UNIT V

RECENT TRENDS IN MEDICAL INSTRUMENTATION

Thermograph, Endoscopy unit Laser in Medicine, Diathermy unit, Electrical safety in Medical Equipment.

THERMOGRAPH:

Thermography is the process of recording true thermal images of surface of objects under study. In medicine, it displays image representing the thermal radiation of skin areas. Thermogram contains both qualitative and quantitative information relevant to the image and to temperature.

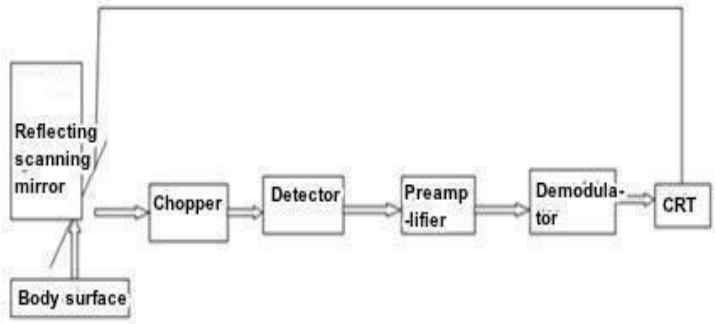

Fig5.1: Simplified Block Diagram of a Thermo Graphic Equipment [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Every thermo graphic equipment is provided with a special Infrared camera that scans the object and Display unit for displaying thermal pictures on screen. The camera contains an optical system in the form of an oscillating flat plane mirror which scans at a very high speed and focuses the collected infrared radiation onto the chopper. The chopper disc interrupts the infrared beam so that A.C signals are produced, amplified and demodulated further. The demodulated signals are given to the cathode ray tube in synchronization with scanning mechanism.

1. Infrared Thermography

2. Liquid crystal Thermography
3. Microwave Thermography

Infrared Thermography:

Human skin emits infrared radiation as an exponential function of its absolute temperature and emissive properties of skin temperature. The radiant energy is emitted in a broad band of wavelengths with maximum emission dependent upon surface temperature.

Photovoltaic and Photo- conductive infrared radiation detectors are commonly used. The operation of a thermography apparatus is as follows. A chopper is inserted infront of a Infrared radiation detector. Infrared radiation from body and from block body enters the detector surface through optical focusing system alternately by chopper to compare the both.

A good thermography equipment must have

- Short frame time
- High resolution
- A small size and light weight optical head
- A wide spectrum band detector
- An easy handling instrument in wards or operation rooms
- Containing interfaces for image processing
- Absolute temperature can be measurable

Solid state electronic circuits can achieve the above said things. There are two types of infrared cameras for medical purpose. a] High speed b] High resolution.

Infra eye, Thermoscope, Thermoviewer, Thermocamera and Infra vision are of the thermographic equipments.

Liquid Crystal Thermography:

Liquid crystals are a class of compounds which exhibit colour-temperature sensitivity in cholesteric phase. Scattering effects with the material give rise to iridescent colours, dominant wavelength being influenced by very small changes in temperature. The high temperature sensitivity makes cholesteric liquid crystals useful for thermal mapping.

i. Red for relatively low temperature.
ii. Violet for high temperature.

In Infrared thermograms violet colour is used to identify low

temperature regions and the bright colour or red for high temperature regions

Microwave Thermography:

Microwave emission intensity from skin surface is very small when compared with infrared radiation intensity. Modern microwave radiometer can defect temperature change of 0.1k. Measurement of temperature by this corresponds to radiations from the skin surface to a depth of several cm.

The error lies in the order of 1-2k. The problem has been solved by adding artificial microwave noise from the antenna, thus providing a radiation balance between the receiver and body surface. Hence a temperature sensitivity of 0.1k could be obtained. To design a thermographs, we must the choice of

- Detector and its response
- Parameters of optical system
- Scanning mechanism
- Time constant of total system
- Method of data presentation

Medical Application of Thermography i]Health cases

The distribution of a health person's skin temperature is symmetrical. This is true with regard to head, face & limbs.

ii] Tumors

In case of benign tumors, difference in temperature with the surrounding tissues is very small, about 1 ^{0}C.

iii] Inflammation

The area of an acute inflammation shows a high temperature because of active metabolism and increase in local blood flow.

iv] Diseases of Peripheral Vessels

When the arteries are occluded, blood flow of peripheral vessels either decreases or disappears resulting a low temperature in that part.

v] Burns and Perniones:

In the treatment of burns and perniones, the first thing to do

is deciding on their degree of serenity.

vi] Skin Grafts and Organ Transplantation

The condition of skin grafts after transplantation can be detected by means of local blood flow.

vii] Collagen Diseases

Collagen diseases are usually attended with peripheral vascular discarders.

viii] Orthopedic Diseases

Fractures, arthritis, bruises and sprains can be easily diagnosed because the local skin temperature rises in these cases.

ix] Brain and Nervous diseases

Temperature distribution can be quantitatively diagnosed by means of thermogram.

x] Hormone diseases

Thyroid glands normally register high temperature due to their active metabolism. Patients affected with hyper thyrodism have high temperature.

xi] Examination of placenta attachment

Detection of location of placenta is possible by means of thermogram because increase in local blood flow leads to a high temperature.

Notes:Theremography- Heat camera in Medicine‘ is useful as a screening procedure and can be used to diagnose breast cancer.

ENDOSCOPES

Optical fibers play a vital role in medical field. Endoscopes or fiberoscopes are designed with low quality, large diameter and short silica fibers. Broncho fiberoscopes, gastrointestinal fiberoscopes and laproscopes are the important endoscopes. Endoscopes are used in hospital for examination, treatment of diseases and surgery.

There are two types

1. Flexible
2. Rigid

In each endoscope, there are two fiber bundles.

A typical glass fiber consists of a central _core‘ glass having

high refractive index surrounded by a cladding made of glass of slightly lower refractive index. The numerical aperture (light collection efficiency) of the fiber is equal to $(n_1^2 - n_2^2)^{1/2}$ where n_1 & n_2 are refractive index of core and cladding respectively.

Endoscopic Laser Coagulator

It uses argon ion laser as high energy optical source and endoscope as the delivery unit. Argon ion lasers are very useful for the coagulation of blood vessels since its green light is highly absorbed by red blood vessels and hemoglobin.

To control gastric haemorrhage photocoagulation technique is adopted. In fiber optic endoscope, output from argon ion laser is delivered to required spot to arrest the gastric bleeding.

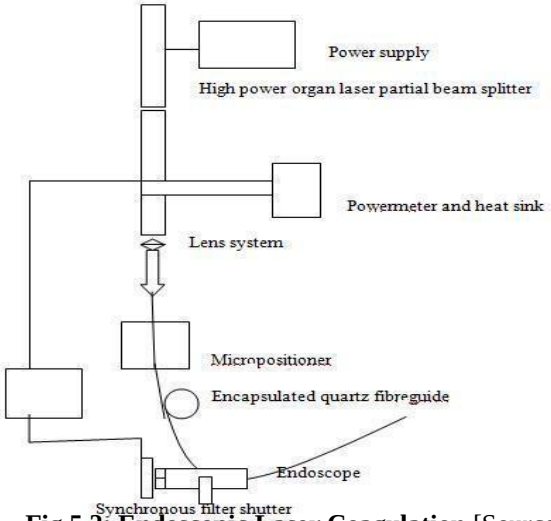

Fig 5.2: Endoscopic Laser Coagulation [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

LASER IN MEDICINE

LASER- Light Amplification by Stimulated Emission of Radiation Basic principle of laser action. Laser beam consists of high intense radiation in unique direction without spreading its energy in other direction. It has high mono chromaticity and high directionality.

Population of atoms in higher energy level is smaller than the lower energy level in an atomic system. During population inversion, the number of atoms in the higher level is more than the number of atoms in the ground level. This can be done by pumping source. Assume that there is population inversion such that the atom in the higher metastable energy level is more.

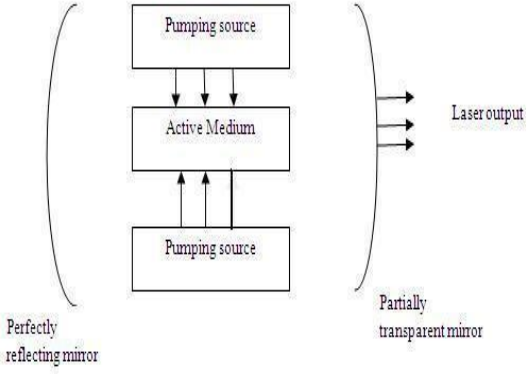

Fig5.3: Laser Principle [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

There are two type of emission

1. Spontaneous emission
2. Stimulated emission

In the case of spontaneous emission, the emission takes place without any inducement. (i.e) Transition from high energy state to any lower energy state takes place voluntarily with the emission of polychromatic radiation. A photo emitted by spontaneous emission has an energy equal to energy difference between laser transmission levels.

Hence laser output can be obtained. The biomedical applications of laser are based on the fact that lasers could produce high photon flux on a localized spot.

The properties of the laser are

- Monochromaticity
- Spatial & Temporal coherence
- Directionality

- Brightness

When light photons fall on the tissues, four bask optical processes may occur

i. Direct reflection at the boundaries of the layer due to change in the refractive index
ii. Scattering by molecules, particle, fibers, cell organelle and cells within the layer
iii. Absorption
iv. Direct transmission through the layer

All the above process depend on

a. Wave of laser
b. Energy density
c. Pulse duration
d. Irradiation time
e. Absorption characteristics of target molecule

The laser photon of wavelength of 600 – 1300 nm can penetrate deep into tissues and that fact is used for phototherapy and selective surgery.

Laser Instrumentation

Laser irradiation of patients with skin tumors is performed in a specially designed operating unit which consists of three

It is intended for remote control unit. The operation can be absorbed by means of a television arrangement.. Lasers are equipped with water cooling system. The energy of radiation is indicated by energy meter and the irradiation time is controlled properly by a timer. The rooms are equipped with warning signal circuits and a blocking system that presents the laser system from working unless the doors of that room are closed.

Advantages of Laser surgery

a. Highly sterile
b. Highly localized & precise
c. Noncontact surgery
d. Dry field, almost bloodless surgery
e. Clear field of view and easy access in confined areas

f. Prompt heating with minimal post operative swelting and scarring

Medical Application of Laser

a) Photothermal Application

Laser heating of tissues is used for two surgical functions. Cutting and photo coagulation. Cutting was used in ophthalmology. It is used to treat variety of eye problems, including retinal bleeding, excessive growth of blood vessels in the eye caused by diabetes and also for spot welding. Spot-welding - Reattaching retinas from back surface of eye, choroid.

b) Photochemical Application

Laser can be used to diagnose and treat diseases non-surgically. Low power lasers can induce more chemical, enzymatic and metabolic changes in human body.

DIATHERMY

Introduction

Operation theatre equipment are very useful both diagnostically and therapeutically.They are mainly useful for monitoring and treatment purpose. During operation, the patient's condition is followed carefully by measuring variable like blood flow velocity, cardiac output, blood pressure, P_H value.

Surgical Diathermy

Diathermy is the treatment process by which cutting, coagulation of tissues are obtained. When high frequency current of 1-3 MHz is applied, heating of tissues takes place. The evolving steam bubbles in the tissues continuously rupture the tissues and by that way cutting action is obtained.

The various electro surgery techniques using diathermy unit are

1. Fulguration

When the electrode is held near the tissue without touching it and due to the passage of electric are, destruction of superficial tissues take place. It is related to the localized surface level destruction of tissues. Needle or Ball electrodes are used.

2. Desiccation

The needle point electrodes are stuck into tissue, while passing electric current a local increase in heat creates drying of

tissues.

3. Electrotomy

When the electrode is kept above the skin, an electrical are is sent. The developed heat produces a wedge shaped cutting of tissue on surface. Continuous R.F current is used for cutting.

4. Coagulation

When the electrode is kept above the skin, high frequency current is sent through the tissues in the form of bursts and heating it locally so that it coagulates from inside.

5. Blending

When the electrode is kept above the skin, the separated tissues can be combined together by an electric arc. This is called blending.

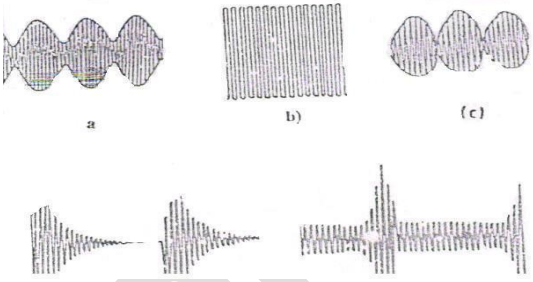

Fig.5.4: Different Types of Waveforms used in Electrosurgical Diathermy Unit

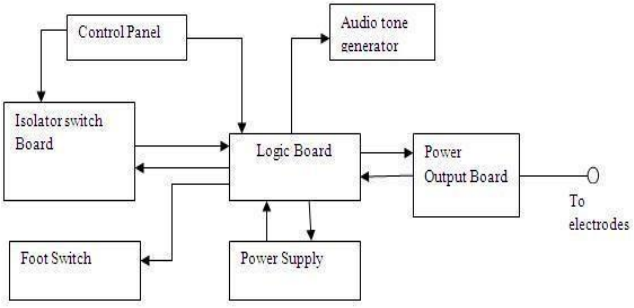

Fig5.5: Block Diagram of Electrosurgical Diathermy Unit [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Logic board is the main part of the unit which produces the necessary waveforms for cutting, coagulation and hemostasis mode of operation. An astable multivibrator generates 500 KHz square pulses. The outputs divided into a number of frequencies using binary counters.

Special Features

(i) To secure safety for the patient or operator, the output unit is isolated and insulated from the low frequency primary and secondary voltages.

(ii) The bipolar electrodes are used such that the active electrode is mounted in an insulated handle and in different electrode is placed at the back of patient in the form of plate.

(iii) The output of the unit may be earth referenced or isolated. The isolated output dose not produces any fibrillation and any serious burns.

Short – Wave Diathermy

The heating of tissues is carried out at a high frequency of 27.12 MHz and a wavelength of 11 m. By using currents with very high frequencies, the motor nerves are not stimulated and there is no contraction of muscles. Thus there is no discomfort to the patient.

The output of R.F oscillator is applied to the pair of patient electrodes. The R.F energy heats the tissues and promotes the heating of injured tissues and inflammations.

When R.F current applied to the pads, the dielectric loss of the capacitor produces heat in the intervening tissues. This technique is called condenser or capacitor method. In inductive method, a flexible cable is coiled around the arm.

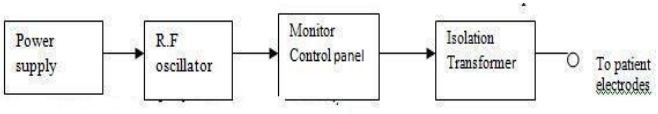

Fig5.6: Block Diagram of Short Wave Diathermy Unit [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Instead of continuous R.F wares, R.F pulses of 65 μs with on interval between pulses of 1600 μs are also used. This is called Dia-pulse shortwave diathermy.

Microwave Diathermy

The frequency used is 2450MHz and wavelength of 12.25 cm. heating of tissues is produced due to adsorption of microwave energy. Better therapeutic results are obtained by using microwave diathermy than short wave diathermy. There is no pad shaped electrode. Microwaves are transmitted into the body directly. Magnetrons are used to produce microwaves.

Ultrasonic diathermy

Ultrasonic therapy is used where short wave treatment is failed and where localization of heat effect is desired. It is very helpful to cure the diseases of peripheral nervous system.

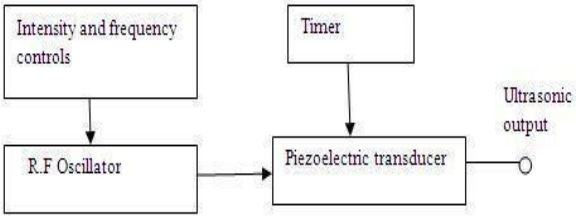

Fig5.7: Block Diagram of an Ultrasonic Diathermy Unit [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

R.F oscillator produces a high frequency alternating current which excites the piezo electric transducer. The ultrasonic waves can be applied in contained or pulsed mode. In

ELECTRICAL SAFETY IN MEDICAL EQU PMENTS

The physiological effects or shock range from discomfort to injury to death, if the heart or respiratory systems are affected. An electrical shock is an unwanted physiological response to current.

Microshock and Macroshock

Macroshock

A physiological response to a current applied to the surface of the body that produces unwanted stimulation like muscle contractions or tissue injury is called macroshock. All hospital patients and medical attendants are exposed to macroshock from

defective electric devices and biomedical equipment.

Microshock

A physiological response to a current applied to the surface of heart that results in unwanted stimulation like muscle contraction or tissue injury is called microshock.

Electrical Accidents in Hospitals.

One of the main hazards connected with the use of medical equipment is electrical shock. A macroshock may cause secondary injury to a limb of technician repairing equipment, such as acts on hand as the person pulls away from equipment.

Table 5.4: skin Resistance at 50 Hz

Condition	Skin resistance per Square Centimeter of Electrode
Dry Skin	93.0k Ω
Electrode gel on skin	10.8k Ω
Penetrated skin	200.0Ω

All electrical and electronic devices in the hospitals are sources of potentially harmful current. The electrical power has consists of three wires a hot wires H‘, a neutral wire N‘and a ground wire G‘.

Microshock hazards

Many devices have a metal chassis and cabinet that can be touched by the medical attendants and patients. If they are not ground then an insulation failure or short circuit result and leads to macroshock or microshock.

a) Leakage currents

Most of the accidents occur due to improper grounding and leakage currents, the leakage currents are an extraneous current flowing along a path. This dangerous accident arises because of open ground of the pacemaker by using a two wire extension cord. The leakage current flow is due to

- Undergrounded equipment
- Broken ground wire
- Unequal ground potential

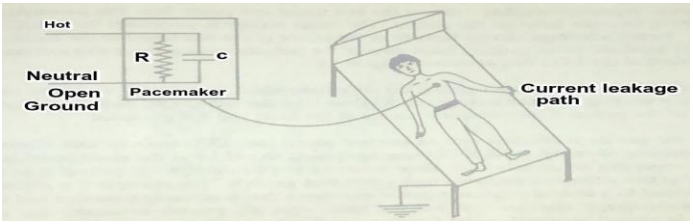

Fig5.8: Microshock due to leakage current [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Even if the three wire (H, N, G) power cord is used with the broken ground wire connection, then the above accident could be occurred. For example the doctor it holding a pacemaker wire by his one hand touching the electrical bed frame by his other hand as shown in fig.

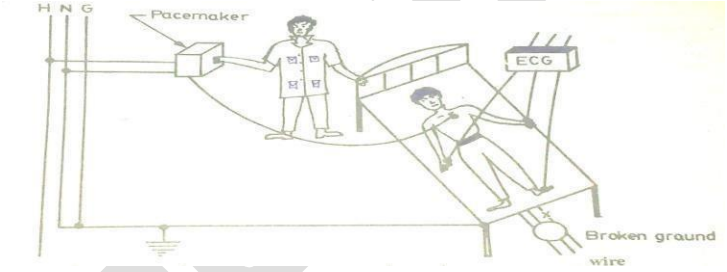

Fig5.8: Microshock for the Patient from the Broken Ground Wire [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Broken ground connection on the electric bed allows a voltage to exist on the frame due to capacitive coupling between bed frame and power line. The pacemaker wire is going into the heart of patient.

b) Static Electricity

Static electricity may be dangerous to people and sensitive equipment having integrated circuit. Sparks from static electricity could ignite flammable gases causing an explosion. Shocks from static electricity could cause cardiac arrest if applied to a pacing catheter. Floor carpeting is very common source of static electricity

charge buildup.

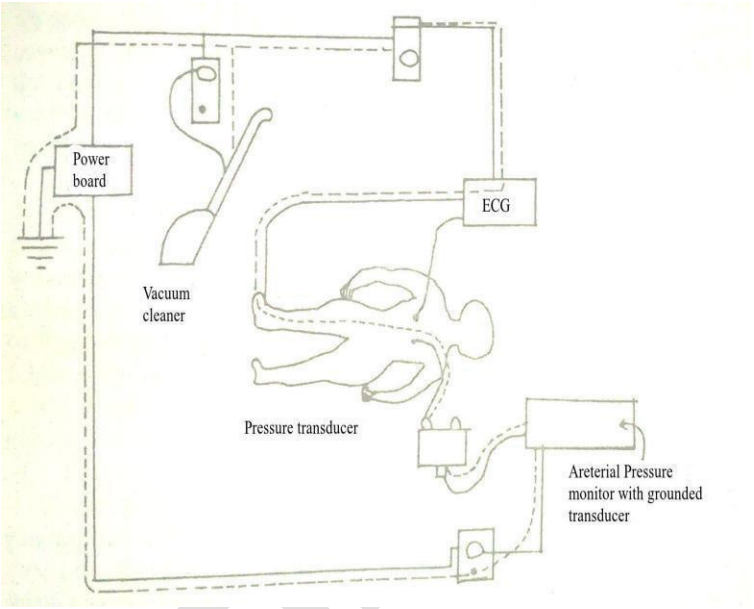

Fig5.8: Microshock from static electricity [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

c) Interruption of Power

Interruption of electrical power to life support equipment can also be hazardous. If a delay occurs before emergency power is brought into operation, the failure of a respirator monitor, defibrillator, pacemaker can be fatal.

Macroshock hazards

Macroshock occurs more often with two-wire system than with three-wire system. If the patient touches H and N wires simultaneously with two limbs, then the currents are flowing directly through vital organs of circulation and respiration. N wires are internally grounded, hence touching H and G wires can produce macroshock.

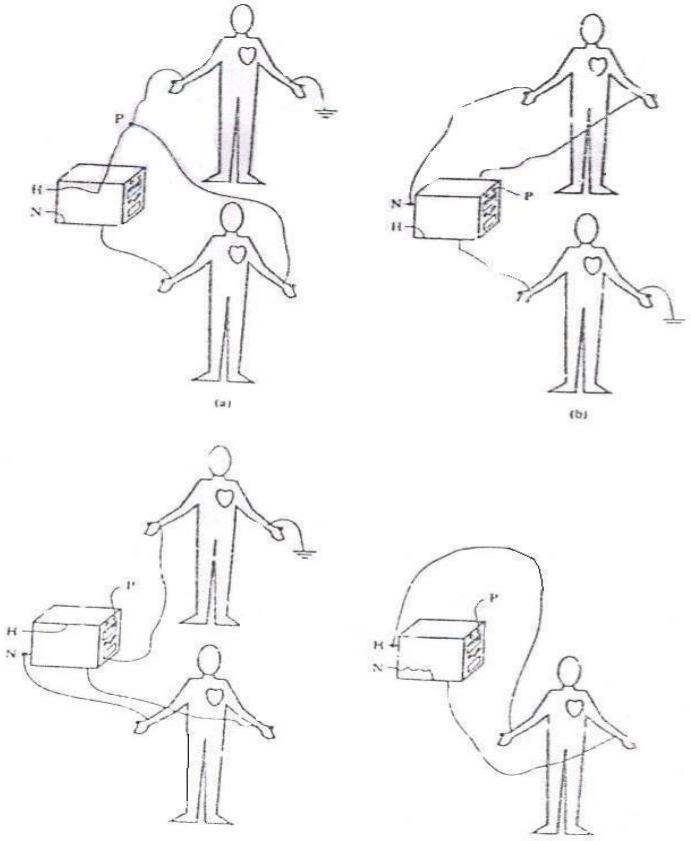

Fig5.9: Microshock Situations in the Case of Two Wire Units [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Fig illustrates additional hazardous situations that result from faults which occur in the equipment. In part (a), H lead shorts to patient lead P. Thus a macroshock result if the patient touches ground or chassis.

DEVICE TO PROTECT AGAINST ELECTRICAL HAZARDS

Several devices are available to protect patient and health care workers from hazardous electrical currents.

Ground Fault Interrupter

A ground fault interrupter (GFI) protects against a shock that occurs if a person touches the hot lead with one hand and ground with the other.

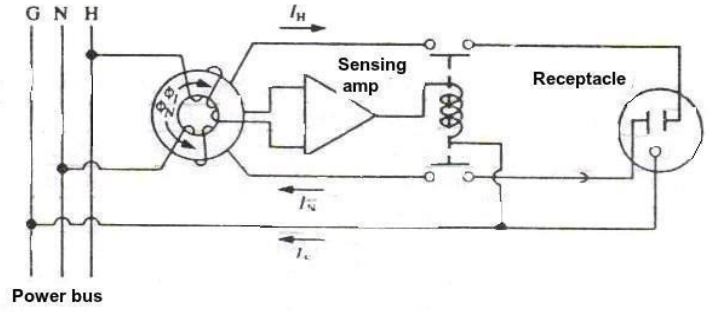

Fig5.10: Ground Fault Interrupts [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

When the system is normal $I_N = I_H$

The magnet flux φ in the coil cancels.

Sensing coil does not have a voltage induced in it

When the hot lead faults or is touched by a person, the fault current. If is shunted to ground. $I_N = I_H - I_F$

I is not equal to I

The corresponding fluxes in the coil are unequal and a net flux exists in the coil which induces a voltage into sensing amplifier.

Isolation Transformer

Isolation transformer provides a second means of protecting against an H lead to G-lead macro shock. It prevents sparks when H lead touches ground, particularly protection in an explosive or flammable environment. Fig (a) shows that a fault such as a short circuit from either secondary lead of transformer to ground will carry no current.

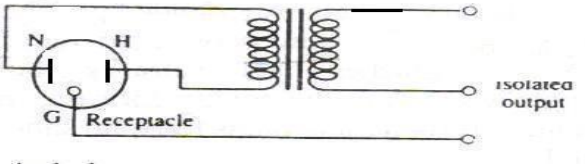

Fig 5.11: An Isolation Transformer [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Line Isolation Monitor:

A line isolation monitor (LIM) puts relatively large impedance from either secondary lead through an ammeter to ground of isolation transformer. If there is a conductive path through the equipment as shown in fig (b) the meter in the LIM will read a current.

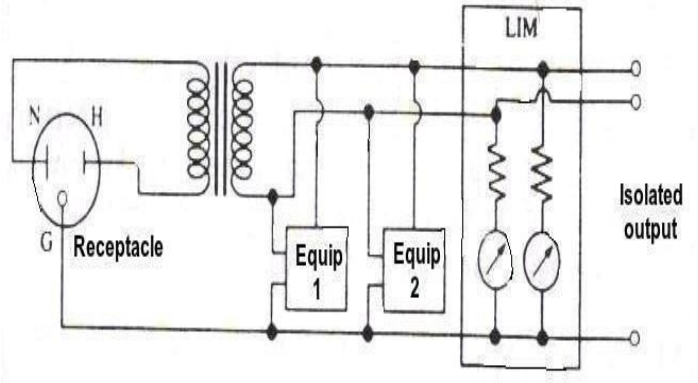

Fig 5.12: An Isolation Transformer Connected to a Line Isolation Monitor and Other Equipment [Source: Leslie Cromwell - Biomedical instrumentation and measurement]