessor supervisors with WDT functions are commonly used to ensure that the processor executes within proper code boundaries. In medical devices, it is usually not acceptable to have the supervisor on the same IC as the microprocessor, as this approach would subject the supervisor to the same transient errors as the microprocessor.

Supervisory functions are critical for ensuring that the pump is operating properly during patient use. Microcontrollers (of which there are often several in a single pump) must be held in reset until all power supplies are within tolerance and stable. All power supplies are monitored with voltage supervisors for undervoltage and overvoltage conditions. Motor loading is monitored and motor-stall detection is provided. (Motor stall is a critical failure causing a top-priority alarm.) Because of the criticality of the system, often power-supply voltages are monitored with ADCs so that their exact value can be recorded periodically. ADCs are also needed for sensor readings, such as temperature, motor loading, IV line pressure, and battery voltage.

Temperature sensing is implemented in the battery pack, the power supply, the motor, and the display. Due to the high efficiency of these designs, fans are usually not needed. These pumps must be splash-proof, so it is difficult to put in openings for airflow.

Alarms

Infusion pumps require audible and visible alarms to alert users to faults or potentially dangerous conditions. Bicolor or tricolor (red/orange/green) LEDs are typically used as visual indicators. Audible alarms vary from simple beepers driven by the microcontroller's pulse-width modulation (PWM) output to more sophisticated alarms (such as voice synthesis) created with an audio DAC.

Even simple audio beepers should include a self-test feature. This function can be implemented either indirectly by monitoring for a speaker impedance within range or directly by incorporating a mic near the speaker to register the audio output and confirm that it is at the proper level.

Timekeeping

Due to the criticality of patient care, every event needs to be logged and time stamped. Every key press, every start and end of an infusion, every change of configuration (pump door opening/closing, AC power disconnect, etc.), and every reported fault condition needs to be logged and time stamped for later review in case of lawsuits or instrument malfunction.

A real-time clock (RTC) is required. Since other clock sources for microprocessors and digital circuitry are not especially critical, standard crystals can be used. If extreme accuracy is needed for the RTC, Maxim has RTCs with built-in temperature-compensated crystal oscillators (TCXOs) that achieve an accuracy of ±2ppm (0°C to +40°C), which is about two orders of magnitude more accurate than a standard crystal.

Electrostatic Discharge

All infusion pumps must pass IEC 61000-4-2 electrostatic discharge (ESD) requirements by either using electronics with built-in protection or by adding ESD line protectors to exposed traces. Maxim offers many interface parts with this high ESD protection built-in, as well as stand-alone ESD diode arrays.

Interfaces

Modern infusion pumps include interfaces to connect to hospital information systems. These are variously hardwired (RS-232, RS-485, USB, and Ethernet) and/or wireless interfaces (Bluetooth® and Wi-Fi®).

For wired interfaces, galvanic isolation is critical to meet the patient safety requirements of IEC 60601-1. Interfaces with unidirectional lines (such as RS-232, RS-485, RS-422) are not difficult to isolate. The only challenge is to create an isolated supply for them residing on the isolated side. An integrated device such as the MAX256 can solve this challenge by providing up to 3W of isolated power for isolated interfaces from a compact SO package.

5.4 IMPLANTED INFUSION PUMPS

Implanted infusion [in-fyu-shuhn] pumps are small devices placed under your skin during surgery. The pump sends liquid pain medicine through a thin, flexible tube (catheter) to a specific part of your body. Infusion pumps can provide targeted and consistent medicine to reduce pain. They are used when other methods don't work or when you need long-term medicines or fluids.

Delivers targeted medicine throughout the day to a specific part of your body

• Requires less medicine than other methods because the medicine doesn't have to go through the entire body

• Relieves chronic pain when oral, IV, or topical medicines fail

• Reduces side effects when compared to other forms of the same medicine

• Avoids the discomfort of catheters through the skin or injections directly into the spine

• Allows you to increase your activity level as you live with less pain and better symptom management

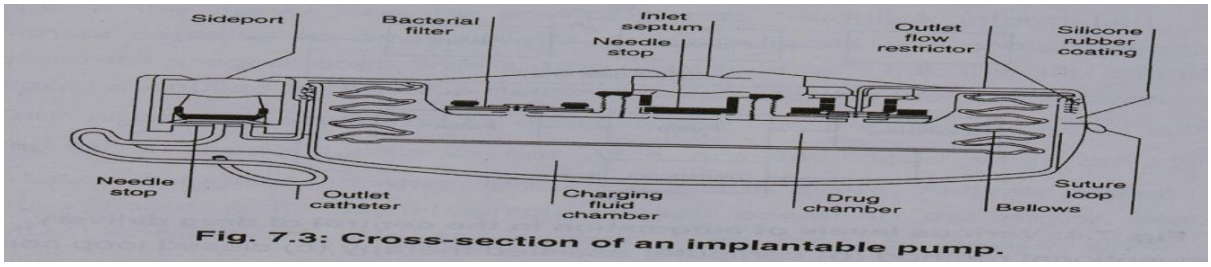


Fig. 7.3: Cross-section of an implantable pump.

5.5 SYRINGE PUMP

• Syringe pumps are particularly helpful under such circumstances as they are programmed to do deliver drug through the vein at a determined rate.

WORKING OF SYRINGE PUMP

• Syringe pump generally consist of a drum that is attached to a piston.

• The piston is operated by a motor through a drive screw or worm gear which helps in pushing the plunger of syringe in or out resulting in a smooth flow.

• The syringe is engaged on a clamp on the frame and the plunger of the syringe is displaced by movement of drum.

• Most of the syringe pump can work with different syringes of different diameters, but the diameter has to be entered in beginning to make sure correct volume is dispensed.

• These guidelines should be read from manufacturer guidelines, and made sure whether syringes with different diameter can be used.

• The user can set the parameters such as flow rate, dispense volume and syringe diameter.

5.6 INSULIN PUMP

Introduction:

• An insulin pump is a small, battery-operated, portable device about the size of a cell phone or a pager. It is worn externally either in the patient's pocket or on a special belt, or it can be concealed under the clothing.

• An insulin pump attempts to mimic the function of a normal pancreas that secretes insulin.

• Insulin pumps help diabetes patients control their blood sugar levels more efficiently and more easily. Diabetics generally prefer insulin pumps to daily injections.

• It is often prescribed to type 1 diabetes patients, and, in some cases, it may be prescribed to type 2 diabetes patients depending on the case.

Requirements for Safe and Effective Use of Insulin Pumps:

• The patient must be mentally stable and has a strong sense of responsibility. • The patient must commit to self-measuring glucose levels.

• Insulin doses must be determined based on blood glucose levels, the amount carbohydrates in meals, and daily activities.

• The patient must be capable of calculating carbohydrates.

Insulin Doses:

Insulin doses administered by an insulin pump are separated into:

• Basal rates: Basal insulin is delivered continuously throughout the day. It keeps blood glucose levels in range between meals and overnight. Often, patients' program different amounts of insulin to be delivered at different times of the day and night.

The Basic Components of an Insulin Pump:

1. A small device that consists of: • Buttons to program insulin delivery. • A display screen. • Battery. • Insulin reservoir.

2. Reservoir: A plastic box containing insulin. It is located inside the pump and it should be replaced every two to three days along with the tube.

3. Tube: A thin tube extending from the reservoir to the plastic needle that is inserted under the skin. The tip of the plastic needle (the cannula) is inserted by another small needle that is removed after the cannula is held in place and secured with a special adhesive patch. There are several different types of tubes for each pump, and they vary depending on the length of the tube and the depth of the plastic needle (cannula).

4. Infusion set: A tool that helps insert the plastic needle quickly and easily.

How an Insulin Pump Works:

Insulin pumps are programmed to automatically deliver certain amounts of fast-acting insulin that is stored in the pump's reservoir. Insulin is delivered to the body through a tube attached to a small plastic needle, which is inserted under the skin. This allows the skin to absorb insulin gradually. Insulin doses can be easily adjusted at any time.

Basic Patient Data Required for Programming Insulin Pumps:

An insulin pump is programmed by entering some basic information about the patient, such as:

- Target blood sugar level.
- Active insulin time.
- Insulin sensitivity.
- Levels of carbohydrates. In addition to the data required for programming constant basal rates and temporary bolus doses (when needed).

The Advantages of Using an Insulin Pump:

- It improves the patient's quality of life and makes it easier for them to live with the disease.
- Fewer injections and needles.
- Tighter control over blood sugar levels (it reduces the risk of low blood sugar and improves average blood sugar levels).
- Easier and more efficient insulin delivery (with the press of a button).
- Insulin pumps allow patients more flexibility with their meal choices, mealtimes, and daily activities.

The Disadvantages of Using an Insulin Pump:

- Insulin pumps can be expensive.
- Higher risk of skin infections and skin irritation.
- It may take the patient a while to adjust when switching from injections to an insulin pump.
- It requires the patient to check their blood sugar level at least four times a day.
- It can cause diabetic ketoacidosis due to pump malfunction if the tube gets blocked, as it prevents the body from getting enough insulin and causes blood sugar levels to increase.
- The length of the tube may cause the patient some discomfort.
- It can cause weight gain and fat accumulation if the patient fails to commit to recommended daily intake of calories.

General Guidelines:

- The tube of the insulin pump should be inserted in the same spots where insulin shots are supposed to be injected.
- It is recommended to change the insertion site every two to three days.
- The pump can be placed anywhere the patient finds appropriate (for example: It can be attached to the waistband on a belt, or

5.7 BABY INCUBATOR

- An incubator (or isolette) is an apparatus used to maintain environmental conditions suitable for a neonate (newborn baby).
- It is used in preterm births or for some ill full-term babies.

WORKING PRINCIPLE

- Light bulbs heat air in the bottom part of the incubator. The air passes over a container with evaporating water, so that its humidity increases.
- The warm, humid air then flows upwards (chimney effect) into the baby compartment. A thermostat in an exit hole compares the air temperature with the desired temperature.
- If it is too high, the light bulbs will be switched off; if it is too low, the bulbs will be switched on.
- The baby can be viewed through plexiglass and it can be handled via two armholes with sleeves.
- The plexiglass front and top can be hinged back for full access.

PARTS OF INCUBATOR

- FAN the fan is used for disinfection and fumigation.
- HEATER the heater is adjustable and helps maintain an infant's core body temperature. the temperature is always monitored through a temperature controller. once set, the heater regulates itself just as a thermostat does on a home heating unit.
- AIR DISTRIBUTORS Air distributors distribute air evenly to ensure equal temperature throughout the incubator. this prevents spaces of cold or stale air.
- CANOPY The canopy is a clear, acrylic covering that protects the baby from the outside world and harmful germs that may infect the child. It also makes the perfect warm and oxygenated environment for a baby that's similar to a mother's womb.
- FILTERS Filters clean the air before it is pulled into the incubator, preventing harmful particles from entering the incubator and possibly infecting the infant's lungs.
- HYGROMETER This part of the incubator measures the amount of humidity inside the incubator. It's also responsible for breathing warm and humidified air into the baby's lungs through endotracheal tubes that run from the baby's nostril into the lungs.
- INLETS Inlets allow the administration of oxygen, medications and IV fluids.
- PORT HOLES Port holes allow nurses and caretakers to handle the baby without contaminating the infant's environment. Port holes are holes sealed with rubber gloves that you must insert your hands into in order have limited and contamination-free access to the inside of the incubator.
- RESPIRATORY TUBING (MECHANICAL RESPIRATOR) These tubes are usually endotracheal (inserted through the nostril for access to the lungs) and are a way to provide artificial oxygenation to an infant.

- PARAMETERS MONITORED
- ECG MONITORING Three electrodes are placed on the babies chest for ECG continuous monitoring. The same electrodes that are used for ECG monitoring are also used for respiration monitoring, since PMS can measure and display both the ECG and the respiration rate.
- MONITORING OF SKIN Premature infants' skin has fewer layers of stratum corneum, hence it is very permeable. Babies's skin may have oedema It has less collagen and fewer elastic fibres in the dermis, little subcutaneous fat. The babies' skin does not sweat, it is non-keratinised. There is a risk of injuries and infection
- NEONATAL JAUNDICE Phototherapy lights are used when babies are jaundiced (yellow). Some degree of jaundice, which is caused by the presence of a molecule called bilirubin in the blood, is common and even normal newborns. However, in sick infants, jaundice can result from a variety of problems, and when jaundice is extreme it can cause brain damage. Certain wavelengths of light (in the blue part of the spectrum) can cause a chemical reaction that converts bilirubin into a harmless form as blood passes through the skin.
- TEMPERATURE & HUMIDITY MONITORING • Temperatures range around 30 to 37ºc, humidity levels range from 50 to 90%, depending on the babies size and age. • The incubator keeps the baby warm with moistened air in a clean environment, and helps to protect the baby from noise, drafts, infection, and excess handling.
- APPLICATIONS • oxygenation. Infant respiratory distress syndrome is the leading cause of death in preterm infants, • observation: modern neonatal intensive care involves sophisticated measurement of temperature, respiration, cardiac function, oxygenation and brain activity. • protection from cold temperature, infection, noise, drafts and excess handling. enclosed in plastic, with climate control equipment designed to keep them warm and limit their exposure to germs. • provision of nutrition, through intravenous catheter. • administration of medications. • maintaining fluid balance by providing fluid and keeping a high air humidity to prevent too great a loss from skin and respiratory evaporation
- EQUIPMENT & PATIENT PREPARATIONS BEFORE USE PREPARE THE INCUBATOR • pre-warmed to a temperature appropriate to the infant's age, size and condition. • use in air mode and must always be switched on with the motor running if in use for a baby. • check and record the incubator temperature hourly. • position it away from direct sunlight
- CARE OF BABY Maintain axilla temperature between 36.5°C and 37.2°C Access baby by using the portholes, limit opening of large door as this interferes with air temperature. Ensure baby is nursed naked apart from a nappy. Position baby utilizing rolled towels/cloth nappies to provide boundaries that support 'nesting' and flexion of limbs but keeping face clear

- EXPLAIN TO PARENTS/CAREGIVERS THE PURPOSE OF AN INCUBATOR FOR THEIR BABY

  Ensure they are familiar with how to access baby as it is optimal for parents to continue to touch and provide comfort. Maintain a quiet environment There is no tapping on the canopy. No equipment is placed on top of the canopy. Careful opening and closing of doors.

5.8 PHOTOTHERAPY

Phototherapy (light treatment) is the process of using light to eliminate bilirubin in the blood. In the standard form of phototherapy, the baby lies in a bassinet or enclosed plastic crib (incubator) and is exposed to a type of fluorescent light that is absorbed by the baby's skin. During this process, the bilirubin in the baby's body is changed into another form that can be more easily excreted in the stool and urine. The light is administered for a prescribed amount of time and, in some cases, at a specific time of day.

During this type of phototherapy:

-The baby is undressed so that as much of the skin as possible is exposed to the light.

-The baby's eyes are covered to protect the nerve layer at the back of the eye (retina) from thebright light.

-The bilirubin level is measured at least once a day.

Another type of phototherapy is a fiber-optic blanket or a band. These devices wrap around a baby and can be used at home. Although fiber-optic phototherapy has been shown to reduce bilirubin levels, it takes longer than conventional phototherapy done in a hospital setting. It can be a good alternative for babies with mild jaundice who are otherwise healthy.

Potential problems that may occur during this standard form of phototherapy include:

-Skin rash.

- Damage to the nerve layer at the back of the eye (retina), if the eyes are not properly protected.

-Dehydration, if the infant does not receive adequate fluids when feeding.

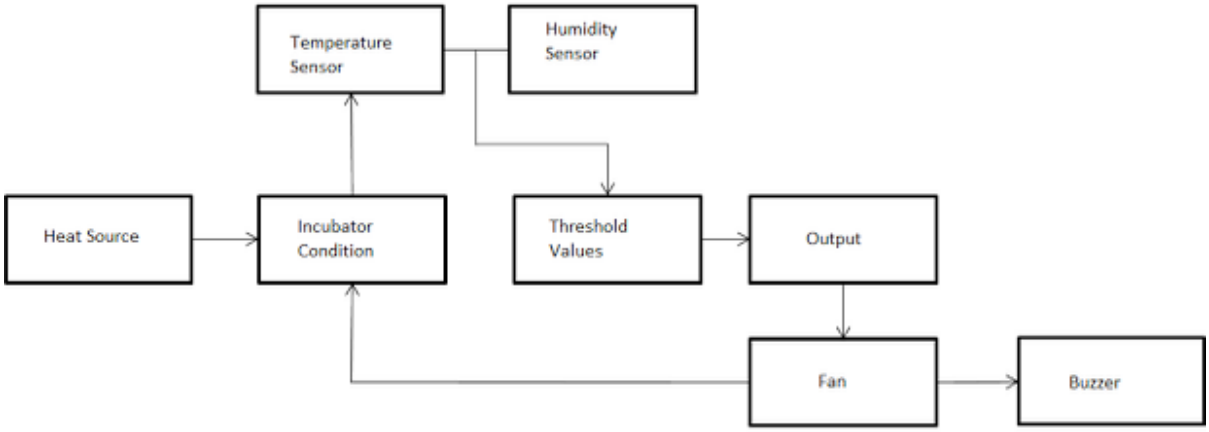
-Difficulty in maintaining the proper body temperature.

5.9 RADIANT WARMER

Radiant Warmer, is a body warming device to provide heat to the body. This device helps to maintain the body temperature of the baby and limit the metabolism rate. Heat has a tendency to flow in the heat gradient direction that is from high temperature to low temperature. The heatloss in some newborn babies is rapid; hence body warmers provide an artificial support to keep the body temperature

constant. In certain areas with very cold climate, babies are kept on Radiant Warmer for couple of hours immediately after birth to ensure the baby is stabilized after birth.

Radiant Warmers consists of an open tray (where the baby is kept) and the artificial heating is provided by a heating mechanism mounted overhead. The heating mechanism consists of quartz which produces the desired heat and a reflecting mechanism to divert the heat at the baby tray. The skin temperature of the baby can be monitored by a temperature measuring knob that is kept continuously attached to the body. The variation in the skin temperature can be seen on a small LCD panel which continuously shows the body temperature. Radiant warmers are equipped with alarm to indicate the change in temperature and hence attract attention of medical professional attending the baby. The heat generated can be controlled manually by a knob as well as automatically depending on the Radiant Heat Warmer.



Radiant Warmers can be manual or automatic (servo system – heater output is determined automatically based on skin temperature. The skin temperature is set at 36.5 degree Celsius) depending on the mechanism that the manufacturer employs for temperature control. The heat generated and the temperature of the skin can be individually seen but the basic difference

between these two models will be the regulation of temperature. The automatic model increases the heat output in small predetermined steps to reach at the desired temperature of the body. The device may seem simple to handle, but it is always recommended to have a proper training and read the manufacturers guidelines for person handling this equipments. It is necessary to regularly clean and disinfect the instrument.

Lack of attention to thermoregulation continues to be a cause of unnecessary deaths in the neonatal population. Maintaining a stable body temperature is essential to ensure optimal growth. If temperature is maintained, caloric expenditure and oxygen consumption is minimal. Newborn babies, in particular the preterm and the low birth weight are exquisitely predisposed to hypothermia. No other equipment is identified more with the special care of newborn babies than the radiant warmers. They provide

intense source of radiant heat energy. They also reduce the conductive losses by providing a warm microenvironment surrounding the baby. The radiant warmer (also called open care system) was developed as an 'open incubator' that ensures ready access to the baby. The overhead quartz heating element produces heat which is reflected by the parabolic reflector on to the baby on the bassinet. The quantity of heat produced is displayed in the heater output display panel. Temperature selection knobs select the desired skin temperature. This information is processed by the microprocessor inside the control panel and matched against the actual temperature of the baby. If the temperature of the baby is lower than the set temperature, the microprocessor will send feedback to the quartz rod heater to increase the heat output till the baby's temperature reaches the set temperature. At this point, the heater output will be reduced. This system in which the heater output is determined automatically based on skin temperature information is called servo system. Servo system is the preferred method of running the open care system. The heat output from the quartz heating rod could also be increased or decreased manually. This is done by the heater output control knobs. This is called the manual mode of operation. Whenever the baby's temperature rises by more than 0.5°C above the set temperature, a visual/audible alarm is activated in the servo mode. Caregiver can pay attention to sort out the fault. Often this occurs when the skin probe comes off the baby.

Parts of open care system • Bassinet For placing the neonate • Quartz rod Provides radiant heat • Skin probe When attached to the baby's skin, displays skin temperature • Control panel Has a collection of display and control features/knobs • Heater output display Indicates how much is the heater output • Heater output control knobs for increasing or decreasing the heater output manually

- Temperature selection panel Select either set temperature or skin temperature
- Temperature selection knobs Select a desired set temperature
- Temperature display: Display temperature as selected, either of the baby's skin (via skin probe) or the set temperature
- Mode selector Selects manual or servo mode

Heater assembly

The heating element (silicon quartz/infrared/ceramic/quartz crystal), the control panels (electronic/electrical/microprocessor based) and alarms (air over temperature/skin over temperature/air sensor fail/power failure etc.) forms the basic unit of all the warming devices. Power consumption is around 750 watts. In good equipment, temperature stability is usually with an accuracy of ± 0.5°C.

Steps for use of warmer

1. Connect the unit to the mains. Switch it on.
2. Select manual mode.
3. Select heater output to 100% for some time to allow quick pre-warming of the bassinet covered with linen.

4. Select servo mode.
5. Select the desired set temperature of baby as 36.5°C.
6. Place baby on the bassinet.
7. Connect skin probe to the baby's abdomen with sticking tape.
8. If you want the manual mode to be used in the baby, select the desired heater output.
9. In manual mode, record baby's axillary temperature at 30 minutes and then 2 hourly.
10. Respond to alarm immediately. Identify the fault and rectify it.

Application of skin probe

Do's

1. Prepare the skin using an alcohol/spirit swab to ensure good adhesion to the skin. 2. Apply probe over the right hypochondrium area in the supine position. 3. Apply probe to the flank in the prone position. 4. Check sensor probe regularly so as to ensure that it is in place. Ensure that skin probe is free of contact with bed. 5. Cover probe with a reflective cover pad, if available (foil covered foam adhesive pad). 6. Ensure that the area where probe is applied is dry.

Don"t

1. Do not apply to bruised skin.

2. Do not apply clear plastic dressings over probe.

3. Do not use fingernails to remove skin surface probes.

4. Do not reuse disposable probes. Use of cling wrap to decrease insensible water losses Use of cling wrap (transparent polythene used for covering fruits or vegetable for storage) over the baby, tied across with the panels of warmer has been shown to reduce insensible water losses and result in better thermal control for VLBW babies

Potential pitfalls of servo-controlled warmer

In the event of displaced probe from baby's abdominal skin, overheating of the baby will occur because the skin probe depicts air temperature and heater output keeps on increasing till probe temperature matches control temperature. In servo mode repeated activation of alarm will occur when baby develops fever. In this situation, one should shift to manual mode with least heater output.