Ethiopian TVET-System

Basic Biomedical Equipment Servicing Level II

Based on May 2011 Occupational Standards

October, 2019

Module Title: Maintaining and Repairing Biomedical Equipment Instrumentation system

TTLM Code: EEL BES2 TTLM 0919v1

This module includes the following Learning Guides

LG41: Plan and prepare for maintenance/ repair

LG Code: EEL BES2 M10 LO1-LG- 41

LG42: Maintain instrumentation system

LG Code: EEL BES2 M10 LO2-LG-42

LG43: Repair instrumentation system

LG Code: EEL BES2 M10 LO3-LG- 43

LG44: Inspect and test the repaired instrumentation and control devices

LG Code: EEL BES2 M10 LO4-LG- 44

Instruction Sheet	LG41: Plan and prepare for maintenance/ repair

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Maintenance or repair work is planned and prepared in line with job requirements.
- OHS policies and procedures are followed in line with job requirements.
- Instrumentation systems are identified in line with job requirements
- Instrumentation system to be maintained or repaired are identified based on job/service order or instructions
- Instrumentation systems for maintenance or repair are checked against specifications and requirements.
- Materials necessary to complete the work are obtained in accordance with established procedures and checked against job requirements.
- Tools, equipment and testing devices needed for the maintenance/repair are obtained and checked for correct operation and safety.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Maintenance or repair work is planned and prepared in line with job requirements.
- OHS policies and procedures are followed in line with job requirements.
- Instrumentation systems are identified in line with job requirements
- Instrumentation system to be maintained or repaired are identified based on job/service order or instructions
- Instrumentation systems for maintenance or repair are checked against specifications and requirements.
- Materials necessary to complete the work are obtained in accordance with established procedures and checked against job requirements.
- Tools, equipment and testing devices needed for the maintenance/repair are obtained and checked for correct operation and safety.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information “Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5 &Sheet 6”.
4. Accomplish the “Self-check 1, Self-check t 2, Self-check 3, Self-check 4 Sheet 5 &Sheet 6”**in page -6, 16, 21, 37, 47 and 65** respectively.

Information Sheet-1	Plan and prepare for maintenance/ repair

1.1. Introducing on Maintenance

Maintenance is a set of organised activities that are carried out in order to keep an item in its best operational condition with minimum cost acquired. The combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.

Maintenance Activities

Activities of maintenance function could be either repair or replacement activities, which are necessary for an item to reach its acceptable productivity condition or these activities, should be carried out with a minimum possible cost.

1.2. Job Orders

Definition: Job order is a documented task specifications that an individual is required to complete the task at a given unit of time.

Job orders are very much and highly recommended for each and every skilled worker in his/her work environment particularly in almost all industries. In which, most of these industries required it for the purpose of written report or a documented report of the task being perform.

There are several kinds of job orders as well as formats and required information that may vary depending upon the nature of the industry or a service center.

JOB ORDER CONTENTS

Job Order Control Number is basically non-identical number usually located at the upper left or right corner of the sheet usually written in different color.

Name of Client This field contains the clients name usually divided in three (3) parts, the family name, first/given name and the middle initial. But some job orders may only have one (1) single field that requires the complete name of the client.

Contact Number requires the client contact number either a cellular phone number or a landline telephone

Client's Address requires the current address of the client

Job Description represents the overall overview of the task to be perform

Date and Time The date when the job order is requested of delivered

Date Finished The date when the task is completed.

Signature Signatures are areas of the job order form that requires the signature of the technician and the client that serves as the specimen of agreement between the two parties

JOB ORDER

Job Order No:			**Date:**	
Name of Client:	*(Family Name):*	*(Given Name):*	*MI:*	Contact No:
Client's Address:				

Appliance Type:	*Brand name:*	*Model:*	Serial:	*Color:*

Appliance Physical Pre-Conditions:
1. _____
2. _____
3. _____

Symptoms:
1. _____
2. _____
3. _____

Date & Time Received: Date_____/Time_____	Expected Date & Time to be released: Date_____/Time_____	*Received by:*

Assigned Technician:	*Date Received:*	*Technician's Pre-Condition Findings:* *1.* _____ *2.* _____

Diagnose Results:
1. _____
2. _____
3. _____

Replacements: (*If any)*

No. of Items	Description	Price/Unit	Total/Unit	Remarks
		TOTAL AMOUNT:		

Report:	*Signature of Technician:*
Total Billing: (Amount in words)	(w/ Service Charge)

Date & Time Released: Date_____/Time_____	*Released by:*	*Received by: (Owner)*

Figure 1: Sample Job Order

1.3. Preparing Job Orders

For most service centers, preparation of job before the start of every task is required. Basically, preparing job orders are just filling out the information required. In addition, a short conversation should take place between the owner and the one who prepares the job order.

Most of the questions that should be ask:

1. When was this equipment started to show irregular operation or malfunctioning.
2. Events took place before the fault happened
3. Repair history of the equipment if any.

These questions are most likely to be asking, since this information could lead some conclusions and future awareness.

1.4. Interpreting Job Orders

For most of the industry they provide job orders to their skilled workers to have a concrete formal request of the task to be done. Before each task to be done the worker should be able to secure the job order, "**no job order means NO task to be done**". Upon receiving the job order make sure that all required fields are correctly and clearly written.

First, check date and Job Order control number for its validity. Next, is to check the client‟s name, address and contact number, this information is highly required, which means that if this required information are missing, the worker should refer to the immediate supervisor.

The most important part of the job order is the task description in which each worker should be able to understand and be able to attain the task requirement within the specific period of time which is also can be seen under the date and time of completion.

As a worker, time consciousness is very important to be able to attain the required span of time

Self-Check 1	Written Test

Part I: Define the following terms

Directions: Answer all the questions below. Illustrations may be necessary to aid some explanations/answers.

1. What is a job order?
2. What should be the first thing to check before performing the task specifications?
3. Why it is that time consciousness is important when performing the task?
4. What is the main principle of a worker when dealing with task/job orders?
5. Why it is that job order number and the date should be check first when receiving the job order?

Part II: Matching Item

Directions: Match the terms with the following statements found on the right side. Write the corresponding letter

Column A

_____1. Job Order Control Number
_____2. Name of Client
_____3. Contact Number
_____4. Client"s Address
_____5. Job Description
_____6. Date and Time
_____7. Date Finished
_____8. Signature

Column B

a. The date when the task is completed.
b. This field contains the clients name usually divided in three(3) parts, the family name, first/given name and the middle initial. But some job orders may only have one(1) single field that requires the complete name of the client.
c. is basically non-identical number usually located at the upper left or right corner of the sheet usually written in different color.
d. requires the current address of the client
e. represents the overall overview of the task to be perform
f. requires the client contact number either a cellular phone number or a landline telephone
g. Signatures are areas of the job order form that requires the signature of the technician and the client that serves as the specimen of agreement between the two parties.
h. The date when the job order is requested of delivered

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Part I

Answers:

1. _____
   _____
   _____
   _____.
2. _____
   _____
   _____
   _____.
3. _____
   _____
   _____
   _____.
4. _____
   _____
   _____
   _____.
5. _____
   _____
   _____
   _____
   _____.

Part II: Matching Item

1._____
2._____
3._____
4._____
5._____
6._____
7._____
8._____

Information Sheet-2	Following OHS policies and procedures

2.1. Personal Protective Equipment (PPE) Selection

The Personal Protective Equipment (PPE) Selection Policy Guideline provides guidance in the identification of personal protective equipment and examples of personal protective equipment that may be available, selected and used.

The Work Health and Safety Act (SA) 2012, its regulation and associated codes of practice place a duty of care on all workers to take reasonable care to protect their own health and safety while at work. This may include the need for using personal protective equipment (PPE) and clothing when undertaking a hazardous task.

2.2. Principles PPE

Personal Protective Equipment is any device or clothing worn by a worker to control the level of risk that cannot be controlled or eliminated by providing protection / shield between the hazard and the worker when exposed to:

- dangerous goods, hazardous chemicals, infectious substances including blood and bodily fluids(BBF)
- dust, fumes or particles
- radiation (ionizing and non-ionizing), ultraviolet or solar radiation
- noise
- moving objects such as vehicles, trolleys and forklifts
- flying objects when using machinery with moving parts
- Environmental factors , for example, high and low temperature

- PPE must be used for additional protection when other risk control measures do not provide sufficient exposure control.
- PPE is one of the least effective methods of controlling risk to work health and safety , as per the hierarchy of control, and must be used :
- When there are no other practical risk control measures available or when identified through a dynamic risk assessment, for example:

  - **Gloves** - for all contact with blood and or body fluids.
  - **Double glove** - application in operating theatres and procedural areas.
  - **Eye protection**- use of a face shield when undertaking any procedure where a splash of fluid may occur
  - **Gowns** - use when undertaking any procedure where a splash of blood or body fluid

may occur

- **Respiratory Masks:** A correctly fitted P2 (N95) respiratory mask must be used for all known or suspected „airborne‟ respiratory diseases such as Tuberculosis, Measles, Chicken Pox and during aerosol generating procedures such as bronchoscopy and pulmonary function testing.
- **Surgical Masks** must be worn for all patients exhibiting signs and symptoms of confirmed or suspected respiratory disease (droplet) such as: Influenza, Pertussis, Meningococcal infection and Respiratory Syncytial virus (RSV).

2.3. The use of PPE and Infection Prevention

The use of PPE must be routine practice for all workers when there is a risk of exposure to blood (including dried blood), all other body substances, secretions and excretion‟s (excluding sweat), regardless of whether they contain visible blood i.e. standard precautions.
The Work Health and Safety Regulations, 2012 (SA) states that it is the responsibility of each Healthcare worker (HCW) to be familiar with and comply with these protective measures at all times when there is an identified risk of exposure to BBF.
PPE in this context refers to a variety of barriers, used alone or in combination, to reduce the risk of acquiring and transmitting potentially infectious microorganisms by:

- protecting skin, eyes, mouth, respiratory system and clothing of staff from potentially infectious excretions and secretions
- Preventing contamination of skin and clothing by microorganisms present in the environment.
    - Selection of PPE should be based on the risk of transmission of potentially infectious microorganisms to the healthcare worker from: Exposure to blood and body substances during an activity (standard precautions) contamination from infectious microorganisms via the contact, droplet or airborne route. (Transmission-based precautions) When a disease agent is unknown, a symptom-based approach will reduce the risk of transmission to the HCW and to other patients. For example, if a patient presents with vomiting or diarrhea or respiratory symptoms (coughing, sneezing and fever) then the appropriate precautions should be implemented immediately, rather than waiting for a definitive diagnosis.
    - Routine use of PPE, especially gloves, should not be encouraged in a patient care environment if there is no risk of a BBF exposure.
    - PPE items used as part of standard and transmission-based precautions include: aprons, gowns gloves, respiratory, face and eye protection.

Further information regarding the use of standard and transmission based precautions can be Detail
Identifying the need for PPE
The identification of the need for Personal Protective Equipment (PPE) is determined through the following process:

- Identification of the hazard / task /activity
- Risk Assessment of hazard / task /activity

- Development of risk control measures through the Hierarchy of Risk Control (Elimination,
- Substitution, Engineering Controls, Administrative Controls, PPE)
- Identification of PPE required to minimize / reduce risk Selection, purchase and accessibility of PPE

2.4. Training in the use of PPE Inspection, Cleaning and Maintenance of PPE

Where PPE is in use, routine inspection, cleaning and maintenance is required.

- The wearer is required to inspect PPE prior to use, for signs of penetration or other damage due to impact, rough treatment or unauthorized alterations which may reduce the degree of safety originally provided.
- Regularly check respiratory devices (every time before and after use), to ensure that filters / cartridges or air supply are in place and replaced as necessary. This is to ensure that the equipment is ready for use at all times.
- Clean/decontaminate all re-useable PPE in accordance with the manufactures instructions. However, in the absence of such instruction the item can be washed thoroughly in detergent and warm water using a soft cloth, then rinsed and dried.
- Avoid using any cleaning agents that are likely to scratch surfaces, particularly the lenses of eye protection equipment.
- Store PPE in clean, sealed containers, such as plastic tubs with lids. This prevents continual exposure to air or other particulates or other environmental factors, for example, prolonged exposure to direct sunlight that may compromise the effectiveness of the equipment (including filter / cartridges).
- Ensure that the PPE is kept clean in between usage.
- Remove damaged PPE from use, and take to the supervisor to arrange for replacement equipment.

2.5. Details of Types of Personal Protective Equipment

- Hand Protection (gloves)
- Eye Protection (goggles, safety glasses, face shields)
- Face Protection and infection prevention (eye wear, face shield, surgical masks)
- Hearing Protection (ear plugs, ear muffs)
- Respiratory Protection (respirators, face masks, cartridge filters)
- Surgical Masks
- Particulate Filters
- Disposal N95 or P2 Masks
- Respiratory Protection with Powered Air Purified Respirator (PAPR)
- Laser Safety
- Skin Integrity and Protection (sunscreen, alcohol gel)
- Protective Clothing (high visibility garments, thermal wear, overalls, aprons, lead aprons,

reflective vests, impervious long-sleeve gowns)

- Footwear (enclosed shoes, safety boots)
- Head Protection (hard hats, helmets, sun hats, bike helmet)
- Falls Protection (safety harness)

2.5.1. Hand Protection

Workers must be educated in the correct manner to clean hands and preserve hand skin integrity. Gloves must be worn for protection from hazards such as:

- ✓ Infectious agents
- ✓ Abrasion
- ✓ Chemicals
- ✓ Sharp Objects
- ✓ Radiation
- ✓ Hot or Cold Materials

The type of glove will vary, defendant on the nature of the task and a range should be available to accommodate individual worker needs. There are some conditions where gloves are not permitted (e.g. some machinery operation)

For gloves to be used with chemicals consult the relevant chemical‟s Safety Data Sheet (SDS) for advice on the type of glove to use

- Hands must be cleaned with soap and water or alcohol gel before and after glove use
- Moisturizing lotion should be made available and should be applied as required
- Consideration should be given to the need for a glove lining or inner glove or moisture /barrier cream where prolonged use of waterproof gloves is envisaged.

Note: Some workers may develop an allergic reaction to latex gloves. Recommendations to avoid reactions include:

- The provision of reduced protein and powder free gloves
- Ensure good housekeeping to reduce latex build up
- Advise workers to wash hands thoroughly after removing latex gloves.

Examples of hand protection

Fig2.1. Examples are provided for illustration only

2.5.2. Gloves and infection prevention

- Gloves can protect both patients and HCW from exposure to potentially infectious microorganisms that may be carried on the hands. As part of standard precautions they are used to prevent contamination of HCW hands when:
- anticipating direct contact with blood or body substances, mucous membranes, non-intact skin and other potentially infectious material
- handling or touching visibly soiled or potentially contaminated patient-care equipment
- there is potential exposure to toxic drugs during administration
- there is exposure to chemicals during the cleaning process

Key considerations in glove selection will include potential exposure to BBF and the potential contact with non-intact skin, mucous membranes or sterile sites.

Types of materials:

Non-sterile single use medical gloves are available in a variety of materials and consist of the following:

- natural rubber latex (NRL)
- NRL alternative - synthetic alternative to latex e.g. nitrile
- Vinyl gloves - do not provide optimal protection against BBF and are not recommended for patient care.
- Polythene gloves - are not suitable for clinical use and are generally used for food handling, preparation and serving.
- Single use disposable sterile gloves are worn when there is contact with sterile instruments or normally sterile parts of the body.
- Reusable utility gloves are indicated for non-patient care activities such as cleaning of contaminated equipment or surfaces, general cleaning duties and instrument cleaning in sterilizing services departments.

Recommendations:

- Gloves must be worn as a single-use item for each invasive procedure, contact with non-intact skin, mucous membranes or sterile site and if the activity has been assessed as being an exposure risk to blood, body substances, secretions and excretions.
- Gloves must be removed and hand hygiene performed before leaving a patient‟s room or area.
- Single use disposable gloves must be changed:
- between episodes of care for different patients
- between each episode of clinical care on the same patient to prevent cross-contamination of body sites e.g. mouth care followed by wound care when the integrity of the glove has been compromised i.e. ripped , torn

- Single use disposable sterile gloves must be worn during: contact with sterile sites procedures requiring aseptic technique where key parts and / or sites are touched directly (i.e. when a non-touch technique cannot be achieved)

Glove risk assessment

Removing and disposing of gloves

- When removing gloves, care should be taken not to contaminate the hands. After gloves have been removed hand hygiene is to be performed as per the SA Health Hand Hygiene Guideline.
- Single use gloves must not be washed or alcohol-based hand rub applied for subsequent reuse.
- Gloves should be disposed of and then discarded into a designated container for waste to contain the contamination.

2.5.3. Eye Protection

- Goggles and safety glasses prevent injury to eyes. Face shields and visors prevent injury to eyes, nose and mouth from dust, flying particles, chemicals/substances, radiation (visible and invisible) and potentially infectious blood or body fluids
- Workers must wear protective eyewear for any procedure where they may be exposed to these situations, or where stated in the safe work procedure
- Eye protection must comply with relevant standards, and provide the level of protection required e.g. arc welding / cutting, infection control procedures
- Normal prescription glasses DO NOT provide adequate protection. Workers requiring reading
- Glasses should seek additional eye protection equipment which does not interfere with the worker‟s vision, yet provides an appropriate barrier to hazards.

Personnel who wear contact lenses, and work with chemical substances, should be aware of the following potential hazards:

- Contact lenses may adhere to the eye
- Contact lenses may absorb chemicals and concentrate them on the surface of the eye
- Contact lenses may interfere with emergency flushing procedures by trapping fumes or solids
- If a worker is unconscious following an injury, rescue personnel may be unaware the contact lenses are in place.
- Refer to the Chemical SDS for safety information regarding wearing of contact lenses.

Examples of eye protection:

Fig2.2. Examples are provided for eye protection

2.5.4. Face Protection and Infection Prevention

The mucous membranes of the nose, mouth and eyes and non-intact skin are portals of entry for infectious microorganisms. Face and eye protection reduces the risk of exposure of healthcare workers to splashes or sprays of blood, body substances, secretions or excretions.

Equipment includes:

- Protective eyewear – are generally fog resistant goggles that can be single use or reusable and provide protection from splashes, sprays from multiple angles. These are required in addition to personal glasses and contact lenses as personal eyewear are not considered adequate eye protection
- Face shield – single use or reusable face shields may be used in addition to surgical masks, as an alternative to protective eyewear. A face shield can provide protection to other parts of the face as well as the eyes. Face shields extending from chin to crown provide better face and eye protection from splashes and sprays
- Surgical masks – are loose fitting, single use items that cover the nose and mouth.

They are used to keep splashes or sprays from reaching the mouth and nose of the person wearing them. They also provide some protection from exposure to respiratory secretions. Surgical masks should be of a fluid resistant material when used for patient care. Considerations when using a surgical mask must include:

- changing the mask when it becomes soiled or wet
- never reapplying when it has been removed
- not left dangling around the neck
- avoid touching the front of the mask while wearing it
- safe removal i.e. using ear loops or ties to remove, avoiding touching the front of the mask
- hand hygiene before and after removal

P2 / N95 respirators (masks) - are medical devices designed to protect the wearer from infectious microorganisms transmitted via the airborne route or during aerosol generating procedures.

2.5.5. Removal and safe disposal of face and eye protection

The front of a mask, protective eyewear or face shield is considered to be contaminated.

Removal of a face shield, protective eyewear and surgical mask can be safely performed after gloves have been removed and hand hygiene has been performed.

Single-use face and eye protection should be disposed of by discarding into a designated container for waste to contain the contamination. Re-usable eyewear or face shields require cleaning with detergent and water and / or disinfectant immediately after use.

2.6. Hearing Protection

In areas of identified high noise hazard (e.g. workshops) ensure that „hearing protection must be worn‟ signs are in place and are complied with Types of hearing protection include: a variety of disposal and re-useable ear plugs, ear muffs or ear canal caps. The selection made will be based on the outcome of a risk assessment in relation

Self-Check-2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What is OH&S Policy &Procedure?
2. Write some types of PPE?
3. What are the advantages of OH&S for an organization?
4. What is the use of PPE and Infection Prevention?
5. Write some types of Gloves used for protection from hazards?

Note: **Satisfactory rating - 25 points** **Unsatisfactory - below 25 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Name: _____ Date: _____

Short Answer Questions

1_____

_____

2._____

_____

3._____

_____

4._____

5._____

Information Sheet 3	Ethiopian environmental proclamations &regulations

3.1. MEDICAL CENTRES SAFETY PROGRAM

- Safety includes a range of hazards including mishaps (an unlucky accident), injuries on the job, and patient care hazards.
- The most common safety mishaps are “needle sticks” (staff accidentally stick themselves with a needle) or patient injury during care.
- As a manager, ensure all staff and patients are safe within the facility.
- Note: it‟s everyone‟s responsibility!

3.2. Laboratory safety

Laboratory Safety Comes First!

- Hand washing
- Standard (Universal) precautions
- Electrical Safety
- Fire Safety

Basic Laboratory Safety Issues

- Hand washing
- Smoking
- Food & Drink
- Eye & Face Protection
- Cosmetics
- Shoes
- Hair & Jewelry
- Eye Wash/Safety Showers
- Do Not Mouth Pipette
- Good Housekeeping
- Sharp Objects

3.3. Basic Rules of Bio Safety

The basic rules of Bio safety are essential to avoid occupational hazards when working in the laboratory.

1. Washing hands following all laboratory activities, following the removal of gloves and immediately after contact with infectious agents.
2. Do not mouth pipette.
3. Use protective laboratory coats and gloves.
4. Do not eat, drink, smoke or store food in the laboratory.

5. Manipulate infectious agent carefully to avoid spills and the production of aerosols and droplets.
6. Decontaminate work surface before and after use, and immediately after spills.
7. Use needles, syringes and other sharps only absolutely necessary.

3.4. Rules of Environmental and Safety Compliance

- All personnel working in laboratories must be trained in safe work practices and hazardous waste disposal.
- Maintain an accurate hazardous materials inventory.
- Properly label all hazardous materials.
- Segregate incompatible materials and place in safe storage locations.
- Use fume hood and other appropriate controls when using flammables, toxic or odorous vapors.
- Wear the appropriate protective equipment, such as a laboratory coat, gloves, safety glasses.
- Use non-hazardous material instead of hazardous materials whenever possible.
    - There are several meeting that are medical equipment managers are required to attend as the organizations technical representative. The following are:
- Patient safety
- Environmental of Care
- Space Utilization Committee
- Equipment Review Board
- Infection Control (optional)
- Safety of our patient/staff is paramount to the success of our organizations mission.
- The Joint Commission on the Accreditation of Healthcare Organization publishes annual lists detailing “National Patient Safety Goals” to be implemented by healthcare organization.
- Goals are developed by experts in patient safety nurses, physicians, pharmacists, risk managers, and other professionals with patient-safety experience in a variety of settings.
- Patient safety is among the most important goals of every healthcare provider, and processes concerned with patient safety provides way for biomedical managers and clinical engineering departments to gain visibility and positively affect their workplace.

- Electrical Safety
- Electrical safety is the containment of limitation of hazardous such as, electrical shock, explosion, fire or damage to equipment and buildings.
- Preventive maintenance programs reduce electrical hazards such as:
- The physiological effects of electricity.

- Leakage current

- Ground fault
- Electrical short hazard.
- The use of proper power wiring distribution, and ground system in reducing electrical shock hazards.
- Specialized electrical safety test equipment

3.5. Chemical Safety

- Laboratories use a lot of chemicals that caustic and corrosives
    - Concentrated acids or bases, organic solvents that are noxious and flammable, eye irritants, mutagens, teratogens, etc.
- Spills are possible
    - Wear gloves
    - Clean the outside of the instrument
    - Look for spill marks inside and clean these as well
- Ask lab personnel to help clean up the equipment, especially if you are taking to the shop
- Address any concerns to the Chemical Safety Officer

3.6. Biological Safety

- A biomedical technician will be working with instruments that come in contact with infectious organisms or patient samples, both of which could be hazardous to ones health. All such samples, whether from healthy or sick, are to be considered hazardous
- Wearing proper protection such as lab coats, eye protection and gloves should be made a habit
- Instruments must be decontaminated by the lab personnel before repair is attempted, especially if moving the equipment to the shop
- Some of the instruments may be located within labs and unmovable
- Work with the biological safety officer to ensure your safety

Levels of Biological Safety

- Depending on the hazard posed by the organism being cultured, different biological safety levels are mandated.
- These safety levels, BSL 1 – BSL 4 specify containment and precautions, with level 1 being least restrained and 4 being highly contained.
- Hazards are generally higher in research lab than in routine clinical labs
- Know the biosafety officer and address questions

Biohazard Signs and Biosafety Levels

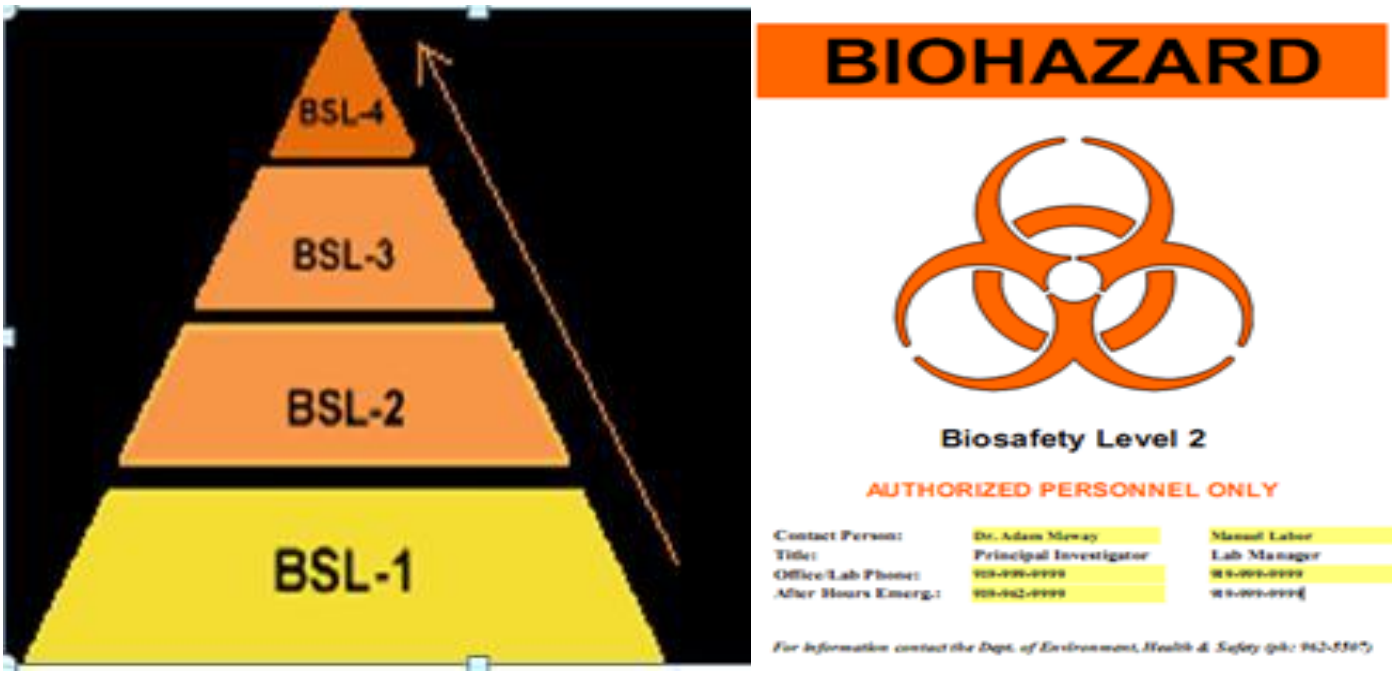


Fig3.1. Biohazard Signs and Biosafety Levels

Self-Check-3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What is OH&S Policy &Procedure?
2. Write some types of PPE?
3. What is the advantage of OH&S for an organization?
4. What is the use of PPE and Infection Prevention?
5. Write some types of Gloves used for protection from hazards?

Note: **Satisfactory rating - 25 points** **Unsatisfactory - below 25 points**
You can ask you teacher for the copy of the correct answers.
Answer Sheet

Name: _____ Date: _____

Short Answer Questions

1_____

_____

2._____

_____

3._____

_____

4._____

5._____

Instruction Sheet-	Identifying Instrumentation systems

4.1. Instrumentation systems

The study of biomedical instruments can be approached from at least four viewpoints. Techniques of biomedical measurement can be grouped according to the *quantity that is sensed*, such as pressure, flow, or temperature. One advantage of this classification is that it makes different methods for measuring any quantity easy to compare.

A second classification scheme uses the *principle of transduction*, such as resistive, inductive, capacitive, ultrasonic, or electrochemical. Different applications of each principle can be used to strengthen understanding of each concept; also, new applications may be readily apparent.

Measurement techniques can be studied separately for each *organ system*, such as the cardiovascular, pulmonary, nervous, and endocrine systems. This approach isolates all important measurements for specialists who need to know only about a specific area, but it results in considerable overlap of quantities sensed and principles of transduction.

Finally, biomedical instruments can be classified according to the *clinical medicine specialties*, such as pediatrics, obstetrics, cardiology, or radiology. This approach is valuable for medical personnel who are interested in specialized instruments. Of course, certain measurements—such as blood pressure—are important to many different medical specialties.

4.2. Bio potential electrodes

In order to measure and record potentials and, hence, currents in the body, it is necessary to provide some interface between the body and the electronic measuring apparatus. Biopotential electrodes carry out this interface function. In any practical measurement of potentials, current flows in the measuring circuit for at least a fraction of the period of time over which the measurement is made. Ideally this current should be very small. However, in practical situations, it is never zero. Biopotential electrodes must therefore have the capability of conducting a current across the interface between the body and the electronic measuring circuit.

Our first impression is that this is a rather simple function to achieve and that biopotential electrodes should be relatively straightforward. But when we consider the problem in more detail, we see that the electrode actually carries out a transducing function, because in the body current is carried by ions, whereas in the electrode and its lead wire it is carried by electrons. Thus the electrode must serve as a transducer to change an ionic current into an electronic current. This greatly complicates electrodes and places constraints on their operation. We shall briefly examine the basic mechanisms involved in the transduction process and shall look at how they affect electrode characteristics. We shall next examine the principal electrical characteristics of biopotential electrodes and discuss electrical equivalent circuits for electrodes based on these characteristics. We shall then cover some of the different forms that biopotential electrodes take in various types of medical instrumentation systems. Finally, we shall look at electrodes used for measuring the ECG, EEG, EMG, and intracellular potentials.

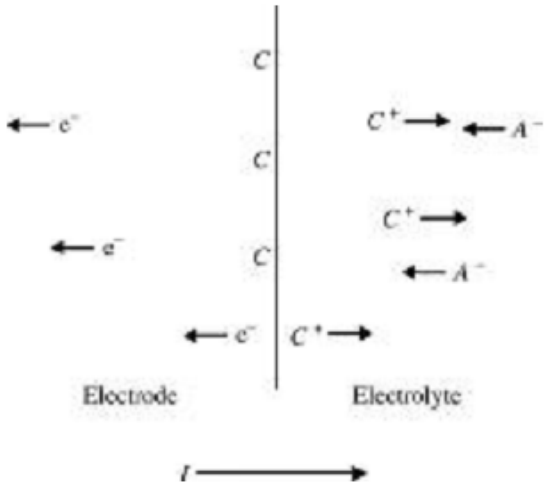


Figure 5.1 Electrode–electrolyte interface The current crosses it from left to right. The electrode consists of metallic atoms C. The electrolyte is an aqueous solution containing cations of the electrode metal C^+ and anions A^-.

"

4.3. Control valves

Control valve: A device, other than a common, hand-actuated ON-OFF valve or self-actuated check valve, that directly manipulates the flow of one or more fluid process streams.

It is expected that use of the designation "hand *control valve*" will be limited to hand-actuated valves that (1) are used for process throttling, or (2) require *identification* as an *instrument*.

4.4. Actuators

An **actuator** is a mechanical device for moving or controlling a mechanism or system. It takes energy, usually transported by air, electric current, or liquid, and converts that into some kind of motion.

Recorders

4.5. Bio potential amplifiers

Amplifiers are an important part of modern instrumentation systems for measuring biopotentials. Such measurements involve voltages that often are at low levels, have high source impedances, or both. Amplifiers are required to increase signal strength while maintaining high fidelity. Amplifiers that have been designed specifically for this type of processing of biopotentials are known as *biopotential amplifiers*. In this chapter we examine some of the basic features of biopotential amplifiers and also look at specialized systems.

4.6. Chemical biosensor

A chemical biosensor is a sensor that produces an electric signal proportional to the concentration of biochemical analytes. These biosensors use chemical as well as physical principles in their operation.

The body is composed of living cells. These cells, which are essentially chemical factories, the input to which is metabolic food and the output waste products, are the building blocks for the organ systems in the body. The functional status of an organ system is determined by measuring the chemical input and output analytes of the cells. As a consequence, the majority of tests made in the hospital or the physician's office deal with analyzing the chemistry of the body.

The important critical-care analytes are the blood levels of pH; P_{O_2}; P_{CO_2}; hematocrit; total hemoglobin; O_2 saturation; electrolytes including sodium, potassium, calcium, and chloride; and various metabolites including glucose, lactate, creatinine, and urea. Table 10.1 gives the normal ranges in blood for these critical-care analytes.

These variables are normally analyzed in a central clinical-chemistry laboratory remote from the patient's bedside. This conventional approach provides only historical values of the patient's blood chemistry, because there is a delay between when the sample is obtained and when the result is reported. (The sample must be transported to the main clinical-chemistry laboratory, and the appropriate analyses must be performed.) This inherent delay is approximately 30 min or more. Other significant drawbacks plague central-laboratory analyses of patient chemistry, including potential errors in the origin of the sample and in sample-handling techniques, and (because of the delay) the timeliness of the therapeutic intervention.

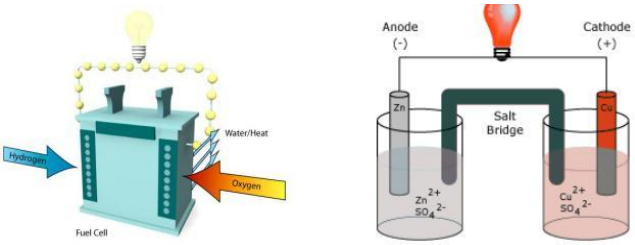
4.7. Sensors/transmitters/transducers

A transducer is a device that translates a mechanical signal into an electrical signal. Transducers are devices that can change one form of energy into another.

Examples of common transducers include the following:

- A microphone converts sound into electrical impulses and a loudspeaker converts electrical impulses into sound (i.e., sound energy to electrical energy and vice versa).
- A solar cell converts light into electricity and a thermocouple converts thermal energy into electrical energy.
- An incandescent light bulb produces light by passing a current through a filament. Thus, a light bulb is a transducer for converting electrical energy into optical energy.
- An electric motor is a transducer for conversion of electricity into mechanical energy or motion.

There are many variables which affect our everyday lives: the speed of a car, the velocity of the wind, and the temperature in a home. In most situations, these variables are continuously monitored. It is these variables that are the feedback that is used to control the speed of a car, the operation of an air conditioner, heater levels, and oven temperatures. The elements that sense these variables and convert them to a usable output are transducers. For example, a transducer known as a thermocouple is able to sense changes in temperature and produce output voltages representative of those changes. A transducer is defined as a substance or a device that converts (or transfers) an input energy into a different output energy. Because of this broad definition, transducers come in many varieties converting many different types of energy. Following are different types of transducers



Electrochemical Transducers *Converting a Chemical Reaction to Electrical Energy (left: Fuel Cell, right: battery)*

Fig 4.2 converting many different types of energy

Some common electrochemical transducers include the following:

- pH probe – Converts chemical energy into an electrical energy
- Molecular electric transducer – Converts motion in an electrolytic solution into electrical energy
- Battery – Converts chemical energy directly into electrical energy
- Fuel cell – Converts the energy from a reaction within a fuel cell to electrical energy.

Let‟s take a closer look at the electrochemical battery illustrated above. This battery converts chemical energy directly into electrical energy. A cathode and an anode (typically two dissimilar

metals) are each immersed in an electrolyte solution containing salts of their respective metals. A

medium (the salt bridge) separates the two electrodes, but allows ions to flow between the two solutions. Due to the flow of ions between the two solutions a potential difference (or voltage) is created. An electrical current flow if a wire is connected between the two pieces of metals. The amount of voltage developed between the cathode and the anode depends on the materials that make up the battery.

Electroacoustic, Electromagnetic, and Electrostatic Transducers

Common electroacoustic transducers:

- Loudspeaker – Converts an electrical signal into sound
- Microphone – Converts sound waves in air into an electrical signal
- Hydrophone - Converts sound waves in water into an electrical signal.

Common electromagnetic transducers:

- Magnetic cartridge – Converts motion in a magnetic field into an electrical energy
- Generator – Converts motion in a magnetic field into electrical energy

Common electrostatic transducers:

- Electrometer – Converts static or energy from a vibrating reed into electricity
- Van de Graff generator – Converts static into high voltage

Electromechanical Transducers

Electromechanical Transducers – (Some are also called actuators)

- Strain gauge – Converts the deformation (strain) of an object into electrical resistance
- Galvanometer – Converts the electric current of a coil in a magnetic field into movement
- Generators – Converts mechanical energy (motion) into electrical energy.
- Motor – Converts electrical energy into mechanical energy (graphic below)

Other Types of Transducers

Photoelectric Transducers:

- Cathode ray tube (CRT) –Converts electrical signals into light energy for a visual output.
- Light bulb –Converts electrical energy into visible light and heat (explained in next section)
- Laser diode – Converts electrical energy into light energy
- Photodiode - Converts light energy into electrical energy

Thermoelectric Transducers:

- Thermocouple – Converts heat energy into electrical energy
- Temperature sensitive resistor (Thermistor) – a variable resistor affected by temperature changes (heat energy to electrical energy)

Basic Concepts of Sensors

Sensors detect the presence of energy, changes in or the transfer of energy. Sensors detect by

receiving a signal from a device such as a transducer, then responding to that signal by converting

it into an output that can easily be read and understood. Typically, sensors convert a recognized signal into an electrical – analog or digital – output that is readable.

In other words, a transducer converts one form of energy into another while the sensor that the transducer is part of converts the output of the transducer to a readable format.
Consider the previous examples of transducers. They convert one form of energy to another, but they do not quantify the conversions. The light bulb converts electrical energy into light and heat; however, it does not quantify how much light or heat. A battery converts chemical energy into electrical energy but it does not quantify exactly how much electrical energy is being converted. If the purpose of a device is to quantify an energy level, it is a sensor.
So, let"s take a look at a sensor that should be familiar to everyone – a temperature sensor.

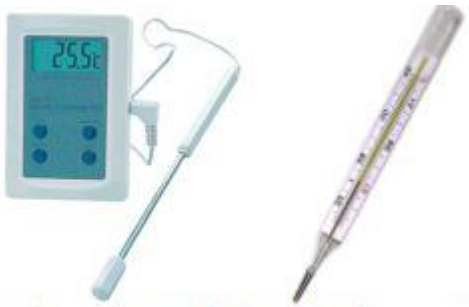
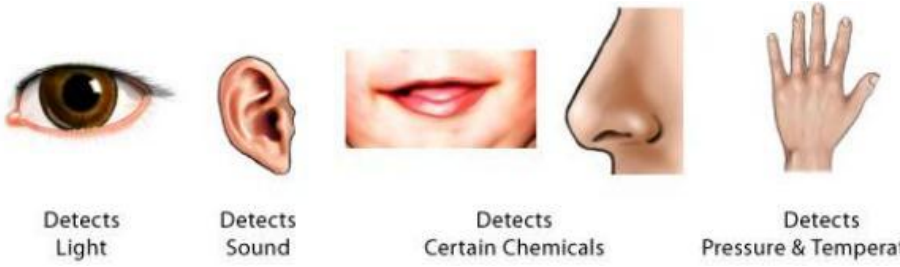


Fig4.3. *Digital Readout and Mercury Thermometers*

A sensor is a device that receives and responds to a signal. This signal must be produced by some type of energy, such as heat, light, motion, or chemical reaction. Once a sensor detects one or more of these signals (an input), it converts it into an analog or digital representation of the input signal. Based on this explanation of a sensor, you should see that sensors are used in all aspects of life to detect and/or measure many different conditions. What are some sensors that you are familiar with or use daily?
Human beings are equipped with 5 different types of sensors.Fig4.4



Eyes detect light energy, ears detect acoustic energy, a tongue and a nose detect certain chemicals, and skin detects pressures and temperatures. The eyes, ears, tongue, nose, and skin receive these signals then send messages to the brain which outputs a response. For example, when you touch a hot plate, it is your brain that tells you it is hot, not your skin. Following are different types of sensors which are classified by the type of energy they detect.

Thermal Sensors

- Thermometer – measures absolute temperature (discussed in the previous section)

- Thermocouple gauge– measures temperature by its affect on two dissimilar metals

A thermocouple is a device that directly converts thermal energy into electrical energy. When two dissimilar metal wires are connected at one end forming a junction, and that junction is heated, a voltage is generated across the junction (see the figure below). If the opposite ends of the wires are connected to a meter, the amount of generated voltage can be measured. This effect was discovered by Thomas Seebeck, and thus named the Seebeck Effect or Seebeck coefficient. The voltage created in this situation is proportional to the temperature of the junction.

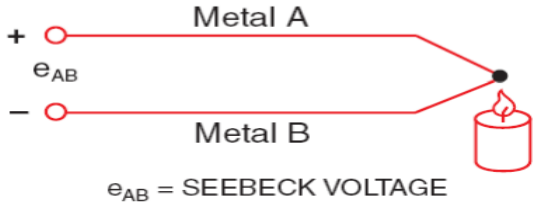


Fig4.5. *Thermocouples operate due to the Seebeck Effect*

Mechanical Sensors

- Pressure sensor – measures pressure
- Barometer – measures atmospheric pressure
- Altimeter – measures the altitude of an object above a fixed level
- Liquid flow sensor – measures liquid flow rate
- Gas flow sensor – measures velocity, direction, and/or flow rate of a gas
- Accelerometer – measures acceleration

Electrical Sensors

- Ohmmeter – measures resistance
- Voltmeter – measures voltage
- Galvanometer – measures current
- Watt-hour meter – measures the amount of electrical energy supplied to and used by a residence or business

Fig4.6. *Schematic and photograph of a Galvanometer used for sensing electrical currents*

Optical Sensors

- Light sensors (photo detectors) – detects light and electromagnetic energy
- Photocells (photo resistor) – a variable resistor affected by intensity changes in ambient light.
- Infra-red sensor – detects infra-red radiation

Key terms/terminologies

- **Electroacoustic:** The interaction between electrical and acoustic phenomena.
- **Electrochemical:** The transfer of electric charge between matter.
- **Electromagnetic:** Objects made magnetic by an electric current.
- **Electromechanical:** A mechanical device which is controlled by an electronic device.
- **Electrostatic:** Of or related to electric charges at rest or static charges.
- **Optical:** Referring to the behavior and properties of light and the interaction of light with matter.
- **Photoelectric:** Relates to the electrical effects caused by light.

What is a Transmitter?

A Transmitter is a device that converts the signal produced by a sensor into a standardized instrumentation signal such as 3-15 PSI air pressure, 4-20 mA DC electric current, Fieldbus digital signal etc., which may then be conveyed to an indicating device, a controlling device, or both. The indicating or controlling device is often located in a centralized control room. The transmitter often combines a sensor and the transmitter in a single piece. The sensor measures the process variable and generate a proportional signal. The transmitter then amplifies and conditions the sensor signal for onward transmission to the receiving or controlling device.

Transmitters Used in Process Instrumentation:

Transmitters can be broadly divided into two broad groups:

(a) Electronic Transmitters
(b) Pneumatic Transmitters

Electronic transmitters can either be analog or digital/smart as the case may be.

We can further group transmitters according to the types of signals they produce namely:

a) Pneumatic Transmitters
b) Analog Transmitters
c) Digital Transmitters

Pneumatic Transmitters

Pneumatic transmitters output a pneumatic signal corresponding to the process variable. The pneumatic signal range that is commonly used in industrial plants today is the 3 – 15psig. 3psig corresponds to the lower range value (LRV) and 15psig corresponds to the upper range value (URV). It is still commonly used today especially in remote locations where electric power is not readily available.

The invention of electronic instruments in the later part of the twentieth century significantly brought down the costs involved in running electrical signal wire through a plant as opposed to running

pressurized air tubes. This has made the pneumatic signal technology less popular.

As shown below, a pneumatic pressure transmitter is supplied with air pressure typically 20 – 30 psig depending on the application. Process pressure is applied to the High port of the transmitter. As the process pressure varies, the transmitter produces an output signal (3 -15psig) that is proportional to the process pressure.

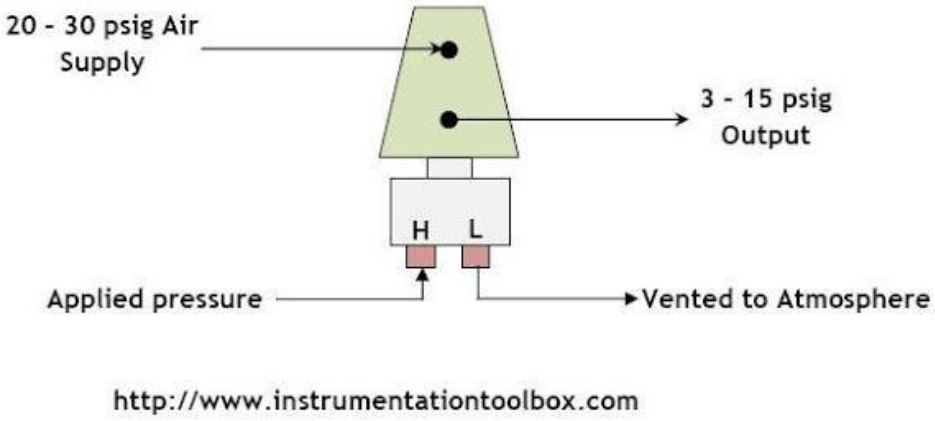


Fig4.7. pneumatic pressure transmitter

4.8. Analog Transmitters

Analog transmitters are mostly electronic in nature. They output an electrical signal (current or voltage) whose magnitude represents a physical measurement or a control quantity. The transmitter is classified as being analog by virtue of the fact that it uses an analog signal standard to communicate information. The most common standard for transmitting an analog signal is the 4-20 mA current signal. With this signal, a transmitter sends a small current, proportional to the physical measurement, through a set of wires. In this signal standard, 4mA represents the lowest possible measurement or the LRV (Lower Range Value) while the 20mA represents the highest possible measurement or URV (Upper Range Value).

As shown below, the transmitter produces an output signal of 4 – 20mA when the process variable is applied to the transmitter:

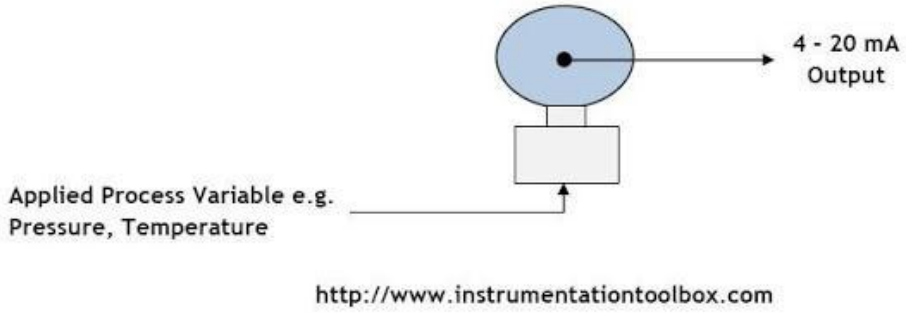


Fig 4.8 Analog transmitters

4.9. Digital Transmitters

Digital transmitters produce digital signals that are combined in a variety of ways to enhance communication with the devices; enhances diagnostic capabilities of the device and makes control of the devices and processes relatively easy and smooth. Digital signals are discrete levels or values that are combined in specific ways to represent process variables and also carry other important information, such as diagnostic information. Digital transmitters combine the digital signals in a variety of ways leading to various communication protocols such as Fieldbus, HART etc.
Most digital transmitters may be referred to as smart instruments. They have inbuilt microprocessors that helps in signal conditioning and processing and gives the devices some diagnostic capability.

Electronic Transmitters

Electronic transmitters can be grouped according to the number of wires necessary to provide transmitter power. Accordingly, there are 2-wire, 3-wire and 4-wire transmitters. Please see Pressure Transmitters Wire Configuration for more details on transmitter wire configuration.

Transmitters Used in Process Instrumentation

In the process industries, there four common process variables of interest:
(a) Pressure
(b) Temperature
(c) Flow Level and
(d) Level
In addition to these variables, there is also the need to analyses various chemical compositions and components. Hence accordingly, the following transmitters are commonly used in the process industries:
(a) Pressure Transmitters
(b) Temperature Transmitters
(c) Flow Transmitters
(d) Level Transmitters
(e) Analytic Transmitters – O2(Oxygen), CO (Carbon Monoxide), PH etc.

Pressure Transmitters

Pressure transmitters are essentially used in measuring various types of process pressures. We have:

a. **Absolute Pressure Transmitter** - This transmitter measures the pressure relative to perfect vacuum pressure.
b. **Gauge Pressure Transmitter** - This transmitter measures the pressure relative to atmospheric pressure at a given location. When the pressure gauge reads 0 PSI, it is means pressure is atmospheric.
c. **Differential Pressure Transmitter** - This transmitter measures the difference between two or more pressures introduced as inputs to the sensing unit. They are used to measure the pressure drop across an oil filter for example. They are also popularly used to measure flow or

level in pressurized vessels.

Various technologies can be used to create pressure transmitters – vibrating wire sensor, capacitance pressure sensor, strain gauge sensor, LVDT (Linear Variable Differential Transformer) etc

Level Transmitters

Level transmitters are used to measure the level of a liquid or solid material within a vessel or space. These transmitters can measure level continuously or at determined points:

(a) **Point Level Transmitters** - Provide an output when a specific level measurement is reached. This output is generally in the form of an audible alarm or an electrical signal to turn on a switch.

(b) **Continuous Level Transmitters** – Measure level within a specified range and provide an output as a continuous reading in proportion to the changing level.

There are various types of level transmitters in use in the process industries. Some of them include:

a) **Ultrasonic Level Transmitters** – Used for non-contact level sensing of highly viscous liquids, as well as bulk solids.

b) **Conductive Level Transmitters** – Used for point level detection of a wide range of conductive liquids such as water, and is especially well suited for highly corrosive liquids such as caustic soda, hydrochloric acid, and similar liquids.

c) **Pneumatic Level Transmitters** – Used in hazardous environments and where there is no electric power. They are also ideal in applications involving heavy sludge or slurry.

d) **Capacitance Level Transmitters** – They are used in liquids that are non-conductive and have a high dielectric constant and can be used for continuous level monitoring.

e) **Hydrostatic based Level Transmitters** – These transmitters use the hydrostatic pressure at a point in a liquid to determine level.

Temperature Transmitters

A temperature transmitter comprises a temperature sensor and transmitter. The transmitter receives a signal from temperature sensors such as a thermocouple or RTD, computes the temperature based on this signal and then converts it to a 4 – 20mA output signal meant for a receiving device such as a controller.

There are different types of temperature transmitters used in the process industries utilizing various temperature measurement technologies. The most common types include:

(c) Thermocouple type Temperature Transmitter – With a thermocouple, the electromotive force generated by changes in the process temperature is used to calculate temperature.

(d) RTD type Temperature Transmitter – When an RTD is used, changes in process temperature results in change in the electrical resistance of the RTD sensor. This relationship between process temperature and electrical resistance is then used to calculate temperature by the transmitter.

Flow Transmitters

A flow transmitter is used to measure and indicate flow. It combines a flow sensor and transmitter in one piece. The flow signal from the flow sensor is used by the transmitter to generate a 4 – 20m A

output that represents changes in flow in the actual process.

Various technologies are used in flow transmitters to measure flow. They range from velocity based flow sensors, Ultrasonic flow sensors to Differential pressure flow sensors. Please see flow meters for more on some of the technologies used.

A converter is a device that converts one type of signal into another type of signal. For example, a converter may convert current into voltage or an analog signal into a digital signal.

Self-Check-4	Written Test

Part I: Define the following terms

1. Transducer
2. Sensor
3. Transmitter
4. Converter

Part II: Enumeration

Direction: Write/List down the following

1. What are the four common process variables
   a. _____
   b. _____
   c. _____
   d. _____
2. The three types of controller
   (a) _____
   (b) _____
   (c) _____
3. Types of transmitters according to the types of signals they produce
   a) _____
   b) _____
   c) _____

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-5	Checking Instrumentation system

5.1. Inspection and Testing Techniques

The testing of an installation implies the use of instruments to obtain readings. However, a test is unlikely to identify a cracked socket outlet, a chipped or loose switch plate, a missing conduit-box lid or saddle, so it is also necessary to make a visual inspection of the installation.

All new installations must be inspected and tested during erection and upon completion before being put into service. All existing installations should be periodically inspected and tested to ensure that they are safe and meet the regulations of the IEE (Regulations 610–634).

The method used to test an installation may inject a current into the system. This current must not cause danger to any person or equipment in contact with the installation, even if the circuit being tested is faulty. The test results must be compared with any relevant data, including the IEE Regulation tables, and the test procedures must be followed carefully and in the correct sequence, as indicated by Regulation 612.1. This ensures that the protective conductors are correctly connected and secure before the circuit is energized.

Visual Inspection

The installation must be visually inspected before testing begins. The aim of the visual inspection is to confirm that all equipment and accessories are undamaged and comply with the relevant British and European Standards, and also that the installation has been securely and correctly erected Regulation 611.3 gives a checklist for the initial visual inspection of an installation, including:

- Connection of conductors;
- Identification of conductors;
- Routing of cables in safe zones;
- Selection of conductors for current carrying capacity and volt drop;
- Connection of single-pole devices for protection or switching in phase conductors only;
- Correct connection of socket outlets, lamp holders, accessories and equipment;
- Presence of fi re barriers, suitable seals and protection against thermal effects;
- Methods of „basic protection" against electric shock, including the insulation of live parts and placement of live parts out of reach by fitting appropriate barriers and enclosures;
- Methods of „fault protection" against electric shock including the presence of earthing conductors for both protective bonding and supplementary bonding.
- Prevention of detrimental influences (e.g. Corrosion);
- Presence of appropriate devices for isolation and switching;
- Presence of under voltage protection devices;
- Choice and setting of protective devices;
- Labelling of circuits, fuses, switches and terminals;
- Selection of equipment and protective measures appropriate to external influences;

- Adequate access to switchgear and equipment;

- Presence of danger notices and other warning notices;
- Presence of diagrams, instructions and similar information;
- Appropriate erection method.

5.2. Approved Test Instruments

The test instruments and test leads used by the electrician for testing an electrical installation must meet all the requirements of the relevant regulations. The HSE has published Guidance Notes GS 38 for test equipment used by electricians. The IEE Regulations (BS 7671) also specify the test voltage or current required to carry out particular tests satisfactorily.

All test equipment must be chosen to comply with the relevant parts of BS EN 61557.

All testing must, therefore, be carried out using an „approved" test instrument if the test results are to be valid. The test instrument must also carry a calibration certificate, otherwise the recorded results may be void. Calibration certificates usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier. This will maintain the accuracy of the instrument to an acceptable level, usually within 2% of the true value. Let us now look at the requirements of three often used test meters.

5.2.1. Continuity tester

To measure accurately the resistance of the conductors in an electrical installation we must use an instrument which is capable of producing an open circuit voltage of between 4 and 24V ac. or dc., and deliver a short-circuit current of not less than 200mA (Regulation 612.2.1). The functions of continuity testing and insulation resistance testing are usually combined in one test instrument.

5.2.2. Insulation resistance tester

The test instrument must be capable of detecting insulation leakage between live conductors and between live conductors and earth. To do this and comply with Regulation 612.3 the test instrument must be capable of producing a test voltage of 250, 500 or 1000V and deliver an output current of not less than 1mA at its normal voltage.

5.2.3. Earth fault loop impedance tester

The test instrument must be capable of delivering fault currents as high as 25A for up to 40 ms using the supply voltage. During the test, the instrument does an Ohm"s law calculation and displays the test result as a resistance reading.

5.2.4. Inspection Requirements

Verify that selected elements associated with the applicant"s program for inspection, test control, and control of M&TE (as identified in an approved inspection plan) are in accordance with the applicant"s approved QA Plan.

5.3. Elements chosen for inspection may include three or more of the following:

Verify that inspection requirements and acceptance criteria are contained in the applicable design documents approved by the responsible design organization. Verify that inspection activities are documented and controlled by instructions, procedures, drawings, checklists, travelers, or other appropriate means.

- Verify that tests required to verify conformance of an item to specified requirements, and to demonstrate satisfactory performance for service, are planned and executed. Verify that the characteristics to be tested and test methods to be employed are specified. Verify that test results are documented and their conformance with acceptance criteria are evaluated.
- Verify that the applicant has established controls for tools, instruments, gauges, and other M&TE used for quality-affecting activities. Verify that M&TE is controlled, calibrated (at specified periods), and adjusted to maintain accuracy within necessary limits.
- Verify that the applicant has established the requirements to identify the status of inspection and test activities. Verify that the status is indicated either on the items or in documents traceable to the items, where it is necessary to assure that required inspections and tests are performed, and to assure that items that have not passed the required inspections and tests are not inadvertently installed, used, or operated. Verify that the status is maintained through indicators (i.e., physical location and tags, markings, shop travelers, stamps, inspection records, computerized logs, or other suitable means). Verify that authority for application and removal of tags, markings, labels, and stamps is specified. Verify that status indicators provide for indicating the operating status of systems and components of the facility (i.e., tagging valves and switches) to prevent inadvertent operation.

5.4. Inspection Guidance

The inspector should refer to the applicant‟s approved QA Plan for specific requirements and commitments. Verify that the following inspection activities are documented and controlled by instructions, procedures, drawings, checklists, travelers, or other appropriate means:

a. Inspection Planning.

Verify that documented inspection planning includes the following:

- Identification of each work operation where inspection is necessary to ensure quality;
- Identification of documents that are used to perform the inspections;
- Identification of the characteristics for inspection and the identification of when, during the work process, inspections are to be performed for those characteristics;
- Identification of inspection or process-monitoring methods employed;
- Sufficient information from the final inspection, to provide a conclusion regarding conformance of the item to specified requirements;
- Identification of the functional-qualification level (category or class) of personnel performing inspections;
- Identification of acceptance criteria;
- Identification of sampling requirements;
- Methods to record inspection results; and Selection and identification of the M&TE to be used to perform the inspection to ensure that the equipment is calibrated and is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

b. Selecting Inspection Personnel to Perform Inspections.

- Determine that the individual who performs an inspection to verify conformance of an item to specified acceptance criteria is qualified to the requirements specified in the applicant‟s approved QA Plan.
- Verify that inspections are performed by personnel other than those who performed or directly supervised the work being inspected. Verify that inspection personnel do not report directly to the immediate supervisor responsible for the work being inspected.

c. Inspection Hold Points.

- If mandatory inspection hold points are used to control work, then verify that specific hold points are indicated in documents.
- When applicable, verify that consent to waive hold points are documented and approved before to continuing work beyond the designated hold point.

d. In-Process Inspections and Monitoring.

- If inspection of processed items is not practicable, then verify that indirect control is provided by the monitoring of processing methods, equipment, and personnel.
- Verify that both inspection and process monitoring are conducted, when control is inadequate with only one method.
- Verify that controls are established and documented for the coordination and sequencing of the work at established inspection points during successive stages of the process.

e. Final Inspection.

- Verify that finished items are inspected for completeness, markings, calibration, adjustments, protection from damage, or other characteristics, as required to verify the quality and conformance of the item to specified requirements.
- Verify that final inspections include a review of the results and resolution of nonconformance‟s identified by earlier inspections. If modifications, repairs, or replacements of items are performed subsequent to the final inspection, then verify that appropriate re-tests or re-inspections are performed.

f. Accepting Items.

Verify that the acceptance of an item is documented and approved by qualified and authorized personnel.

g. Inspection Documentation.

Verify that inspection documentation includes the following:

- The item inspected, date of inspection, the name of the inspector, or the inspector‟s unique identifier, who documented, evaluated, and determined acceptability;
- The name of the data recorder, as applicable, and the type of observation or method of inspection;
- The inspection criteria, sampling plan, or reference documents used to determine acceptance;
- Results indicating acceptability of characteristics inspected;
- M&TE used during the inspection, including the identification number and the most recent

calibration date; and

- Reference to information on actions taken in connection with nonconformance.

Verify that the following test control activities are conducted and documented in accordance with the applicant's approved QA Plan:

a. Test Planning.

Verify that test planning includes the following:

- Identification of documents to be developed to control and perform tests;
- Identification of items to be tested, test requirements, and acceptance limits, including required levels of precision and accuracy;
- Identification of test methods to be employed and instructions for performing the test;
- Identification of test prerequisites addressing, calibration for instrumentation, adequacy of test equipment and instrumentation, qualifications of personnel, condition of test equipment and the item to be tested, suitably controlled environmental conditions, and provisions for data acquisition;
- Identification of mandatory hold points and methods to record data and results; and
- Selection and identification of the M&TE to be used to perform the test to ensure that the equipment is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

b. Performing Tests.

Verify that tests are performed in accordance with the applicant‟s QA procedures, and, as applicable, include the following:

- Provisions for determining when a test is required, describing how tests are performed, and ensuring that testing is conducted by trained and appropriately qualified personnel.
- Test objectives and provisions for ensuring that prerequisites for the given test have been met, adequate calibrated instrumentation is available and used, necessary monitoring is performed, and suitable environmental conditions are maintained.
- Test requirements and acceptance criteria provided or approved by the organization responsible for the design of the item to be tested, unless otherwise designated.
- Test requirements and acceptance criteria based on specified requirements contained in applicable design or other pertinent technical documents.
- Potential sources of uncertainty and error.

c. Use of Other Testing Documents.

Other testing documents (e.g., American Society for Testing and Materials specifications, vendor manuals, or other related documents containing acceptance criteria) may be used instead of preparing special test procedures. If the applicant uses other documents, then verify that the information is incorporated directly into the approved test procedure, or incorporated by reference in the approved test procedure.

d. Tests Results.

Verify that test results are documented and their conformance with acceptance criteria evaluated by a qualified individual within the responsible organization, to ensure that the test requirements have been satisfied.

e. Test Documentation.

Verify that test documentation includes the following:

- Item or work product tested, date of test, names of tester and data recorders, type of observation, and method of testing;
- Test criteria or reference documents used to determine acceptance;
- Results and acceptability of the test;
- Actions taken in connection with any nonconformance‟s noted;
- The individual evaluating the test results; and M&TE used during the test, including the identification number and the most recent calibration date.

f. Qualification of Test Personnel.

Verify that the individual who directs a test to verify conformance of an item to specified acceptance criteria is qualified in accordance with the applicant‟s approved QA Plan. Verify that tests are directed by personnel other than those who performed or directly supervised the work being tested. Verify that test directors do not report directly to the immediate supervisor responsible for the work being tested.

Self-Check-5	Written Test

Direction: Answer the following questions accordingly

1. List the initial visual inspection of an installation checklist. (at least 4)
2. What is the aim/purpose of visual inspection?
3. What are the elements chosen for visual inspection?

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-6	Obtaining materials necessary to complete the work

6.1. Use of electrical test equipment

Test equipment is necessary for determining proper set-up, adjustment, operation, and maintenance of electrical systems and control panels.

Fig 6.1 Test equipment

VOLTMETERS: For measuring differences of potential (voltage) between two points in an electrical circuit. The instrument is connected in parallel with the circuit being measured. Ranges vary from a few tenths volt to a few thousand volts. Instruments are capable of measuring both A.C. and D.C voltage.

OHMETERS: For measuring the electrical D.C. ohm resistance of a circuit, circuit part, or component. Calibrated from zero ohms to infinite. Measures either series or parallel resistance.

AMMETERS: Measure magnitude of electrical current flow in an electrical circuit. When measuring D.C. currents, some types must be inserted in series with the circuit. A.C. ammeters are of two types. One requires that it be connected in series with the circuit; the other needs only to be clamped around the current carrying conductor.

Frequency meter

Fig 6.2 Frequency meter

A frequency meter is an instrument that displays the frequency of a periodic electrical.

Various types of frequency meters are used. Many are instruments of the deflection type, ordinarily used for measuring low frequencies but capable of being used for frequencies as high as 900 Hz. These operate by balancing two opposing forces. Changes in the frequency to be measured cause a change in this balance that can be measured by the deflection of a pointer on a scale. Deflection-type meters are of two types, electrically resonant circuits and radiometers.

An example of a simple electrically resonant circuit is a moving-coil meter. In one version, this device has two coils tuned to different frequencies and connected at right angles to one another in such a way that the whole element, with attached pointer, can move. Frequencies in the middle of the meter‟s range cause the currents in the two coils to be approximately equal and the pointer to indicate the midpoint of a scale. Changes in frequency cause an imbalance in the currents in the two coils, causing them, and the pointer, to move.

USING A MULTIMETER

A multimeter is a device used to measure voltage, resistance and current in electronics & electrical equipment. It is also used to test continuity b/n two points to verify if there is any break in circuit or line. There are two types of multimeter: analogue and digital.

- Analogue has needle style gauge
- Digital has LCD display

There are 2 styles of multimeter.

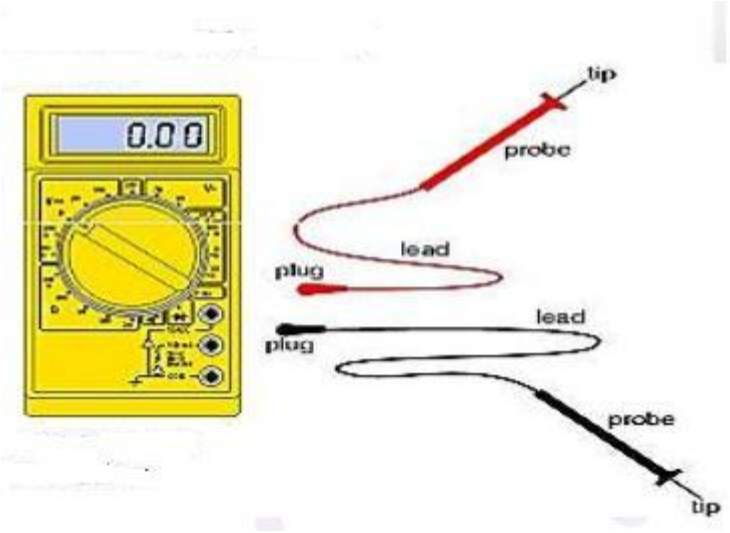
1. **Switched Manually:** switches b/n ranges to get most accurate reading.

2. **Auto Range:** Switches b/n ranges automatically for best reading.

Meter Leads

- Red meter lead: Is connected to Voltage/ Resistance or Amperage port.
  Is considered the positive connection.

Probes: Are the handles used to hold tip on the tested connection.
Tips: Are at the end of the probe and provides a connection point.
Black meter lead: Is always connected to the common port is considered the negative connection.



DISPLAY AND DIAL SETTINGS

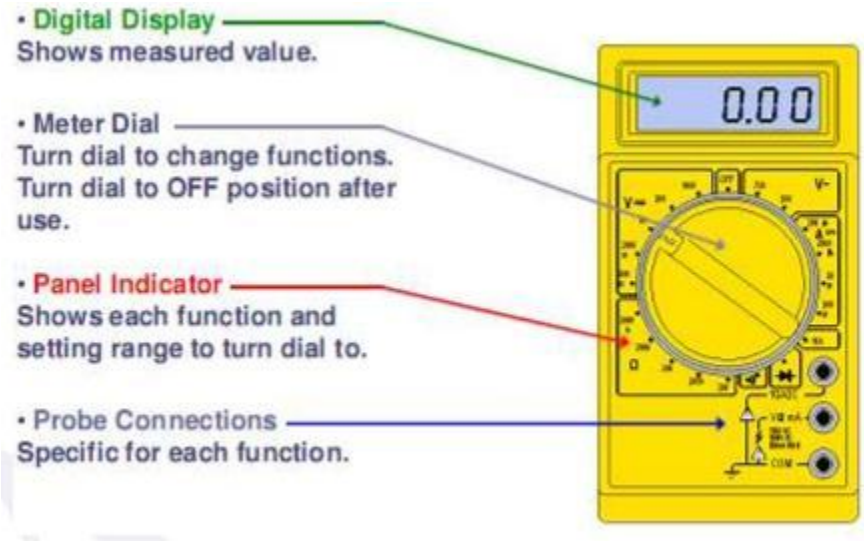


Fig 6.3 multimeter

COMMON DMM SYMBOLS

~	AC Voltage	⏚	Ground
⎓	DC Voltage	⊣⊢	Capacitor
Hz	Hertz	µF	MicroFarad
+	Positive	µ	Micro
—	Negative	m	Milli
Ω	Ohms	M	Mega
⏚	Diode	K	Kilo
•)))	Audible Continuity	OL	Overload

These symbols are often found on multimeter and schematics. They are designed to symbolize components and reference values.

6.2. MEASURING VOLTAGE

VOLTAGE is the unit of electrical pressure; one volt is the potential difference needed to cause one amp of current to pass through one ohm of resistance.

There are two types of voltages: AC & DC

Alternating Voltage (AC) is the house voltage (220v) & Direct Current (DC) is the battery voltage (12v dc)

- Be very careful not to touch any other electronic components within the equipment and do not touch the tips to each other while connected to anything else.

MEASURING VOLTAGE

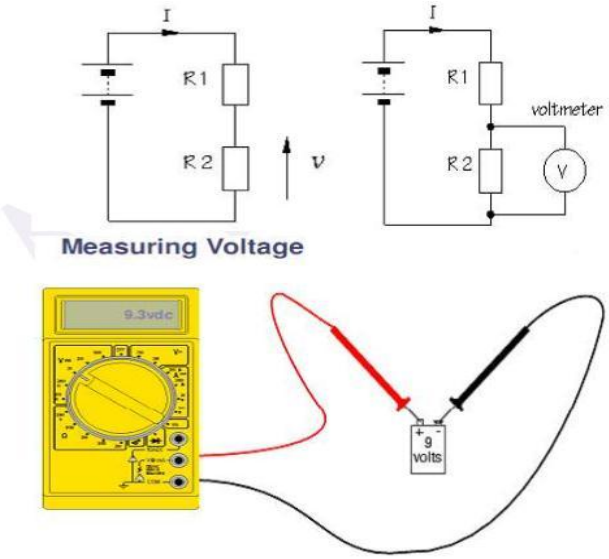


fig 6.4 measuring voltage

6.3. MEASURING RESISTANCE AND CONTINUITY

Resistance is the opposition to current. It is measured in ohm.

Testing for continuity is used to verify if a circuit, wire or fuse is complete with no open. Audible continuity allows an alarm if circuit is complete. If there is no audible alarm resistance of 1 ohm to 0.1 ohm should be present.

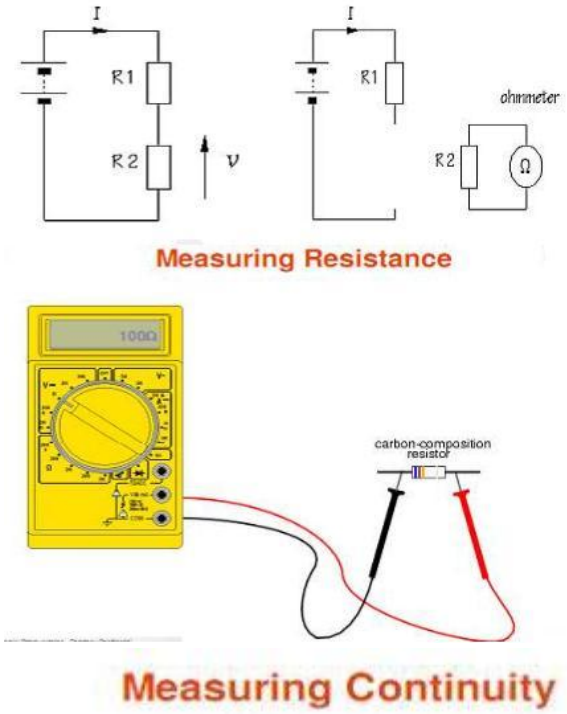


Fig 6.5 measuring resistance and continuity

6.4. MEASURING CURRENT

Current is the flow of electrical charge through a component or conductor. It is measured in amps or

amperes.

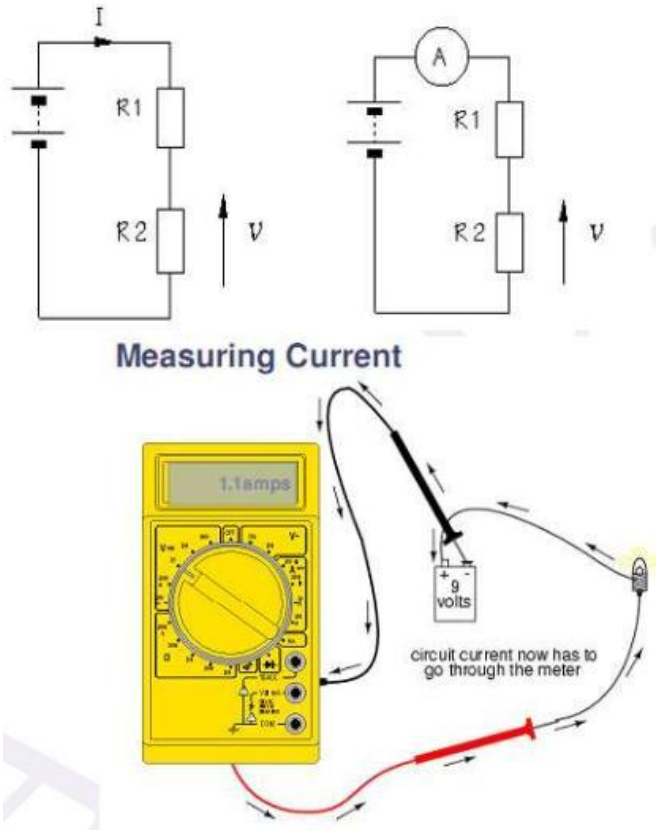


Fig 6.6 Measuring insulation resistance

Insulation resistance testers can be used to determine the integrity of windings or cables in motors, transformers, switch-gear, and electrical installations. The test method is determined by the type of equipment being tested and the reason for testing. For instance, when testing electrical cabling or switchgear (low-capacitance equipment) the time-dependent capacitive leakage and absorption leakage currents become insignificant and decrease to zero almost instantly. A steady conductive leakage current flow is reached almost instantly (a minute or less) providing perfect conditions for the spot-reading/short- time resistance test.

6.5. Insulation Resistance & Leakage Currents and Predictive Maintenance Tests

On the other hand, when the equipment to be tested is a long run of cable, large motor,
Or generator (high-capacitance equipment) the time-dependent currents will last for hours.
These currents will cause the meter readings to change constantly, making it impossible to obtain an accurate steady reading. This condition can be overcome by using a test that establishes a trend between readings, such as the step voltage or dielectric-absorption test. These tests do not depend on a single reading but on a collection of relative readings. It would be a waste of time to perform these tests on low-capacitance equipment since the Time-dependent currents diminish

quickly,resulting in all the measurements being the same.

6.5.1. Installation testing

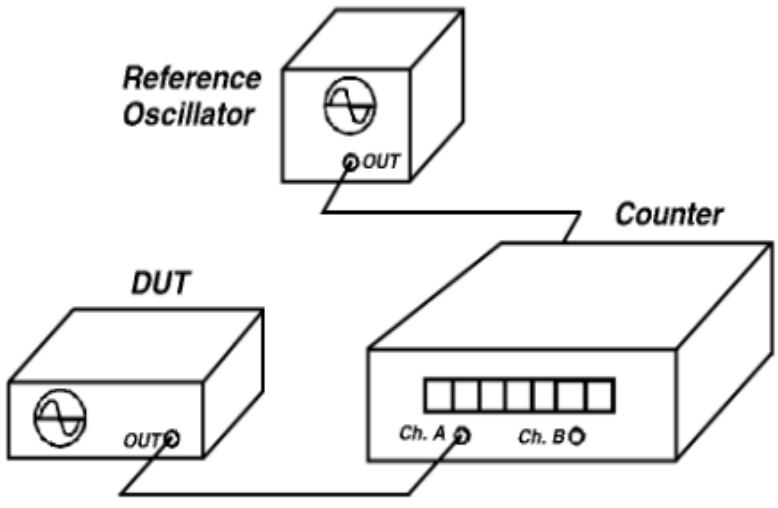
The most important reason for testing insulation is to insure public and personal safety. By performing a high dc voltage test between de-energized current-carrying (hot), grounded, and grounding conductors, you can eliminate the possibility of having a life-threatening short circuit or short to ground. This test is usually performed after the initial installation of the equipment. This process will protect the system against mis-wired and defective equipment, and it will insure a high quality installation, customer satisfaction, and protect against fire or shock.

6.5.2. Maintenance testing

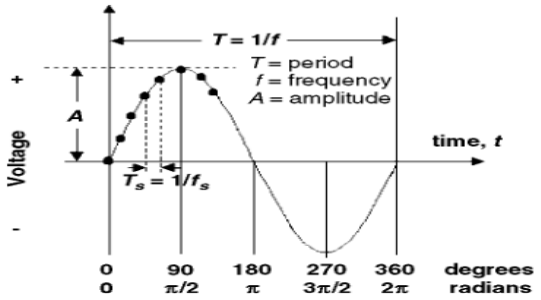
The second most important reason for insulation testing is to protect and prolong the life of electrical systems and motors. Over the years, electrical systems are exposed to environmental factors such as dirt, Grease, temperature, stress, and vibration. These conditions can lead to insulation failure, resulting in loss of production or even fires. Periodic maintenance tests provide valuable information about the state of deterioration and will help in predicting possible failure of the system. Correcting problems will result not only in a trouble-free system, but will also extend the operating life for a variety of equipment.

6.5.3. Measuring frequency

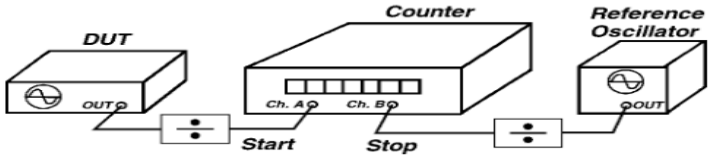
Time and frequency measurements follow the conventions used in other areas of metrology. The frequency standard or clock being measured is called the device under test (DUT).A measurement compares the DUT to a standard or reference The standard should outperform the DUT by a specified ratio, called the test uncertainty ratio (TUR).Ideally, the TUR should be 10:1 or higher. The higher the ratio, the less averaging is required to get valid measurement results.



Measurement using a frequency counter.



An oscillating sine wave.



Measurement using a time interval counter.

Fig 6.7 Measuring frequency

The test signal for time measurements is usually a pulse that occurs once per second (1 pps). The pulse width and polarity varies from device to device, but TTL levels are commonly used. The test signal for frequency measurements is usually at a frequency of 1 MHz or higher, with 5 or 10 MHz being common. Frequency signals are usually sine waves, but can also be pulses or square wave.

6.5.4. Measuring power

Fig 6.8 Measuring frequency

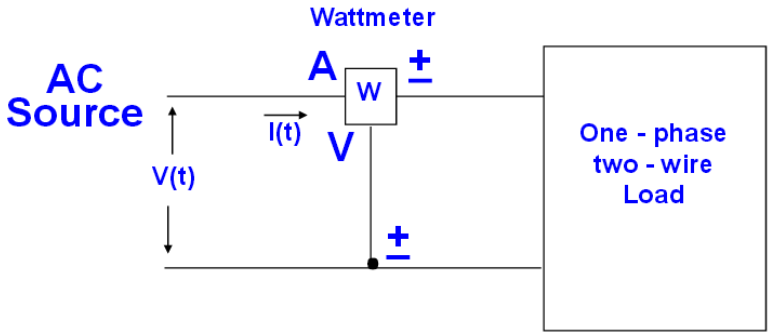
Power: A unit of Power equal to one Joule of Energy per Second

DC Source: W = V x A
AC Source: W = V x A x PF

Active Power:

Watts P = V_{rms} x A_{rms} PF
Also sometimes referred to as True Power or Real Power

Apparent Power:
Volt-Amps S = V_{rms} x A_{rms}



Single Wattmeter Method

Single Phase Two Wire System

- The voltage and current detected by the meter are the voltage and current applied directly to the Load.
- The indication on the Meter is the power being dissipated by the load.

6.5.5. Oscilloscope

An **oscilloscope** (also known **O-scope**)is one of the most important pieces of test equipment available because it allows observation of constantly varying signals in a two-dimensional graph . voltage in the vertical or 'Y' axis, and time or frequency in the horizontal or 'x' axis.
Oscilloscopes are commonly used to observe the exact wave shape of an electrical signal. In addition to the amplitude of the signal, an oscilloscope can show distortion, the time between two events such as pulse width, period, or rise time, and relative timing of two related signals.
Oscilloscopes are used in the sciences, medicine, engineering, and telecommunications industry. General-purpose instruments are used for maintenance of electronic equipment and laboratory work. Special-purpose oscilloscopes may be used for such purposes as analyzing an automotive ignition system, or to display the waveform of the heartbeat as an electrocardiogram.
Originally all oscilloscopes used cathode ray tubes as their display element and linear amplifiers for signal processing, however, modern oscilloscopes have LCD or LED screens, fast analog-to-digital converters and digital signal processors.

Here is Fig 6.9 of an older analog O Scope for the 70"s

Display and general external appearance

The basic oscilloscope is typically divided into four sections: the display, vertical controls, horizontal controls and trigger controls. Older O Scope used a CRT (cathode Ray Tube) and most modern scopes use a solid state display. The display is usually laid out with both horizontal and vertical reference lines referred to as the graticule.

The vertical section controls the amplitude of the displayed signal. This section carries a Volts-per-Division (Volts/Div) control, an AC/DC/Ground control.

The horizontal section controls the time base or “sweep” of the instrument. The primary control is the Seconds-per-Division (Sec/Div) selector.

The trigger section controls the start event of the sweep. The trigger can be set to automatically restart after each sweep or it can be configured to respond to an internal or external event. An external trigger input (EXT Input) and level adjustment will also be included.

In addition to the basic instrument, all oscilloscopes require probes. The probe is the device that us used to connect to the desired signal. The probes often have a 1X and 10X selector switch which allow the probe to provide the exact signal or divide it by certain division.

O Scope protocol:

1. Check probe for 1X or 10X
2. Inform scope of probe choice
3. Choose AC or DC coupling
4. Set appropriate volt/division
5, Set estimated time/division
6. When all else fails, press “Auto set”

6.6. Electrical Safety Analyser

Safety Analyser

Fig 6.10 Safety Analyses

Safety Analyser Tests

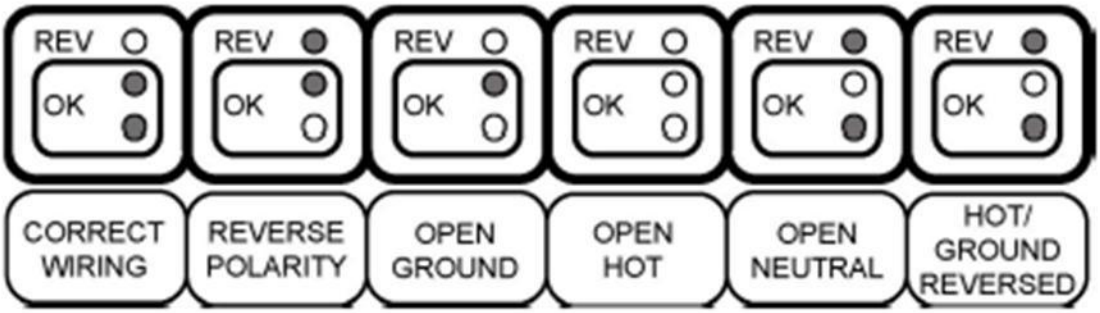
1. Mains Voltage
2. Device Current
3. Earth Resistance
4. Earth(Ground) Leakage Current
5. Enclosure Leakage Current
6. Lead to Earth (Patient Leakage Current)
7. Lead to Lead Leakage
8. Lead Isolation
9. External Leakage test or point to point test

Power Receptacle Confirmation

Once plugged in, the first step is to ensure that the wall receptacle the Safety Analyzer is plugged into is wired properly (120 VAC Non-Isolated Power Systems Only). There are three neon indicators in the unit that provide this confirmation. The REV indicator is red and the other two are green. If the two green indicators are on, the receptacle is wired correctly. If not, utilize the following patterns to help determine the problem. Do not proceed with any testing until you get only the two green lights.

NOTE: Neutral/Ground Reversal is not checked.

NOTE: These Indicators are valid only for 120 VAC Non-Isolated Power Systems.



Mains Voltage

With the Mains Voltage function selected, the display will show the Voltage that is present on the incoming power lines. This is measured from Line to Neutral.

Note that the voltage may drop when the DUT is turned on.

Ensure that this value is within the DUT specifications.

DUT - Device Under Test.

Device Current

With the Device Current function selected, the display will show the current draw of the DUT. The Receptacle should be configured with HOT-CLOSED, NEUTRAL-CLOSED, GROUND-CLOSED and POLARITY-FWD.

Note the specifications for current capacity and permitted duty cycle for this test mode.

SA-2010 & SA-2010-INTL MODELS

15 Amps, 30 minutes

20 Amps, 5 minutes

Device Current

The Receptacle should be configured with HOT-CLOSED, NEUTRAL-CLOSED, GROUND-CLOSED and POLARITY-FWD.

Note the specifications for current capacity and permitted duty cycle for this test mode.

SA-2010 & SA-2010-INTL MODELS

15 Amps, 30 minutes

20 Amps, 5 minutes

Earth Resistance

With the Earth Resistance function selected, the display will show the resistance between the

Chassis Test lead and **Receptacle Earth/Ground**.

This resistance is a combination of the resistance within the DUT enclosure and the resistance of the Earth/Ground Lead in the DUT power cord.
NOTE: This test has no meaning for equipment that does not use a grounded cord.
The test requires that the Chassis Test lead be plugged into the Chassis Connector. The other end should be connected to a solid ground point on the DUT.
The display is in hundredths of Ω and will read to 19.99 Ω. Over-range shows as “1_ _ _”.

Earth/Ground Leakage Current

With the Earth/Ground Leakage function selected and the Ground-Open, the display will show the **leakage current** in the ground wire of the DUT.
NOTE: This test has no meaning for equipment that does not use a grounded cord.
Selecting this function automatically opens the connection to Earth/Ground and passes any leakage current through a 1000 Ω load with either AAMI ES1-1993 or IEC 601 frequency compensation as selected by the Load Selection switch.

Enclosure Leakage

With the Enclosure function selected, the display will show the leakage current between the Enclosure (Chassis) and Earth/Ground.
The test requires that the Chassis Test lead be plugged into the Chassis Connector.
The other end should be connected to a solid ground point on the DUT.
NOTE: If a non-conductive enclosure is used, a 200 cm2 conductive foil pad should be used. This foil is to be placed in close contact with the enclosure and connected to the Chassis Test lead.

Lead to Earth/Ground Leakage

With the Lead to Earth/Ground function selected, the display will show the leakage current between the selected lead and Earth/Ground.
Attach the **patient leads** to the connectors on the **top** of the Safety Analyser. The Up and Down arrow keys may then be used to select any individual lead or all of the leads.
This test should be done for each lead individually and all leads together.
This test measures the leakage current that would flow through the leads if the patient were to come into contact with Earth/Ground.

Lead to Lead Leakage

With the Lead to Lead function selected, the display will show the leakage current between the selected Patient Lead and all other patient leads.
Attach the **patient leads** to the connectors on the top of the Safety Analyser.
The Up and Down arrow keys may then be used to select any individual lead. Internally, relays connect the leads as necessary. The LEDs indicate the selected lead.
This test should be done for each lead individually.
This test measures the current that would flow from a lead to other leads. Normally these are Auxiliary currents from bias, measurement and sensing circuits

Lead Isolation

With the Lead Isolation function selected and the “ISO” Test key depressed, the display will show the leakage current between the selected Patient Lead(s) and Earth/Ground.

Attach the patient leads to the connectors on the top of the Safety Analyzer. The Up and Down arrow keys may then be used to select any individual lead and all of the leads.

Lead Isolation-

As each lead and then All leads are selected, depress and hold the “ISO” Test key. This will apply 110% of the line voltage through a 121 kΩ resistor to the selected lead(s) and measure the current that flows to Earth/Ground through a 1000 Ω load with either AAMI ES1-1993 or IEC 601 frequency compensation as selected by the Load Selection switch.

This test is to be done for each lead individually and All leads together.

This test measures the leakage current that would flow through the lead(s) if the patient were to come into contact with Line voltage. This is referred to as MAP (MAINS on Applied Parts).

Point to point measurement

- External Leakage Test or Point to point leakage test

With the external function selected, the display will show the leakage current between the test leads.

The test requires that the chassis test lead be plugged into the chassis connector and external test lead plugged into the external connector.

The other end of the leads are attached to the point of interest.

Point to point resistance

With the earth resistance function selected, the display will show the resistance between the two test leads.

The test requires that the chassis test lead be plugged into the chassis connector and external test lead plugged into the external connector. the other end of the leads are attached to the point of interest.

Self-Check-6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Write some types of electrical testing equipment?
2. Define oscilloscope and its function?
3. Write the purpose of measuring insulation test equipment?
4. Write each parts of electrical safety analyzer?

Note: **Satisfactory rating - 25 points** **Unsatisfactory - below 25 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Name: _____ Date: _____

Short Answer Questions

1_____

_____

2._____

_____

3._____

Instruction Sheet	LG42: Maintain instrumentation system

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Scheduled/periodic maintenance is performed in accordance with manufacturer‘s requirements
- Normal function of instrumentation and control device is checked in accordance with manufacturer‘s instructions & standard procedures.
- Necessary adjustments, replacement of components or parts of instruments, control devices and correction measures are responded appropriately.
- Unplanned events or conditions are responded to in accordance with established procedures
- Appropriate personal protective equipment is used as per OH&S procedure.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Scheduled/periodic maintenance is performed in accordance with manufacturer‘s requirements
- Normal function of instrumentation and control device is checked in accordance with manufacturer‘s instructions & standard procedures.
- Necessary adjustments, replacement of components or parts of instruments, control devices and correction measures are responded appropriately.
- Unplanned events or conditions are responded to in accordance with established procedures
- Appropriate personal protective equipment is used as per OH&S procedure.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information ―Sheet 1 and Sheet 2,‖
4. Accomplish the ―Self-check 1, and Self-check t 2‖ **in page -7 and 18** respectively.
5. If you earned a satisfactory evaluation from the ―Self-check‖ proceed to ―Operation Sheet 1, **in page -19.**
6. Do the ―LAP test‖ **in page – 27** (if you are ready).

1.1. Predictive Maintenance (PDM):_ is a set of activities that detect changes in the physical condition of equipment (signs of failure) in order to carry out the appropriate maintenance work for maximising the service life of equipment without increasing the risk of failure. It is classified into two kinds according to the methods of detecting the signs of failure:

A. *Condition-based predictive maintenance*
B. *Statistical-based predictive maintenance*

A. ***Condition-based predictive maintenance*** depends on continuous or periodic condition monitoring equipment to detect the signs of failure.

B. ***Statistical-based predictive maintenance*** depends on statistical data from the meticulous recording of the stoppages of the in-plant items and components in order to develop models for predicting failures.

Instruments are devices which are used to measure attributes of physical systems. The variable measured can include practically any measurable variable related to the physical sciences. These variables commonly include: pressure, flow, temperature, level, density, viscosity, radiation, current, voltage, inductance, capacitance, frequency, chemical composition, chemical properties, various physical properties, etc. Instruments can often be viewed in terms of a simple input-output device. For example, if we "input" some temperature into a thermocouple, it "outputs" some sort of signal. (Which can later be translated into data?) In the case of this thermocouple, it will "output" a signal in millivolts.

1.2. Measurements

Measurements provide us with a means of describing various phenomena in quantitative terms. It has been quoted "whatever exists in some amount". The determination of the amount is measurement all about. There are innumerable things in nature which have amounts. The determination of their amounts constitutes the subject of Mechanical Measurements. The measurements are not necessarily carried out by purely mechanical means. Quantities like pressure, temperature, displacement, fluid flow and associated parameters, acoustics and related parameters, and fundamental quantities like mass, length, and time are typical of those which are within the scope of mechanical measurements. However, in many situations, these quantities are not measured by purely mechanical means, but more often are measured by electrical means by transducing them into an analogous electrical quantity.

The Measurement of a given quantity is essentially an act or result of comparison between a quantity whose magnitude (amount) is unknown, with a similar quantity whose magnitude (amount) is known, the latter quantity being called a Standard. Since the two

quantities, the amount of which is unknown and another quantity whose amount is known

are compared, the result is expressed in terms of a numerical value. This is shown in the Fig. 1.1.

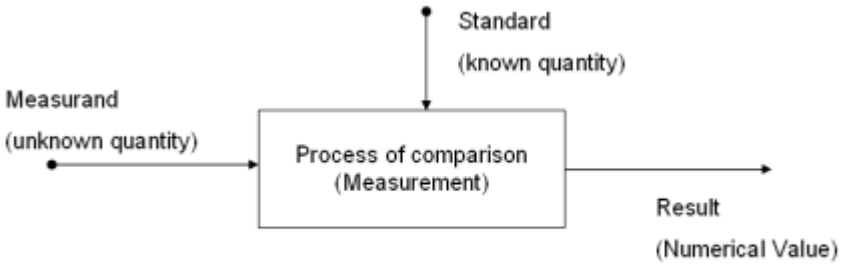


Fig. 1.1 Fundamental Measuring Process.

In order that the results of measurement are meaningful, the basic requirements are:

I. The standard used for comparison purposes must be accurately defined and should be commonly acceptable,
II. The standard must be of the same character as the measured (the unknown quantity or the quantity under measurement).
III. The apparatus used and the method adopted for the purposes of comparison must be provable.

1.3. Instruments and Measurement Systems

Measurements involve the use of instruments as a physical means of determining quantities or variables. The instrument enables the man to determine the value of unknown quantity or variable. A measuring instrument exists to provide information about the physical value of some variable being measured. In simple cases, an instrument consists of a single unit which gives an output reading or signal according to the unknown variable (measured)

applied to it. In more complex measurement situations, a measuring instrument may consist of several separate elements. These elements may consist of transducing elements which convert the measured to an analogous form.

The analogous signal is then processed by some intermediate means and then fed to the end devices to present the results of the measurement for the purposes of display, record and control. Because of this modular nature of the elements within it, it is common to refer the measuring instrument as a measurement system.

3.2. Mechanical, Electrical and Electronic Instruments

The history of development of instruments encompasses three phases of instruments, viz.:

a) Mechanical instruments,
b) Electrical instruments and
c) Electronic instruments.

The three essential elements in modern instruments are:

(i) A detector,

(ii) An intermediate transfer device, and

(iii) An indicator, recorder or a storage device.

Mechanical Instruments:-These instruments are very reliable for static and stable conditions. Major disadvantage is unable to respond rapidly to measurements of dynamic and transient conditions. This is due to the fact that these instruments have moving parts that are rigid, heavy and bulky and consequently have a large mass. Mass presents inertia problems and hence these instruments cannot follow the rapid changes which are involved in dynamic measurements. Thus, it would be virtually impossible to measure a 50 Hz voltage by using a mechanical instrument but it is relatively easy to measure a slowly varying pressure using these instruments. Another disadvantage of mechanical instruments is that most of them are a potential source of noise and cause noise pollution.

Electrical Instruments:-Electrical methods of indicating the output of detectors are more rapid than mechanical methods. Electrical system normally depends upon a mechanical meter movement as indicating device. This mechanical movement has some inertia and therefore these instruments have a limited time (and hence, frequency) response. For example, some electrical recorders can give full scale response in 0.2 s, the majority of industrial recorders have responses of 0.5 to 24 s.

Electronic Instruments.: The necessity to step up response time and also the detection of dynamic changes in certain parameters, which require the monitoring time of the order of *ms* and many a times, *μs*, have led to the design of today's electronic instruments and their associated circuitry. These instruments require use of semiconductor devices. Since in electronic devices, the only movement involved is that of electrons, the response time is extremely small on account of very small inertia of electrons. For example, a Cathode Ray Oscilloscope (CRO) is capable of following dynamic and transient changes of the order of a few ns (10^{-9} s).

In general, electronic instruments have the following characteristics

(i) A higher sensitivity

(ii) A faster response,

(iii) A greater flexibility,

(iv) Lower weight,

(v) Lower power consumption and

(vi) A higher degree of reliability

Basic Electrical Instruments and their functions

Electrical Instrument	Electrical Quantity	Units
1. Voltmeter (V)	Voltage (V)	Volts (V)
2. Ammeter (A)	Current (I)	Amps (A)
3. Watt meter (W)	Power (P)	Watts (W)
4. Energy meter (kwh)	Energy (E)	Units, Kwh
5. Ohm meter	Resistance (R)	Ohms( )
6. Multi-meter (AVO)	Current, Voltage, Resistance	Amps, Volts, ohms.
7. Frequency meter	Frequency (f)	Heartz (Hz)
8. Tachometer	Speed of motor	revolutions per minute (rpm)
9. Clamp meter	Current (I)	Amps (A)
10. Megger	Resistance (R)	kilo ohms, mega ohms

Self-Check 1	Written Test

Part II: Enumeration

Direction: Write/List down the following

1. Measurable variables used in physical science
   a) _____
   b) _____
   c) _____
   d) _____
   e) _____
2. Three essential elements in modern instruments
   a) _____
   b) _____
   c) _____
3. The three phases of instruments
   a) _____
   b) _____
   c) _____
4. Characteristics of electronic instruments
   a) _____
   b) _____
   c) _____

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-2	Doing necessary adjustments

2.1. Replacing of components

A spare part: - spare, service part, repair part, or replacement part, is an interchangeable part that is kept in an inventory and used for the repair or replacement of failed units.

This section addresses the issue of how to dismantle some of basic biomedical equipment in order to replace faulty parts.

The warnings below apply to all work inside the device.

- Before any work on an open device, you need to imperatively check if the high voltage capacitor is properly discharged.
- Before dismantling the device, remove the battery or the cell from its slot.
- The device contains circuits sensitive to electrostatic discharge. Some work on the medical device shall be performed in accordance with ESD rules. The repairs shall be performed on an antistatic mat connected to the earth and the operator shall wear an antistatic strap also connected to the mat. In the event of any work on the high-voltage part of the device, remove the antistatic strap.

2.2. Parts of instruments

A spare part, spare, service part, repair part, or replacement part, is an interchangeable part that is kept in an inventory and used for the repair or replacement of failed units

Examples of medical equipment spare part include:

Heating element	Fuse	Push button
Carbon brush	Sample tube	Lens
Lamp	Motor	tube
Filter	board	

Information Sheet-3	Responding correction measures appropriately

3.1. **Calibration**

Medical Equipment Calibration is the process of ensuring the output quality of said equipment is at par with the industry defined standards. This is done to ensure that the functionality of the item, as well as the result/reading it provides, is accurate at the point of delivery.

The term ―calibration‖ defines the comparison between the value indicated by an instrument and the corresponding real value, while ―adjustment‖ defines the set of operations carried out on an instrument in order to have the given values measured with stated accuracy.

Tracking Instruments for Calibration Status

- ✓ Each instrument should be labeled with the unique identifier (e.g. serial number, model number, location, etc.)
- ✓ Calibration status of each instrument , the date of calibration, the next calibration date and the identification of person performing calibration should be readily available
- ✓ Appropriate systems to document calibration status must include calibration logs and calibration stickers

Calibration Process

- ✓ Written calibration procedures that use traceable calibration standards and/or calibration equipment.
- ✓ Qualified individuals (having the appropriate education, training, background and experience) responsible for calibrating & maintaining instrumentation

3.2. Medical Equipment Testing

Medical Equipment Testing & Calibration is the act of ensuring that all medical equipment is in full working order, and is calibrated to a known standard so as to ensure that the reading/result/functionality of the item is accurate at the point of delivery to a patient. It is your responsibility to ensure that your medical equipment is in full working order and

maintained through regular medical device testing.

Information Sheet-4	Personal protective equipment and OH&S

4.1. Introduction

Hazards exist in every workplace in many different forms: sharp edges, falling objects, flying sparks, chemicals, noise and a myriad of other potentially dangerous situations. The Occupational Safety and Health Administration (OSHA) require that employers protect their employees from workplace hazards that can cause injury.

Controlling a hazard at its source is the best way to protect employees. Depending on the hazard or workplace conditions, OSHA recommends the use of engineering or work practice controls to manage or eliminate hazards to the greatest extent possible. For example, building a barrier between the hazard and the employees is an engineering control; changing the way in which employees perform their work is a work practice control.

I. **The Requirement for PPE**

to ensure the greatest possible protection for employees in the workplace, the cooperative efforts of both employers and employees will help in establishing and maintaining a safe and healthful work environment.

In general, employers are responsible for:

- Performing a "hazard assessment" of the workplace to identify and control physical and health hazards.
- Identifying and providing appropriate PPE for employees.
- Training employees in the use and care of the PPE.
- Maintaining PPE, including replacing worn or damaged PPE.
- Periodically reviewing, updating and evaluating the effectiveness of the PPE program.

II. In general, employees should:

- Properly wear PPE,
- Attend training sessions on PPE,
- Care for, clean and maintain PPE, and
- Inform a supervisor of the need to repair or replace PPE.

Specific requirements for PPE are presented in many different OSHA standards, published in 29 CFR. Some standards require that employers provide PPE at no cost to the employee while others simply state that the employer must provide PPE. Appendix A at page 40 lists those standards that require the employer to provide PPE and those that require the employer to provide PPE at no cost to the employee.

Information Sheet-4	Personal protective equipment and OH&S

4.2. The Hazard Assessment

A first critical step in developing a comprehensive safety and health program is to identify physical and health hazards in the workplace. This process is known as a "hazard assessment." Potential hazards may be physical or health-related and a comprehensive hazard assessment should identify hazards in both categories. Examples of physical hazards include moving objects, fluctuating temperatures, high intensity lighting, rolling or pinching objects, electrical connections and sharp edges. Examples of health hazards include overexposure to harmful dusts, chemicals or radiation. The hazard assessment should begin with a walk-through survey of the facility to develop a list of potential hazards in the following basic hazard categories:

- Impact,
- Penetration,
- Compression (roll-over),
- Chemical,
- Heat/cold,
- Harmful dust,
- Light (optical) radiation, and
- Biologic.

In addition to noting the basic layout of the facility and reviewing any history of occupational illnesses or injuries, things to look for during the walk-through survey include:

- Sources of electricity.
- Sources of motion such as machines or processes where movement may exist that could result in an impact between personnel and equipment.
- Sources of high temperatures that could result in burns, eye injuries or fire.
- Types of chemicals used in the workplace.
- Sources of harmful dusts.
- Sources of light radiation, such as welding, brazing, cutting, furnaces, heat treating, high intensity lights, etc.

- The potential for falling or dropping objects.

- Sharp objects that could poke, cut, stab or puncture.
- Biologic hazards such as blood or other potentially infected material.

When the walk-through is complete, the employer should organize and analyze the data so that it may be efficiently used in determining the proper types of PPE required at the worksite. The employer should become aware of the different types of PPE available and the levels of protection offered. It is definitely a good idea to select PPE that will provide a level of protection greater than the minimum required to protect employees from hazards. The workplace should be periodically reassessed for any changes in conditions, equipment or operating procedures that could affect occupational hazards. This periodic reassessment should also include a review of injury and illness records to spot any trends or areas of concern and taking appropriate corrective action. The suitability of existing PPE, including an evaluation of its condition and age, should be included in the reassessment.

Documentation of the hazard assessment is required through a written certification that includes the following information:

- Identification of the workplace evaluated;
- Name of the person conducting the assessment;
- Date of the assessment; and
- Identification of the document certifying completion of the hazard assessment.

4.3. **Training Employees in the Proper Use of PPE**

Employers are required to train each employee who must use PPE. Employees must be trained to know at least the following:

- When PPE is necessary.
- What PPE is necessary?
- How to properly put on, take off, adjust and wear the PPE.
- The limitations of the PPE.
- Proper care, maintenance, useful life and disposal of PPE.

4.4. Eye and Face Protection

Many occupational eye injuries occur because workers are not wearing any eye protection while others result from wearing improper or poorly fitting eye protection. Employers must be sure that their employees wear appropriate eye and face protection and that the selected form of protection is appropriate to the work being performed and properly fits each worker exposed to the hazard.

4.5. **Eye Protection for Exposed Workers**

OSHA suggests that eye protection be routinely considered for use by carpenters, electricians, machinists, mechanics, millwrights, plumbers and pipefitters, Sheet metal workers and tinsmiths, assemblers, sanders, grinding machine operators, sawyers, welders, laborers, chemical process operators and handlers, and timber cutting and logging workers. Employers of workers in other job categories should

decide whether there is a need for eye and face PPE through a hazard assessment.

Examples of potential eye or face injuries include:

- Dust, dirt, metal or wood chips entering the eye from activities such as chipping, grinding, sawing, hammering, the use of power tools or even strong wind forces.
- Chemical splashes from corrosive substances, hot liquids, solvents or other hazardous solutions.
- Objects swinging into the eye or face, such as tree limbs, chains, tools or ropes.
- Radiant energy from welding, harmful rays from the use of lasers or other radiant light (as well as heat, glare, sparks, splash and flying particles).

4.6. ***Types of Eye Protection***

Selecting the most suitable eye and face protection for employees should take into consideration the following elements:

- Ability to protect against specific workplace hazards.
- Should fit properly and be reasonably comfortable to wear.
- Should provide unrestricted vision and movement.
- Should be durable and cleanable.
- Should allow unrestricted functioning of any other required PPE.

Some of the most common types of eye and face protection include the following:

- **Safety spectacles.** These protective eyeglasses have safety frames constructed of metal or plastic and impact-resistant lenses. Side shields are available on some models.
- **Goggles.** These are tight-fitting eye protection that completely cover the eyes, eye sockets and the facial area immediately surrounding the eyes and provide protection from impact, dust and splashes. Some goggles will fit over corrective lenses.
- **Welding shields.** Constructed of vulcanized fiber or fiberglass and fitted with a filtered lens, welding shields protect eyes from burns caused by infrared or intense radiant light; they also protect both the eyes and face from flying sparks, metal spatter and slag chips produced during welding, brazing, soldering and cutting operations. OSHA requires filter lenses to have a shade number appropriate to protect against the specific hazards of the work being performed in order to protect against harmful light radiation.
- **Laser safety goggles.** These specialty goggles protect against intense concentrations of light produced by lasers. The type of laser safety goggles an employer chooses will depend upon the equipment and operating conditions in the workplace.
- **Face shields.** These transparent sheets of plastic extend from the eyebrows to

below the chin and across the entire width of the employee's head. Some are

polarized for glare protection. Face shields protect against nuisance dusts and potential splashes or sprays of hazardous liquids but will not provide adequate protection against impact hazards. Face shields used in combination with goggles or safety spectacles will provide additional protection against impact hazards.

4.7. **Head Protection**

protecting employees from potential head injuries is a key element of any safety program. A head injury can impair an employee for life or it can be fatal. Wearing a safety helmet or hard hat is one of the easiest ways to protect an employee's head from injury. Hard hats can protect employees from impact and penetration hazards as well as from electrical shock and burn hazards.

Employers must ensure that their employees wear head protection if any of the following apply:

- Objects might fall from above and strike them on the head;
- They might bump their heads against fixed objects, such as exposed pipes or beams; or
- There is a possibility of accidental head contact with electrical hazards.

In general, protective helmets or hard hats should do the following:

- Resist penetration by objects.
- Absorb the shock of a blow.
- Be water-resistant and slow burning.
- Have clear instructions explaining proper adjustment and replacement of the suspension and headband.

4.8. **Foot and Leg Protection**

Employees who face possible foot or leg injuries from falling or rolling objects or from crushing or penetrating materials should wear protective footwear. Also, employees whose work involves exposure to hot substances or corrosive or poisonous materials must have protective gear to cover exposed body parts, including legs and feet. If an employee's feet may be exposed to electrical hazards, non-conductive footwear should be worn. On the other hand, workplace exposure to static electricity may necessitate the use of conductive footwear.

Examples of situations in which an employee should wear foot and/or leg protection include:

- When heavy objects such as barrels or tools might roll onto or fall on the employee's feet;

  Working with sharp objects such as nails or spikes that could pierce the soles or uppers of ordinary shoes;

  Exposure to molten metal that might splash on feet or legs;

  Working on or around hot, wet or slippery surfaces; and
- Working when electrical hazards are present.

4.9. ***Special Purpose Shoes***

Electrically conductive shoes provide protection against the buildup of static electricity. Employees working in explosive and hazardous locations such as explosives manufacturing facilities or grain elevators must wear conductive shoes to reduce the risk of static electricity buildup on the body that could produce a spark and cause an explosion or fire. Foot powder should not be used in conjunction with protective conductive footwear because it provides insulation, reducing the conductive ability of the shoes. Silk, wool and nylon socks can produce static electricity and should not be worn with conductive footwear. Conductive shoes must be removed when the task requiring their use is completed. Note: Employees exposed to electrical hazards must never wear conductive shoes.

Electrical hazard, safety-toe shoes are nonconductive and will prevent the wearers' feet from completing an electrical circuit to the ground. These shoes can protect against open circuits of up to 600 volts in dry conditions and should be used in conjunction with other insulating equipment and additional precautions to reduce the risk of a worker becoming a path for hazardous electrical energy. The insulating protection of electrical hazard, safety-toe shoes may be compromised if the shoes become wet, the soles are worn through, metal particles become embedded in the sole or heel, or workers touch conductive, grounded items. Note: Nonconductive footwear must not be used in explosive or hazardous locations.

4.10. Hand and Arm Protection (Glove)

Care of Protective Gloves

Protective gloves should be inspected before each use to ensure that they are not torn, punctured or made ineffective in any way. A visual inspection will help detect cuts or tears but a more thorough inspection by filling the gloves with water and tightly rolling the cuff towards the fingers will help reveal any pinhole leaks. Gloves that are discolored or stiff may also indicate deficiencies caused by excessive use or degradation from chemical exposure.

Any gloves with impaired protective ability should be discarded and replaced. Reuse of chemical-resistant gloves should be evaluated carefully, taking into consideration the absorptive qualities of the gloves. A decision to reuse chemically-exposed gloves should take into consideration the toxicity of the chemicals involved and factors such as duration of exposure, storage and temperature.

4.11. **Body Protection**

Employees who face possible bodily injury of any kind that cannot be eliminated through engineering, work practice or administrative controls, must wear appropriate body protection while performing their jobs. In addition to cuts and radiation, the following are examples of workplace hazards that could cause bodily

injury:

- Temperature extremes;
- Hot splashes from molten metals and other hot liquids;
- Potential impacts from tools, machinery and materials;
- Hazardous chemicals

Protective clothing comes in a variety of materials, each effective against particular hazards, such as:

- **Paper-like fiber** used for disposable suits provide protection against dust and splashes.
- **Treated wool and cotton** adapts well to changing temperatures, is comfortable, and fire-resistant and protects against dust, abrasions and rough and irritating surfaces.
- **Duck** is a closely woven cotton fabric that protects against cuts and bruises when handling heavy, sharp or rough materials.
- **Leather** is often used to protect against dry heat and flames.
- **Rubber, rubberized fabrics, neoprene and plastics** protect against certain chemicals and physical hazards. When chemical or physical hazards are present, check with the clothing manufacturer to ensure that the material selected will provide protection against the specific hazard.

4.12. Safety and Health Program Management Guidelines

The guidelines identify four general elements critical to the development of a successful safety and health management program:

- Management leadership and employee involvement.
- Work analysis.
- Hazard prevention and control.
- Safety and health training.

Self-Check-2	Written Test

1. Some common types of eye and face protection equipment‘s
   a. _____
   b. _____
   c. _____
   d. _____
2. Common examples of personal protective equipment‘s
   a. _____
   b. _____
   c. _____
   d. _____
3. List of potential hazard categories
   a. _____
   b. _____
   c. _____
   d. _____

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

OPERATION TITLE	Operating Oscilloscope, Function Generator and Multi-Meter Reading
PURPOSE	This experiment introduces the three basic electronic instruments you will use in the course: the oscilloscope, the function generator, and the digital multi-meter. Spend enough time in the lab this week to become familiar with the instruments. There are no pre-lab homework problems for this first lab, and you do not have to write a report.
EQUIPMENT, TOOLS AND MATERIAL	Function generator Oscilloscope Multi-Meter Wire Logic probe
CONDITIONS OR SITUATIONS FOR THE OPERATION	With all the given material perform the testing of equipment‘s- function generator, Oscilloscope and multi tester.

PROCEDURE

Start Your Activity here

Any time you develop a new circuit, repair an electronic instrument, or measure the performance of an electronic component or system, you will need to use one or more items of test equipment. Almost every task requires an oscilloscope, the basic instrument for visualizing the time dependence of electronic signals. A signal or function generator is used to produce periodic signals of the frequency, amplitude, and waveform needed for input to the device under test. The digital multimeter measures voltages, currents, resistance, and it can test silicon diodes and transistors. Everything you do in an electronics laboratory depends upon your familiarity with these instruments.

The instructions for this experiment are designed help you start seeing patterns on the oscilloscope screen as soon as possible, and to familiarize you with the basic controls of each instrument. They do not cover all of the capabilities of the instruments. For greater detail, consult the manufacturer's manuals.

Begin by setting up the 'scope for basic one-channel operation. First, remove all cables left by previous users, and turn the 'scope on by depressing the ON/OFF button. The settings are

remembered from the last user so you need to verify the state of the setup; refer to the manual if you can't spot the right control. Now set the following using the panel and menu controls as follows (you may want to use this standard setup in the future if you have trouble):

Display Intensity	WAVEFORM INTENSITY	50%	Intensity of the A sweep.
	B TRIG	Off	Turn off B sweep.
Cursor Controls	CURSOR Menu	Off option	Inactivates the digital measurement system.
Vertical Controls	CH 1, then Menu		Select channel 1 to display.
	POSITION (CH 1)	Midrange	Vertical position for Channel 1
	SCALE Knob	0.2 V/div	Note value is displayed on screen.
	COUPLING (CH 1)	GND	Gives 0 V I input for setting baseline
	COUPLING	1 MΩ	Input Termination of 1 MΩ
	BANDWIDTH	FULL	
	INVERT	OFF	
Horizontal Controls	POSITION	Midrange	Horiz. Position. (Knob)
SCALE 1 ms/div Sweep speed.			Value is displayed on screen.
MAGNIFY	OFF		(Lets you expand the scale)
	DELAY	OFF	
Trigger Controls	MENU	Pick CH 1	Use CH 1 signal for triggering.
	B TRIG	OFF	Selects A sweep only. (Green light off)
	MODE	AUTO	Sweep even when no signal present.
	COUPLING	DC	Send CH 1 to trigger with no filtering.

=

The baseline beam trace should appear as a horizontal straight line. Readjust Waveform Intensity for desired brightness, move the trace vertically until it coincides with the X-axis using the POSITION knob. Position the start of the trace so that it is visible at the left hand

side of the screen using the horizontal POSITION control.

You may need to turn CH 2, 3, or 4 off. Press the button CH #, then the off button under the vertical position knob.If no yellow trace is visible, check that the trigger MODE is on AUTO. If that fails, depress

AUTO SETUP. If you still don't see a trace, get help from an instructor.

Next we will try to display the signal from the scope‘s calibration signal, a 5V p-p (peak-to- peak) 1 kHz square wave. This output is labeled PROBE COMP because it can be used to adjust the ⎓compensation‘ of oscilloscope probes. Connect the PROBE COMP signal to the CH 1 input with a short coaxial cable and alligator clip probes. Note that the outside of the coax is always ground, and the inner conductor carries the signal. The inner conductor is connected to the red clip, so connect the red clip to the PROBE COMP output. Now set the CH 1 vertical COUPLING to DC. A signal should appear on screen. Adjust the TRIGGER LEVEL (upper right corner of panel) to give a stable and stationary waveform. Note the little arrow on the display which indicates the value of the trigger level. Get some help if you can't see the waveform.

Explore the effect of the following controls one at a time. Return each control to the original setting before you change the next.

- CH 1 VOLTS/DIV, both the calibrated control and FINE ADJUST (variable).
- HORIZ SCALE, (sec/div)
- CH 1 COUPLING: AC/DC/GND. Observe and understand the change in level.
- TRIGGER LEVEL and SLOPE.

The trigger level controls the voltage at which the trace starts. Stability is lost when the trigger level lies outside range of the displayed voltage. Change TRIGGER MODE to NORMAL. Note that the trace now ―freezes‖ when the trigger level is misadjusted. You can see whether the scope is actually being triggered by looking for the small writing TRIG‘D or TRIG? at the top of the display.

Measure the peak-to-peak voltage and the period of the waveform using the screen scale. The peak-to-peak voltage is the difference between the high and low extremes of the waveform.

First adjust the scale factors to give a large trace—between 50% and 95% of the screen in

height and about two periods horizontally. Finally measure the dc voltages of the lowest and highest part of the waveform, and measure the time for a complete cycle. What is the frequency of the waveform? Do the peak-to-peak amplitude and the frequency agree with what you expected?

Now try to get the same trace showing the PROBE COMP signal, but use the CH 2 vertical input.

FUNCTION GENERATOR

Provides sine, square, triangle, pulse and ramp waveforms over the frequencies from 0.0001 Hz to 15 MHz in ten decades. The output amplitude is 50 mV to 10 V peak-to-peak from an impedance of 50 Ω. The frequency may be controlled manually or swept automatically between START and STOP frequency settings set in a menu. The symmetry of the waveform may be varied, enabling square waves to be turned into pulses and triangle waves into ramps. The output may be modulated either by amplitude modulation or frequency modulation. Set up the Function Generator as a free running oscillator with manual control of frequency. This is almost always the way we will use it. Remove any cables left by previous users, and turn the function generator on. There are several methods of setting numbers for amplitude, freq and offset; to become familiar with these,

Frequency	1.000 kHz		
Shape		Button	Select sine waveform.
Amplitude	1.0 VP-P	(See p. 20)	
DC Level	OFFSET	0.0 VDC (p.21)	
Frequency Sweep	SWEEP DURATION	OFF (button)	Default is off at power up

Use a BNC coaxial cable to connect the function generator OUTPUT (lower right corner of panel) to the CH 1 input of the oscilloscope. Set up the 'scope to view the signal on channel 1 with dc coupling. Adjust the 'scope trigger level to obtain a stable waveform. Observe the sine wave and verify that the amplitude and frequency are as expected from the function generator controls.

Explore the effect on the waveform of the following controls. Vary only one control at a time and return it to its original value before changing to the next.

- Depress the (square), (triangle), and (sine) buttons and observes the waveforms.
- Use the knob to change AMPL. Observe the amplitude changes.
- Use the knob to change the OFFSET value. Note the change in dc level.
- Set to (square), use the knob to change the DUTY CYCLE
- Return to (sine) and change the FREQUENCY using the knob; note how you need to use the small arrow buttons to get the full range (100 µHz – 15 MHz).Changing the function generator OFFSET control will change the ‗scope display in the same way as the ‗scope‘s vertical POSITION knob. But these two controls do very different things, since the first changes the actual signal, while the second only changes the way it is displayed.

The function generator has a trigger output which can be used to trigger the 'scope (called SYNC). Using the trigger output is more convenient than triggering the scope off of the waveform itself because you avoid having to readjust the 'scope trigger every time you change the waveform. To see how the trigger output works, first return the function generator to 1 V p-p sine waves at 1 kHz with zero dc offset. Then setup to display both the CH 1 and the CH 4 on the 'scope. Set the 'scope trigger SOURCE to CH 4, and connect a coaxial cable from the function generator trigger output to the 'scope CH 4 input. Observe both the sine wave and the trigger signal on the 'scope. Adjust the 'scope trigger level for a stable display. Now change the amplitude and frequency of the sine wave, and notice how the 'scope remains nicely triggered.

The function generator you are using is actually a synthesizer, which means that its output is derived from a highly stable quartz oscillator. We have some instruments in the lab called counter/timers, which can be used to make very accurate frequency and time interval measurements. There is not much point in using a counter/timer to measure the frequency of a synthesizer, except to check that it is not broken. Counter/timers are useful when studying signals generated by a circuit you build or that come from an outside source of unknown or unstable frequency.

DIGITAL MULTIMETER

Most measurements that are done with the digital multimeter could also be made with the 'scope, but the multimeter is usually more accurate, and it is very convenient for continuously

Monitoring steady voltages or currents.

Check the accuracy of the ohms range by measuring precision resistors of 1 Ω, 1 kΩ, and 1 MΩ. Identify an ordinary 1 kΩ 1/4-watt resistor by its color code and measure it with the multimeter.

Determine the frequency range for which the multimeter can be used to measure ac voltage. Generate 500 Hz sine waves of 1 V p-p amplitude with the function generator, and arrange that the oscilloscope and multimeter both measure the same signal. Be sure that the 'scope input is dc coupled. Determine the amplitude from the oscilloscope trace and compare with the multimeter reading. Note that the multimeter measures rms amplitudes and recall that p-p = 2

2 rms. Now vary the frequency from 10 Hz to 10 kHz. What is the frequency range over which the multimeter reading is constant to within 2%? Remember in the future that this is the usable frequency range for the ac setting of the multimeter.

CURSOR MEASUREMENTS WITH THE OSCILLOSCOPE

Digital measurements of voltage, time, and frequency can be made for signals of the oscilloscope. There are several modes of operation: a manual mode using CURSORS and an automatic mode called up with the measurement menu. The CURSORS are more accurate but the menu buttons are easier to use. A menu system is used to access the functions. The cursor measurements will be most accurate when the displayed signal nearly fills the oscilloscope screen. Set the amplitude to cover about 5 divisions vertically and the sweep speed to give about 2 periods horizontally (An example is in the manual, p. 2-12).

Try using the CURSORS to measure the p-p amplitude of a 1 kHz sine wave from the function generator. If you get lost in the menu system, you can always get back to the beginning by pressing the MENU OFF button.

Next try out the MEASURE system using the same 1 kHz sine wave. Measure the peak-to-peak amplitude and the dc level. Then introduce some dc offset from the function generator and note the changed readings. Try all the different measurements available.

Note that the automatic mode searches for the very top and bottom of the signals. For example, in the schematic of a noisy sine wave below, automatic mode will return the upper and lower most lines which will include the noise contribution. A careful manual measurement indicated by the inner (shorter) lines can remove the noise from the amplitude measurement.

With small or noisy signals, the automatic mode will give very poor results.

SET UP TEST WAVEFORMS

This is an important check point to evaluate your understanding and skill. If you are having trouble, be sure to get help from an instructor.

Set the oscilloscope vertical and horizontal controls such that the display covers about 5 vertical divisions and about 2 periods across the screen. Use the counter-timer and the digital measurements on the oscilloscope to verify that you have obtained the signal you are seeking.

1. 5 Hz triangle waves with a peak-to-peak amplitude of 3 V. (You will have to use NORMAL triggering, not AUTO. Why?)
2. 15 MHz sine waves with amplitude of 500 mV. (If you have trouble getting the scope to trigger at high frequencies, try pushing AUTO SETUP to restore the default settings.)
3. 10 kHz square waves with low value at 0 V and high value at + 5.0 V. Do the scope scales agree with the output of the function generator?
4. Pulses at a frequency of 1 kHz, with an 800 µs low level at 0 V and a 200 µs high level at + 5.0 V. (This could be used as a logic signal).

Write your conclusion and recommendation for the experiment

_____

_____

_____

_____

_____

_____

PRECAUTIONS	For Oscilloscope • Avoid overheating the instrument. Do not block ventilation of the interior by laying books or clothes on the case. This precaution applies to any instrument. • Do not apply more than 400 V to any input terminal.

- Avoid serious or fatal injury from electrical shock. Voltages up to 14 kV

	occur inside the unit. Do not remove the cover or insert anything metallic through the vent holes. • On older analog ⎓scopes you could burn out the screen by setting the intensity too high. This is not an issue with digital ⎓scopes. Again, there are a few precautions to keep in mind: • Do not cover the perforated outer case—the instrument will overheat. • Do not connect any output of the 33120A directly to dc power or to the output of any other instrument. Doing so will burn out the output amplifier. Except for these precautions the instrument cannot be damaged by incorrect settings.
QUALITY CRITERIA	The result should be accurate based on actual readings with acceptable percent of error of 2 % .

LAP Test Method	Practical Demonstration
LAP Test Title/Activity 1	Reading Function Generator and Oscilloscope Data

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instructions:

1. You are required to perform the following:

   Task 1- Group yourself in two (Two trainees / Instrument)

   Task 2- Request for a function generator and oscilloscope instrument.

   Task 3- Set up 5 Hz triangle waves with a peak-to-peak amplitude of 3 V. Draw the Waveform

   Task 1. Set up 15 MHz sine waves with an amplitude of 500 mV, Draw the Waveform

Task 2. 10 kHz square waves with low value at 0 V and high value at + 5.0 V

Task 3. Request your teacher for evaluation and feedback

Instruction Sheet	LG43: Repair instrumentation system

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Normal function of instrumentation and control devices is checked in accordance with manufacturer's instructions.
- Fault/s or problem/s in system or component is/are diagnosed in line with the standard operating procedures.
- Necessary adjustments including calibrations and other correction measures are responded appropriately
- Unplanned events or conditions are responded to in accordance with established procedures
- Appropriate personal protective equipment is used in line with standard procedures..

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Normal function of instrumentation and control devices is checked in accordance with manufacturer's instructions.
- Fault/s or problem/s in system or component is/are diagnosed in line with the standard operating procedures.
- Necessary adjustments including calibrations and other correction measures are responded appropriately
- Unplanned events or conditions are responded to in accordance with established procedures
  Appropriate personal protective equipment is used in line with standard procedures.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information –Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5 and Sheet 6‖.
4. Accomplish the –Self-check 1, Self-check t 2, Self-check 3 and Self-check 4‖ **in page -6, 13, 21 and 31** respectively.
5. If you earned a satisfactory evaluation from the –Self-check‖ proceed to –Operation Sheet 1, Operation Sheet 2 and Operation Sheet 3 ‖ **in page -31,33&34.**

Information Sheet-1	Checking normal function of instrumentation and control device

1.1. Introduction

Having established the symptoms of a fault it is then necessary to conduct tests to confirm the symptoms and to attempt to determine the location of the fault within the equipment. A sound knowledge of the technical concepts and the operation of the system may assist in locating the fault but sometimes the testing will be extensive and an overall procedure should be adopted.

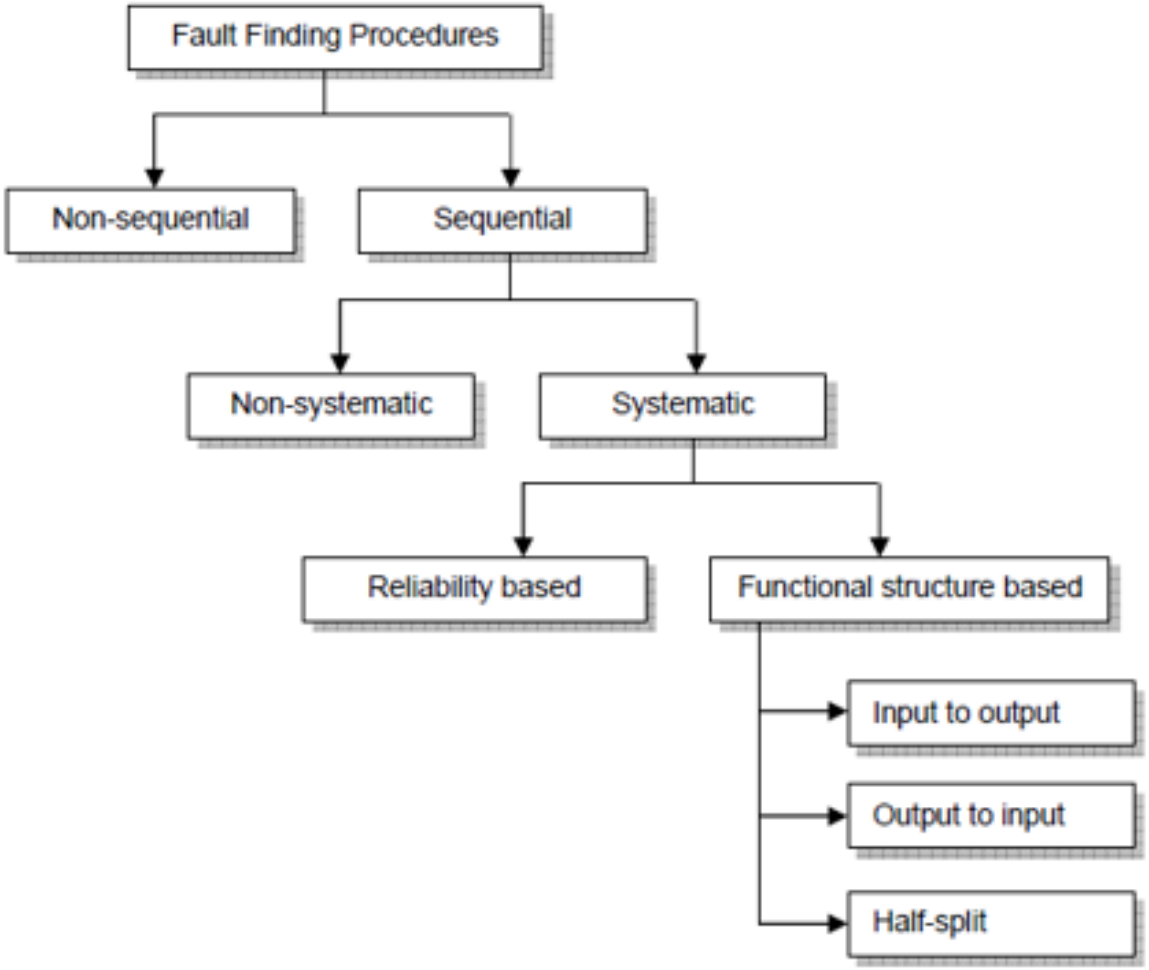


Figure 1.1.Fault Finding Procedures

Non-sequential systems use the collection of a lot of test data by operating the equipment with a range of different inputs and measuring outputs. By checking these against known conditions the component at fault may be determined. This method is particularly suited to fault finding digital and computer based systems using automated test equipment.

Sequential systems use a sequence of tests of the function of different parts of the equipment. They can be non-systematic; that is applied randomly based on the whim of the technician. This is where experience and technical knowledge can assist but will not reliably lead to quick resolution.

1.2. A systematic approach is preferred

One type of systematic approach is to first test the least reliable component or block within the equipment. If this is ok, then test the next least reliable block. This system requires a lot of information to be available to indicate which block should be tested first. Again experience may play a part.

The system based on functional blocks can then be classified on the order of testing within the equipment. The first two -input to outputll and –output to inputll are fairly self- explanatory. The third can be shown to locate the fault with fewer tests

The –half splitll technique says split the system in half and test at the center. This will locate the fault in either the first half or second half of the system. This section should then be split and a test conducted in the middle of that part. Continuing in this way will locate the faulty block with fewer tests.

These techniques are simple to apply to systems that are linear, that is, where the signal passes from one block to the next all the way through. Systems like this are actually not that common.

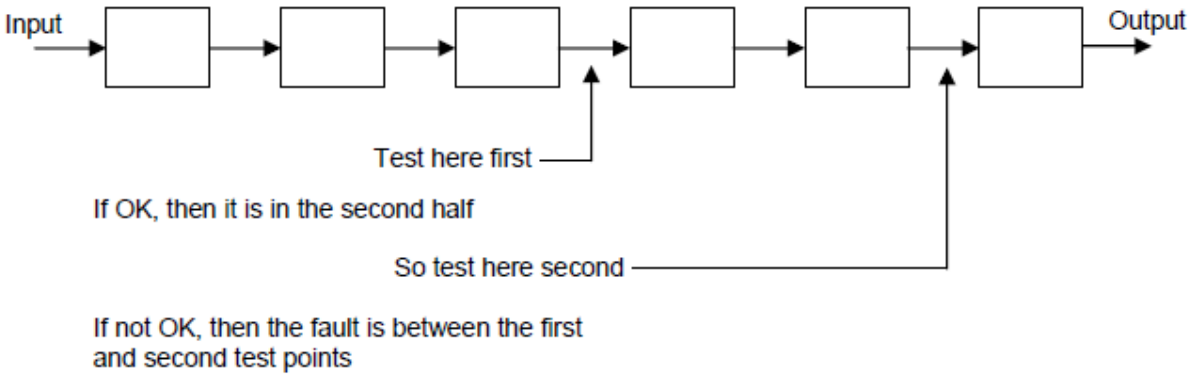
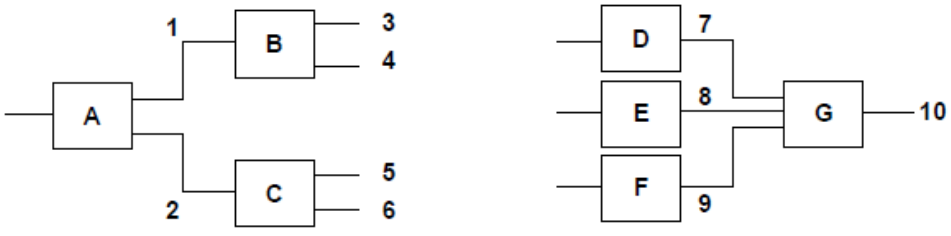


Figure1. 2. "Half-split" fault finding techniques

The direct application of these techniques to divergent or convergent systems or for systems with feedback is bit more complicated and relies a lot more on the technical expertise and experience of the technician.

Figure1. 3. Divergent and Convergent systems

In the



Divergent System Convergent System

divergent system if the outputs at 3, 4 and 5 are ok then blocks A and B must be ok, the connections between the blocks ok, and the fault must be in block C

In the convergent system, an incorrect output at 10 does not indicate a fault in block G and the conditions at 7, 8 and 9 must be tested.

Self-Check-1	Written Test

Name: _____ Date:_____

Section: _____

Part I: Essay

Instruction: Answer the following questions.

1. What is -half splitǁ fault finding technique? 15 points)

   _____

   _____

   _____

   _____

   _____.

2. What is the difference between sequential and non-sequential systems of fault finding procedures? (20 points)

   _____

   _____

   _____

   _____

   _____

   _____.

Information Sheet-2	Diagnosing Fault/s or problem/s in system or component in line with the standard operating procedures

2.1. Diagnosing Fault/s or problem/s in system

Basic troubleshooting techniques apply to every situation and occupation. Positive identification of the problem(s) is absolutely essential to solving the problems. Many times, the inexperienced troubleshooter will mistake one or more of the symptoms for the problems. Solving the symptom(s) will normally just postpone the problems to a later date.

An example is when, a fuse in a circuit blows and the maintenance person gets the replacement fuse and inserts it into the fuse holder. There are many things that could have caused the fuse to blow, depending on the complexity of the circuit.

Excess current caused the fuse to open (blow). Excess current could have been caused by: overload on the load; short circuit between the wires, grounded wires, short circuit in the load, ground in the load, voltage spike, voltage droop, etc. If the maintenance person does not troubleshoot the circuit prior to replacing the fuse and restoring power, negative consequences could arise.

It is not uncommon for a process to develop a number of small problems and continue to function at a degraded level of operational capability. Then, one more small problem occurs and the whole process breaks down. Finding and correcting the last problem will not necessarily restore the operational capability of the process. The process continued operations with the small problems, but the small problems may not allow the process to restart from a dead stop. All the other small problems must be identified and corrected before the process is restored to full operational capability.

2.2. Troubleshooting in the Field:

Unless prior experience dictates otherwise, always begin at the beginning.

Ask questions of the Operator of the faulty equipment:

- Was equipment running when problem occurred?
- Does the Operator know what caused the problem, and if so, what, in their opinion, caused the problem?
- Is the equipment out of sequence?
- Check to ensure there is power
- Turn on circuit breaker, ensure motor disconnect switch is on, and operate start button/switch.

Use voltmeter to check the following at incoming and load side of circuit breaker(s) and/or fuses, ensure that voltages are normal on all legs and read voltage to ground from each leg:

- Main power, usually 460 VAC between phases and 272 to ground
- Control & power, 208/240 between phases and 120 to ground and 120 VAC to neutral on a

grounded system

- Low voltage control power, usually 24 to 30 VAC and/or VDC between phases and possibly to ground, usually negative is connected to ground

Check controlling sensors in area of problem, then make complete check of all sensors, limit switches and other switches to ensure they are in correct position, have power, are programmed, set, and are functioning correctly.

If and when a problem is found, whether electrical or mechanical, the problem should be corrected and the fault-finding begun anew, a seemingly unrelated fault or defect could be the cause of the problem.

When there is more than one fault, the troubleshooting is exponentially more difficult, do not assume that all problems are solved after completing one, always test the circuit and operation prior to returning the equipment to service.

Testing and troubleshooting are the areas of maintenance that require the greatest technical skill. Testing procedures are referred to as measurements, tests, and checks. The definitions of these terms often overlap, depending on their use and the results obtained. For example, a power measurement and a frequency check could constitute a test of the operation of the same radio transmitter.

2.2.1. **Troubleshooting** is a term which we in the electronics field use daily. But what does it mean?

Troubleshooting is sometimes thought to be the simple repair of a piece of equipment when it fails to function properly. This, however, is only part of the picture. In addition to repair, you, as a troubleshooter, must be able to evaluate equipment performance. You evaluate performance by comparing your knowledge of how the equipment should operate with the way it is actually performing. You must evaluate equipment both before and after repairs are accomplished.

Equipment performance data, along with other general information for various electronic equipment's, is available to help you in making comparisons. This information is provided in performance standards books for each piece of equipment. It illustrates what a particular waveform should look like at a given test point or what amplitude a voltage should be, and so forth. This data aids you in making intelligent comparisons of current and baseline operating characteristics for the specific equipment assigned to you for maintenance. ("Baseline" refers to the initial operating conditions of the equipment on installation or after overhaul when it is operating according to design.)

2.3. Test Equipment Safety Precautions

The electrical measuring instruments included in test equipment are delicately constructed and require certain handling precautions to prevent damage and to ensure accurate readings. In addition, to prevent injury to personnel, you must observe precautions while using test equipment. You can find a list of applicable instructions in appendix II of this module.

I. Instrument Precautions

To prevent damage to electrical measuring instruments, you should observe the precautions relating to three hazards: mechanical shock, exposure to magnetic fields, and excessive current flow.

II. **Mechanical Shock**. —Instruments contain permanent magnets, meters, and other Components that are sensitive to shock. Heavy vibrations or severe shock can cause these instruments to lose their calibration accuracy.

III. **Exposure to Strong Magnetic Fields**:-strong magnetic fields may permanently impair the accuracy of a test instrument. These fields may impress permanent magnetic effects on permanent magnets, moving-coil instruments, iron parts of moving-iron instruments, or in the magnetic materials used to shield instruments.

IV. **Excessive Current Flow—**this includes various precautions, depending on the type of instrument. When in doubt, use the maximum range scale on the first measurement and shift to lower range scales only after you verify that the reading can be made on a lower range. If possible, connections should be made while the circuit is de-energized. All connections should be checked to ensure that the instrument will not be overloaded before the circuit is reenergized.

2.4. Other Instrument Precautions

Precautions to be observed to prevent instrument damage include the following:

- Keep in mind that the coils of wattmeter's, frequency meters, and power meters may be carrying large quantities of current even when the meter pointer is on scale.
- Never open secondary of current transformers when the primary is energized.
- Never short-circuit secondary of potential transformers the primary is energized.
- Never leave an instrument connected with its pointer off-scale or deflected in the wrong direction.
- Ensure that meters in motor circuits can handle the motor starting current. This may be as high as six to eight times the normal running current.
- Never attempt to measure the internal resistance of a meter movement with an ohmmeter since the movement may be damaged by the current output from the ohmmeter.

- Never advance the intensity control of an oscilloscope to a position that causes an excessively bright spot on the screen; never permit a sharply focused spot to remain stationary for any period of time. This results in burn spots on the face of the cathode-ray tube (CRT).
- In checking electron tubes with a tube tester that has a separate "short test," always make the short test first. If the tube is shorted, no further test should be made.
- Before measuring resistance, always discharge any capacitors in the circuit to be tested. Note and record any points not having bleeder resistors or discharge paths for capacitors.
- Always disconnect voltmeters from field generating or other highly inductive circuits before you open the circuit.

2.5. Working on Energized Circuits

Insofar as is practical, you should NOT undertake repair work on energized circuits and equipment. However, it could become necessary, such as when you make adjustments on operating equipment. In such cases, obtain permission from your supervisor, then proceed with your work, but carefully observe the following safety precautions:

- DO NOT WORK ALONE.
- Station an assistant near the main switch or circuit breaker so the equipment can be immediately
- De-energized in case of an emergency.
- Someone qualified in first aid for electrical shock should be standing by during the entire operation.
- Ensure that you have adequate lighting. You must be able to see clearly if you are to perform the job safely and properly.
- Be sure that you are insulated from ground by an approved rubber mat or layers of dry canvas and/or wood.
- Where practical, use only one hand, keeping the other either behind you or in your pocket.
- If you expect voltage to exceed 150 volts, wear rubber gloves.
- DO NOT work on any type of electrical apparatus when you are wearing wet clothing or if your hands are wet.

- DO NOT wear loose or flapping clothing.

- The use of thin-soled shoes and shoes with metal plates or hobnails is prohibited.
- Flammable articles, such as celluloid cap visors, should not be worn.
- Remove all rings, wristwatches, bracelets, and similar metal items before working on the equipment. Also ensure that your clothing does not contain exposed metal fasteners, such as zippers, snaps, buttons, and pins.
- Do not tamper with interlock switches; that is, do not defeat their purpose by shorting them or blocking them open.
- Ensure that equipment is properly grounded before energizing.
- De-energize equipment before attaching alligator clips to any circuit.
- Use only approved meters and other indicating devices to check for the presence of voltage.

Observe the following procedures when measuring voltages in excess of 300 volts:

- Turn off the equipment power.
- Short-circuit or ground the terminals of all components capable of retaining a charge.
- Connect the meter leads to the points to be measured.
- Remove any terminal grounds previously connected.
- Turn on the power and observe the voltage reading.
- Turn off the power.
- Short circuit or ground all components capable of retaining a charge.
- Disconnect the meter leads.

Self-Check-2	Written Test

Part I: Enumeration

Direction: Write/List down the following

1. Safety precaution while working on energized circuits
   a) _____
   b) _____
   c) _____
   d) _____
   e) _____
   f) _____
2. Precaution to prevent damage to electrical measuring instruments
   a) _____
   b) _____
   c) _____

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-3	Checking and inspect Instruments to ensure safe operation

3.1. Inspection

3.1.1. Procedures of Visual Inspection

a) Inspection and test activities should be documented.
b) Inspection and testing requirements, records should be maintained and documented in the quality plan of procedures.

Receiving inspection

- Ensure that incoming product is not to be processed /used until confirmed as acceptable.
- Amount/nature of receiving inspection should be defined and the decision traceable
- In process inspection and testing
- Inspection / testing should be carried out to documented procedures.
- Product should not be released until conformance confirmed
- Final inspection and testing
- Final inspection and testing should be carried out to quality plan and procedure
- Evidence of finished product conformance to the specified requirements should be identifiable
- Ensure that all identified inspection and testing activities are carried out.
- No completed product should be dispatched until all activities are completed and associated documentation.
- Inspection and test records
- Records should be maintained to provide evidence that the product has been inspected/tested
- Records should clearly indicate if products have passed
- Records should indicate inspection authority responsible for the release of the product.

3.1.2. Control of Inspection, Measuring and Test Equipment

a) The control, calibration, maintenance of equipment's should be documented
b) Equipment should be used in a manner which ensures that at the measurement uncertainty is known and consistent with the required capability
c) Test software/comparative references should be checked to ensure the capability of verifying acceptability
d) Equipment/references should be periodically checked for acceptability
e) Measurements should be made and accuracy maintained

f) All inspection, measuring and testing equipment should be clearly identified and maintained under calibration controls
g) Calibration status should be identified
h) Calibration records should be maintained
i) Ensure correct working and calibration conditions
j) Ensure adequate handlings, storage, preservation
k) Equipment should be safeguarded from unauthorized adjustment

3.2. Meeting Test Specifications

Measurement acceptability is determined by comparing values of the unit under test(UUT) to standard values. A nominal value from the UUT is compared to an actual value determine from standard. The measurement passes if the difference between the two value is less than that specified by the tolerance. If the difference is greater than the tolerance then the measurement fails and some type of corrective action occurs such as adjustment, repair, and replacement of the UUT.

After corrections have been made, testing is again required to determine if the correction were effective. When testing a measurement device, several values throughout the range of operability or use are usually chosen to be tested. Signal checkpoints can also be specified depending on the application. If any one of the specified test values fails to meet its tolerance requirements, the device is usually considered to have failed the calibration requirements.

3.3. Instrument Handling

One of the most important systems in a distribution center is the instrument handling system for classifying, ordering, sorting and transporting units. Depending on the complexity of the handling system, units may need to be simply transferred from one location to another but applications can vary to be more complex. Example applications can include monitoring integrity of units to see if the package or unit has been damaged, sorting units depending on shape, size or even barcode value, realigning units to be handled further down the instrument handling line and even removing units from handling system altogether. Because of these numerous possibilities and the varied levels of complexity required by a instrument handling system, a flexible solution is essential. NI’s control platform solves this challenge by providing a comprehensive family of control and monitoring products while offering an unparalleled degree of flexibility and ease of use.

3.4. Typical instrument handling system

Typical systems in instrument handling include a vision system, belt drives as well as system specific sensors and actuators depending on system needs. Sensors include photo-sensors, pressure transducers, pneumatic-controlled rollers as well as handling robots. The vision system is chiefly responsible for unit identification and inspection but can be used to determine other information such as alignment. The belt drives are critical since they are responsible for the primary movement and transport of units in the distribution center including motion on the main belt itself. Sensors can be used to determine position along the belt and other information including size and weight. There are also invariably other actuators and pneumatics used to

control sorting, picking and placing of units.

For starting measurement an attention must be paid specially to the following.

1. Measurements must be made with the following objectives always in mind
    - Know the structure and operation of instruments by your own hands
    - Compare theory with measured values
    - Cultivate the ability of application and correction
2. Studies must be made on the test item before making actual measurements
3. Apparatus and instruments must be selected precisely. if inappropriate apparatus or instrument is selected, measurement cannot be made smoothly, and accurate result cannot be obtained. If the apparatus or instrument is damage any dangerous may be caused. Therefore, the following must be observed in selecting instruments
    - When the quantity is measured, the kind of any instrument suitable the quantity should be used
    - The apparatus or instrument used must have an appropriate capacity
    - Depending on the purpose of measurement any instrument with a proper grade must be selected.
4. Apparatus or instrument must be arranged and connected scale fully. In measurement apparatus or instruments must be arranged and connected by observing.
    - Put things in order in the place when measurement is made.
    - The instrument had better be placed in a way to allow easy observation, and as specified in circuit diagram.
    - For wiring, it is recommended to complete a main circuit, and then to arrange an auxiliary circuit. Before turning on a switch, be sure to check.
5. For measurement, all the members must co-operate with each other.

Information Sheet-4	Responding Necessary adjustments including calibrations and other correction measures

4.1. Procedure of calibration

I. Manual and automatic calibration procedure

Calibration methods for modern devices can be both manual and automatic, depending on what kind of device is being calibrated. Manual calibration - US serviceman calibrating a temperature gauge. The device under test is on his left and the test standard on his right.

II. Manual

Manual calibration procedure on a pressure test gauge The procedure is complex, but overall it involves the following: (i) depressurizing the system, and turning the screw, if necessary, to ensure that the needle reads zero, (ii) fully pressurizing the system and ensuring that the needle reads maximum, within acceptable tolerances, (iii) replacing the gauge if the error in the calibration process is beyond tolerance, as this may indicate signs of failure such as corrosion or material fatigue.

III. Automatic calibration

Automatic calibration - A U.S. serviceman using a 3666C auto pressure calibrator

The use of a 3666C automatic pressure calibrator, which is a device that consists of a control unit housing the electronics that drive the system, a pressure intensifier used to compress a gas such as Nitrogen, a pressure transducer used to detect desired levels in a hydraulic accumulator, and accessories such as liquid traps and gauge fittings.

The Calibration Process There are a number of stages in the process of calibrating an analytical instrument. These are summarized below:

- Plan the experiments;
- Make measurements;
- Plot the results; •
- Carry out statistical (regression) analysis on the data to obtain the calibration function;
- Evaluate the results of the regression analysis;
- Use the calibration function to estimate values for test samples;
- Estimate the uncertainty associated with the values obtained for test samples.

4.2. Process description and documentation

All of the information above is collected in a calibration procedure, which is a specific test method. These procedures capture all of the steps needed to perform a successful calibration. The manufacturer may provide one or the organization may prepare one that also captures all of the organization's other requirements. There are clearing houses for calibration procedures such as the Government-Industry Data Exchange Program (GIDEP) in the United States.

This exact process is repeated for each of the standards used until transfer standards, certified reference materials and/or natural physical constants, the measurement standards with the least uncertainty in the laboratory, are reached. This establishes the traceability of the calibration.

See Metrology for other factors that are considered during calibration process development.

After all of this, individual instruments of the specific type discussed above can finally be calibrated. The process generally begins with a basic damage check. Some organizations such as nuclear power plants collect "as-found" calibration data before any maintenance is performed. After routine maintenance and deficiencies detected during calibration are addressed, an "as-left" calibration is performed.

More commonly, a calibration technician is entrusted with the entire process and signs the calibration certificate, which documents the completion of a successful calibration. The basic process outlined above is a difficult and expensive challenge. The cost for ordinary equipment support is generally about 10% of the original purchase price on a yearly basis, as a commonly accepted rule-of-thumb. Exotic devices such as scanning electron microscopes, gas chromatograph systems and laser interferometer devices The 'single measurement' device used in the basic calibration process description above does exist. But, depending on the organization, the majority of the devices that need calibration can have several ranges and much functionality in a single instrument. A good example is a common modern oscilloscope. There easily could be 200,000 combinations of settings to completely calibrate and limitations on how much of an all-inclusive calibration can be automated can be even more costly to maintain.

An instrument rack with tamper-indicating seals

To prevent unauthorized access to an instrument tamper-proof seals are usually applied after calibration. The picture of the oscilloscope rack shows these, and proves that the instrument has not been removed since it was last calibrated as they will possible unauthorized to the adjusting elements of the instrument. There also are labels showing the date of the last calibration and when the calibration interval dictates when the next one is needed. Some organizations also assign unique identification to each instrument to standardize the record keeping and keep track of accessories that are integral to a specific calibration condition.

When the instruments being calibrated are integrated with computers, the integrated computer programs and any calibration corrections are also under control.

The adjustment of an instrument of its output accurately corresponds to its input throughout a specified range. This definition specifies the outcome of a calibration

Process, but not the procedure it is the purpose of this section to describe procedures for efficiently calibrating different types of instruments.

4.3. Linear instruments

The simplest calibration procedure for a linear instrument is the so-called zero-and-span method. The method is as follows:

Apply the lower-range value stimulus to the instrument; wait for it to stabilize Move the zero adjustment until the instrument registers accurately at this point.

Apply the upper-range value stimulus to the instrument, wait for it to stabilize

Move the span adjustment until the instrument registers accurately at this point.

Repeat steps1 through 4 as necessary to achieve good accuracy at both ends of the range

An improvement over this basic procedure is to check the instruments response at several points between the lower-and upper- range values.

A common example of this is the so-called five-point calibration where the instrument is checked at 0% (LRV), 25%, 50%, 75%, and 100% (URV) of range.

A variation on this theme is to check at the five points of 10%,25%, 50%, 75% ,and 90%, while still making zero and span adjustments at 0% and 100%.

Regard less of the specific percentage points chosen for checking, the goal is to ensure that we achieve (at least) the minimum necessary accuracy at all points along the scale, so the instruments response may be trusted when placed into service.

Yet another improvement over the basic five-point test is to check the instruments response at five calibration points decreasing as well as increasing. Such tests are often referred to as Up-down calibrations. The purpose of such a test is to determine if the instrument has any significant hysteresis: a lack of responsiveness to a change in direction.

Self-Check-4	Written Test

Instructions: Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the answer sheet provided:

1. Write the manual calibration procedure on a pressure test gauge?
2. Write calibration process stages in the process of calibrating an analytical instrument.
3. When instruments are calibrating?
4. What is bench calibration?
5. start- up calibration includes what points?

Note: **Satisfactory rating - 15 points** **Unsatisfactory - below 15 points**

You can ask you teacher for the copy of the correct answers.

Information Sheet -5	Responding Unplanned events or conditions accordance with established procedures

What to Look for in a Documenting Calibrator - A documenting calibration system can be as simple as a single multi-function calibrator with an easy to use software package or it can be a more sophisticated system with extensive database software, custom reporting and multiple brands or types of calibrators. There is a lot of choice in the marketplace, so it's important to determine your needs and buy accordingly rather than having a system that dictates to you.

Information Sheet -6	Appropriate personal protective equipment in line with standard procedures

6.1. OH & S Police and procedure

OH&S Policies and Procedures are a major part of protecting the safety, health and welfare of people engaged in work or employment. Having a clear set of OHS Policies and Procedures will make it clear to all concerned where the guidelines and boundaries are in relation to the operation of the organization. As an employer you are required by law to provide a ―safe system of work‖. What that means is the employer needs a method of communicating, duplicating and implementing safe work environment. This begins with OH&S Policy. Most OHS Policies and Procedures follow a similar format.

AIM: The main goal that the policy intends to achieve.

POLICY: This would be the actual working document. This is the specifics of what needs to be done and how the company will achieve its goal.

PROCEDURES: This would explain a step by step process on how a task should be done safely.

The most economical way to start your business using it's own OHS Policies and Procedures would be to purchase a OH&S System that come with editable word documents. This system will provide you with most of the OHS Policies and Procedures you will need. The organization should know that it must be their very own obligation to train workers their OHS policies and procedures around the place of work. Many employees were entirely unaware of the health and safety procedures put in place by their employer. Some researches indicate that Up to 50 % of the personnel interviewed claimed they had never looked at any OHS policy paperwork whilst they worked within a company which in fact had a labor force of several or more people.

A small proportion of personnel were unaware of their company's fire safety procedure or even knew their particular health and safety supervisor. Some workers did not even know where the first aid kit was to be found. It is vital that every company make sure that their own staff are up-to-date with all the latest workplace health and safety legislation because this will certainly minimize the injury risk to personnel as well as possible claims against businesses. Regardless of these particular mitigating aspects, companies need to remain worried about the potential of serious injury across the work environment and make a plan to treat any kind of challenges or issues.

Maintaining accurate documentation of work-related near-miss incidents can help organizations to distinguish any sort of required workplace alterations that have to be made in order to safeguard workers. A lot of organization are worried that complying with workplace health and safety legalization will definitely cost them revenue nonetheless it is more probable that it's going to help save them money in the long-term as a result of lowered cases of staff

injury.

Having the correct OHS Policies and procedures will help the organization make sure they are following correct legislation in order to keep their staff and businesses safe. They are the best and easiest way to get your business or organization started with an OHS policy system. OHS Policy templates come in a word document so you can edit them with your business name and add a logo.

Some common OHS Policy templates are:

- Chemical Emergency Management Policy and Procedure Module
- Contractor Management Policy and Procedure Module
- Incident & Hazard Report Policy and Procedure Module
- Manual Handling Policy and Procedure Module
- Noise Management Policy and Procedure Module
- Personal Protective Equipment (PPE) Policy and Procedure Module
- Sun Safety Policy and Procedure Module
- Workplace Policy and Procedure Module

This is just a small sample of OHS Policy templates that an organization should have as part of their Occupational Health and Safety strategy.

6.2. Instrumentation Safety (Preventing Fire and Explosion)

Naturally, we must safely accomplish measurement, control calculations, and process modulation through adjusting the final element. Control systems contribute to safe process operation through basic control design, valve failure positions, alarms, safety interlock systems, and pressure relief systems (e.g., Marlin, 2000; AIChE, 1993; Lees, 1996). This section addresses one important hazardous condition, fire and explosion, that is affected by the design and implementation of control and transmission equipment. The material in this section is applicable to a wide range of processes and industries using either analog or digital transmission.

All control equipment outside of a protected control room is in an environment with air and possibly, combustible materials; hydrocarbons, dust or other materials. Note that these combustibles might not normally be present but they are present in the process (e.g., within vessels and pipes) and could be in proximity to control equipment during unusual situations. The electrical power provided for the instrument introduces the third of the three components required for combustion or explosion, as shown in Figure Naturally, combustion and explosion must be prevented, and two commonly employed approaches to prevent hazards are summarized in this section.

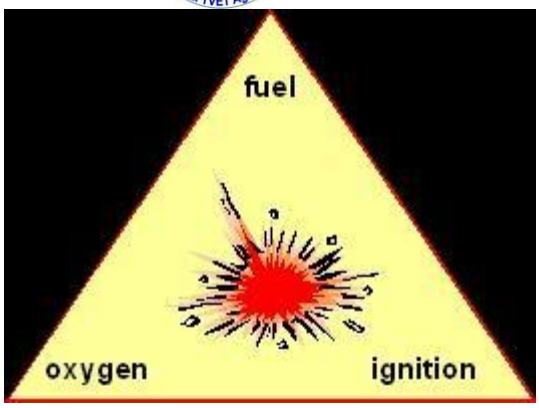


Figure Triangle showing the three key elements leading to fire and explosions.

Safety can be achieved by removing at least one of the elements in the environment around instrumentation. An additional safety measure could contain the effects of any fire or explosion in a small region, which would prevent it from propagating and creating a major hazard. An approach for achieving safety by influencing each approach is introduced in the following.

- **Fuel** - A controlled environment can be continuously purged with air or an inert to remove fuel.
- **Oxygen** - The environment around an instrument can be immersed in a liquid or granular solid that will prevent oxygen (and fuel) from being affected by the source of ignition.
- **Ignition** - The power source can be maintained below the critical value that could initiate fire or explosion.
- **Containment** - An instrument can be surrounded with an enclosure that can contain a fire or explosion within the small region, where it will extinguish quickly because of lack of fuel and oxygen. This approach is termed "explosionproofing" in the United States and Canada and "flameproofing" in Europe; note that the term ―proof‖ here does not mean -no explosion or flame‖, it means the combustion is contained and will not propagate to other areas in the process.

Generally, a process has a centralized control building that has an environment free from combustibles. The computers performing control calculations, safety controllers, historical data storage and other higher-level computing are located in this building, as are operations personnel. Sensors and final elements are located at the process, which can have oxygen and fuel present. We note that the fuel should not be present in high concentrations, except within process vessels and pipes. Instrumentation must be designed and operated to be safe, and instrumentation located in areas where a fuel source is not normally present must be safe even during the occurrence of very infrequent fuel releases due to small leaks or spills.

6.3. Hazardous Area Classification and additional specifications

The proper instrumentation design and installation depends on the likelihood of fuel being present and the type of fuel that could be present. The engineer must select the area classification from several categories and ensure that the instrumentation is compatible with safe operation. The appropriate local regulatory agency defines the categories, and the instrumentation manufacturer defines the set of specifications appropriate for each equipment. In most countries, the instrumentation equipment must be tested by an independent agency, such as Factory Mutual or Underwriters Laboratory, to verify the specifications given by its manufacturer.

Hazardous Area

The hazardous area classifications differ from country to country; for example, the classifications are different between North America and Europe, although efforts are being made to make them consistent. The classifications presented here are for North America, although since the classifications are in a state of change, the practicing engineer should check with the relevant agency for up-to-date information. Then, references are given for comparisons between the North American and European standards. Area classifications for combustible vapors and dusts are given in Table.

Hazardous Zone categories

Area Designation	Area Description
Zone 0	Ignitable concentrations of flammable gases or vapors are present continuously or present for long periods of time. Examples include, • Interior of tanks • Locations near vents
Zone 1	There may be ignitable concentrations during normal operating conditions or concentrations exist frequently from repair or maintenance of the equipment. Examples include, • An area where the breakdown of equipment could lead to a release • Remember that pumps and compressors can have small leaks

Zone 2	There may be ignitable concentrations during temporary situations. Examples include, • Storage where hazardous materials are in containers. • Areas adjacent to Zone 1 with no hazards of its own • Ventilation could prevent the hazard, but it could fail during a leak

6.4. Electrical Safety Policy

Electric shock can be received by either direct or indirect contact with an energized item, tracking through or across a medium (such as water), or by arching. Electrical burning and arching from equipment can also release toxic gases and air contaminants.

Organizations under the WHS Regulations are obligated to protect workers and others from the risk of injury from the use of electricity, and from working in the vicinity of electricity. The Electrical Safety Module is a document that provides guidance on the management strategies and mechanisms organization can implement to eliminate, or reduce and control risks arising from electricity.

The policy includes:

- Electrical Safety Policy
- Electrical Safety Procedure
- Electrical Equipment Register
- Electrical Safety Checklist

6.5. PROCESS SAFETY MANAGEMENT

Unexpected releases of toxic, reactive or flammable liquids and gases in processes involving highly hazardous chemicals have been reported for many years in various industries that use chemicals with such properties. Regardless of the industry that uses these highly hazardous chemicals, there is a potential for an accidental release any time they are not properly controlled, creating the possibility of disaster.

To help ensure safe and healthful workplaces, OSHA has issued the Process Safety Management of Highly Hazardous Chemicals standard (29 CFR 1910.119), which contains requirements for the management of hazards associated with processes using highly hazardous chemicals. EPA's Risk Management Program (RMP) regulations (Title 40 CFR Part 68) is very similar in scope, however the EPA rules also require an evaluation of off-site consequences.

Process safety management (PSM) is addressed in specific performance-based standards for the general industry. OSHA's standard establishes a systematic method to identify, prevent and mitigate the risks of catastrophic incidents from the loss of containment of highly hazardous chemicals. Therefore, an effective PSM program is a continuously improving program that, once established at a facility, provides mechanisms for examination and improvement through the use of key program elements, such as PHA Revalidation, Audits,

Incident Investigation and Management of Change. Some industries can find themselves somewhat complacent, thinking that the safe operation of a process is assured by the existence of a PSM program. However, learning from near misses, involving your employees and ensuring that Process Safety is just not another safety program on the shelf, will go a long way to preventing a catastrophe in the workplace and possibly in the surrounding community.

6.6. Electrical, Control & Instrumentation (EC & I)

In the Onshore Chemicals Explosives and Microbiological Sectors In many processes and activities, EC & I equipment and systems provide important prevention and mitigation measures against accidents.

Functional safety

Functional safety is the part of the overall safety of plant and equipment that depends on the correct functioning of safety-related systems and other risk reduction measures such as safety instrumented systems (SIS), alarm systems and basic process control systems (BPCS).

6.7. Safety instrumented systems SIS

SIS is instrumented systems that provide a significant level of risk reduction against accident hazards. They typically consist of sensors and logic functions that detect a dangerous condition and final elements, such as valves, that are manipulated to achieve a safe state.

The general benchmark of good practice is BS EN 61508, *Functional safety of electrical/electronic/programmable electronic safety related systems*. BS EN 61508 has been used as the basis for application-specific standards such as:

- BS EN 61511: process industry
- BS EN 62061: machinery
- BS EN 61513: nuclear power plants

BS EN 61511, *Functional safety - Safety instrumented systems for the process industry sector*, is the benchmark standard for the management of functional safety in the process industries. It defines the safety lifecycle and describes how functional safety should be managed throughout that lifecycle. It sets out many engineering and management requirements, however, the key principles of the safety lifecycle are to:

- use hazard and risk assessment to identify requirements for risk reduction
- allocate risk reduction to safety instrumented systems (SIS) or to other risk reduction measures
- specify the required function, integrity and other requirements of the SIS
- design and implement the SIS to satisfy the safety requirements specification
- install, commission and validate the SIS
- operate, maintain and periodically proof-test the SIS
- manage modifications to the SIS
- decommission the SIS

BS EN 61511 also defines requirements for management processes (plan, assess, verify, monitor and audit) and for the competence of people and organizations engaged in functional

safety. An important management process is Functional Safety Assessment (FSA) which is

used to make a judgement as to the functional safety and safety integrity achieved by the safety instrumented system.

Alarm Systems

Alarm systems are instrumented systems designed to notify an operator that a process is moving out of its normal operating envelope to allow them to take corrective action. Where these systems reduce the risk of accidents, they need to be designed to good practice requirements considering both the EC & I design and human factors issues to ensure they provide the necessary risk reduction.

In certain limited cases, alarm systems may provide significant accident risk reduction, where they also might be considered as a SIS.

BPCS

BPCS are instrumented systems that provide the normal, everyday control of the process. They typically consist of field instrumentation such as sensors and control elements like valves which are connected to a control system and could be operated by plant operator. A control system may consist of simple electronic devices like relays or complicated programmable systems like DCS (Distributed control system) or PLCs (programmable logic controllers).

BPCS are normally designed for flexible and complex operation and to maximize production rather than to prevent accidents. However, it is often their failure that can lead to accidents and therefore they should be designed to good practice requirements.

6.8. Electrical power systems

The topic of Electrical power systems is concerned with risks arising from electrical distribution systems and equipment at major accident hazard sites. Specifically, it is concerned with:

- the management, design, installation, operation and maintenance of electrical power systems so that they provide the necessary reliability, availability and survivability and so that they prevent danger to personnel;
- the initiation of major accidents by electrical equipment through fire and explosion.

Electrically powered hazardous installations such as large-scale chemical manufacturing processes should be designed to fail to a safe state on loss of electrical power, however, in certain circumstances it may be necessary to maintain electrical power to ensure safety. In some situations, partial failure of the electrical distribution network may lead to more severe consequences than complete failure.

Electrical distribution systems generate, store and transmit extremely large amounts of energy. Uncontrolled releases of electrical energy, for example from catastrophic failure of equipment or poorly designed or maintained equipment, have been seen to result in electrical fires and explosions that are dangerous in themselves but can also initiate major accidents at major hazard sites.

The risks arising from the reliability, availability and survivability of electrical supplies and from catastrophic failure of electrical equipment should be managed by:

- identifying the consequence of complete and partial failure of electrical supplies
- identifying the consequence of catastrophic failure of electrical equipment
- ensuring the electrical power system integrity is consistent with any risk reduction claimed
- installing electrical equipment remote from major hazard installations or in protected locations
- designing electrical distribution systems to discriminate faults to prevent cascading a failure across the site
- selecting electrical equipment that is capable of withstanding anticipated fault currents
- maintaining electrical equipment and protection devices
- having robust safe systems of work and competency assurance to ensure electrical systems are only operated by competent persons.

Self-Check- 6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What is OH&S Policy &Procedure?
2. Write some templets of OH&S?
3. What is the advantage of OH&S for an organization?
4. What are the key principles of safety?
5. How electrical shock is occurring?

Note: **Satisfactory rating - 15 points** **Unsatisfactory - below 15 points**

You can ask you teacher for the copy of the correct answers.

Operation Sheet 1	Techniques of Repairing instrumentation system

IPM FORM	**ECG Machine**

SYSTEM COMPONENTS	
Identification Code	Description

SPECIAL PRECAUTIONS

Testing monitor isolation requires the use of a line voltage source. Although this source should include a current-limiting resistor, use caution to avoid contact with any portions of the energized circuit.

TEST APPARATUS	
	Control/Serial No.
ECG simulator (calibrated output amplitudes and rates are required for some tasks)	
Leakage current meter or electrical safety analyzer	
Ground resistance ohmmeter	
Signal generator	
Attenuator	
Oscilloscope	
Transparent metric scale	
Stopwatch or watch with a second hand	

Inspection testing may deplete the battery of battery-powered ECG monitors. Ensure that a replacement unit or a fully charged battery is available before you begin testing.

QUALITATIVE TASKS

Pass	Fail			Pass	Fail	

QUALITATIVE TASKS					
Pass	Fail		Pass	Fail	
		Chassis/Housing			Fittings/Connectors
		Handle/Grip			Electrodes
		Mount			Controls/Switches
		Casters/Brakes			Battery/Charger
		AC Plug/Receptacles			Indicators/Displays
		Audible Signals			Square Wave Pulse Response
		Line Cord			Recorder
		Strain Reliefs			Alarms
		Circuit Breaker/Fuse			Labeling
		Cables			Accessories

QUANTITATIVE TASKS				
	Set/Indicated	Measured	Pass	Fail
Grounding Resistance (□0.5 □)				
Chassis Leakage Current (□300 µA)				
Lead-to-Ground Leakage Current (Isolated Lead) (□10 □A [grounded]; □50 □A [ungrounded])				
Interlead Leakage Current (Isolated Lead) (□10 □A [grounded]; □50 □A [ungrounded])				
Lead Input Isolation (□50 □A [grounded])				
Rate Calibration (□5% or 5 bpm at 60 and 120 bpm)				
Rate Alarm (□5% or 5 bpm at 40 and 120 bpm)				
Common Mode Rejection Ratio (CMRR) (□10,000:1)				
Gain (□10%)				
QRS Sensitivity (□0.15 mV)				
Paper Speed (□2%)				
Alarm Delay (□10 sec)				
Battery Operating Time (manufacturer's specifications)				

PREVENTIVE MAINTENANCE			
Done		Done	
	Clean		Replace
	Lubricate		

NOTES/REMARKS

IPM FORM	**Pulse Oximeters**

SYSTEM COMPONENTS	
Identification Code	Description

TEST APPARATUS	
	Control/Serial No.
Ground resistance ohmmeter	
Leakage current meter or electrical safety analyzer	
Pulse waveform simulator (if available from the manufacturer)	
s_pO_2 and pulse rate simulator (optional)	

QUALITATIVE TASKS					
Pass	Fail		Pass	Fail	
		Chassis/Housing			Connectors
		Handle/Grip			Probes
		Mount/Fasteners			Controls/Switches
		AC Plug/Receptacles			Battery/Charger
		Line Cord			Indicators/Displays
		Strain Reliefs			Alarms
		Circuit Breaker/Fuse			Audible Signals
		Cables			Labeling

QUANTITATIVE TASKS				
	Set/Indicated	Measured	Pass	Fail
Grounding Resistance (≤0.5 Ω)				
Chassis Leakage Current (≤300 μA)				

PREVENTIVE MAINTENANCE			
Done		Done	
	Clean		Replace

NOTES/REMARKS

IPM FORM	**Fetal Monitors**

SYSTEM COMPONENTS	
Identification Code	Description

TEST APPARATUS	
	Control/Serial No.
Ground resistance ohmmeter	
Leakage current meter or electrical safety analyzer	
Digital pressure meter (capable of reading ≥100 mm Hg)	
Transducer simulator	
ECG simulator	

SUPPLIES	
20 cc disposable syringe	
Y-connector	

QUALITATIVE TASKS

Pass	Fail		Pass	Fail	
		Chassis/Housing			Electrodes/Transducers
		Handles			Controls/Switches
		Mounts			Fan
		Casters/Wheels/Brakes			Battery
		Display			Indicators/Displays
		AC Plugs			Recorder
		Line Cord			User Calibration/Self-Test
		Strain Reliefs			Alarms/Interlocks
		Circuit Breaker/Fuse			Audible Signals
		Cables			Accessories
		Fittings/Connectors			Labeling

QUANTITATIVE TASKS

	Set/Indicated	Measured	Pass	Fail
Grounding Resistance (≤0.5 Ω)				
Chassis Leakage Current (≤300 μA)				
Chassis Leakage Current (≤300 μA)				
Lead-to-Ground Leakage Current (Isolated Lead) (≤10 μA (grounded); ≤50 μA (ungrounded))				
Interlead Leakage Current (Isolated Lead) (≤10 μA (grounded); ≤50 μA (ungrounded)				
Lead Input Isolation (≤50 μA (grounded))				
Rate Calibration (±5% or 5 bpm at 60 bpm and 120 bpm)				

QUANTITATIVE TASKS				
	Set/Indicated	Measured	Pass	Fail
Rate Alarm (±5% or 5 bpm at 40 and 120 bpm)				
Intrauterine Pressure (IUP) Transducer (±2 mm)				
Common Mode Rejection Ratio (CMRR) (≥10,000:1)				
Gain (±10%)				
QRS Sensitivity (≥0.15 mV)				
Paper Speed (±2%)				
Alarm Delay (≤10 sec)				
Battery Operating Time (manufacturer specifications)				

PREVENTIVE MAINTENANCE			
Done		Done	
	Clean		Calibrate
	Lubricate		Replace

NOTES/REMARKS

Instruction Sheet	LG44: Inspect and test the repaired instrumentation and control devices

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Instruments are checked/ inspected to ensure safe operation
- Conduct appropriate functional test(s) and inspection to ensure that the testing conducted on the device conforms with the manufacturer"s instruction/manual
- Work site is cleaned and cleared of all debris and left in safe condition in accordance with company procedures
- Test results are recorded in Instrument/ control devices history cards
- Report is prepared and completed according to company requirements.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Instruments are checked/ inspected to ensure safe operation
- Conduct appropriate functional test(s) and inspection to ensure that the testing conducted on the device conforms with the manufacturer"s instruction/manual
- Work site is cleaned and cleared of all debris and left in safe condition in accordance with company procedures
- Test results are recorded in Instrument/ control devices history cards
- Report is prepared and completed according to company requirements.

Appropriate personal protective equipment is used in line with standard procedures.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information “Sheet 1, Sheet 2, Sheet 3 and Sheet 4”.
4. Accomplish the “Self-check 1, Self-check t 2, Self-check 3 and Self-check 4” **in page -9, 28, 32 and 35** respectively.
5. If you earned a satisfactory evaluation from the “Self-check” proceed to “Operation Sheet 1,” **in page -36.**
6. Do the “LAP test” **in page – 37** (if you are ready).
7.

Information Sheet-1	Checking & inspecting Instruments to ensure safe operation

1.1. Inspection and Testing Techniques

The testing of an installation implies the use of instruments to obtain readings. However, a test is unlikely to identify a cracked socket outlet, a chipped or loose switch plate, a missing conduit-box lid or saddle, so it is also necessary to make a visual inspection of the installation.

All new installations must be inspected and tested during erection and upon completion before being put into service. All existing installations should be periodically inspected and tested to ensure that they are safe and meet the regulations of the IEE (Regulations 610–634).

The method used to test an installation may inject a current into the system. This current must not cause danger to any person or equipment in contact with the installation, even if the circuit being tested is faulty. The test results must be compared with any relevant data, including the IEE Regulation tables, and the test procedures must be followed carefully and in the correct sequence, as indicated by Regulation 612.1. This ensures that the protective conductors are correctly connected and secure before the circuit is energized.

1.2. Visual Inspection

The installation must be visually inspected before testing begins. The aim of the visual inspection is to confirm that all equipment and accessories are undamaged and comply with the relevant British and European Standards, and also that the installation has been securely and correctly erected Regulation 611.3 gives a checklist for the initial visual inspection of an installation, including:

- Connection of conductors;
- Identification of conductors;
- Routing of cables in safe zones;
- Selection of conductors for current carrying capacity and volt drop;
- Connection of single-pole devices for protection or switching in phase conductors only;
- Correct connection of socket outlets, lamp holders, accessories and equipment;
- Presence of fi re barriers, suitable seals and protection against thermal effects;
- Methods of „basic protection" against electric shock, including the insulation of live parts and placement of live parts out of reach by fitting appropriate barriers and enclosures;

- Methods of „fault protection" against electric shock including the presence of earthing conductors for both protective bonding and supplementary bonding.

- Prevention of detrimental influences (e.g. Corrosion);
- Presence of appropriate devices for isolation and switching;
- Presence of under voltage protection devices;
- Choice and setting of protective devices;
- Labeling of circuits, fuses, switches and terminals;
- Selection of equipment and protective measures appropriate to external influences;
- Adequate access to switchgear and equipment;
- Presence of danger notices and other warning notices;
- Presence of diagrams, instructions and similar information;
- Appropriate erection method.

1.3. Approved Test Instruments

The test instruments and test leads used by the electrician for testing an electrical installation must meet all the requirements of the relevant regulations. The HSE has published Guidance Notes GS 38 for test equipment used by electricians. The IEE Regulations (BS 7671) also specify the test voltage or current required to carry out particular tests satisfactorily.

All test equipment must be chosen to comply with the relevant parts of BS EN 61557.

All testing must, therefore, be carried out using an „approved" test instrument if the test results are to be valid. The test instrument must also carry a calibration certificate, otherwise the recorded results may be void. Calibration certificates usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier. This will maintain the accuracy of the instrument to an acceptable level, usually within 2% of the true value. Let us now look at the requirements of three often used test meters.

1.4. Continuity tester

To measure accurately the resistance of the conductors in an electrical installation we must use an instrument which is capable of producing an open circuit voltage of between 4 and 24V ac. or dc., and deliver a short-circuit current of not less than 200mA (Regulation 612.2.1). The functions of continuity testing and insulation resistance testing are usually combined in one test instrument.

I. Insulation resistance tester

The test instrument must be capable of detecting insulation leakage between live conductors and between live conductors and earth. To do this and comply with Regulation 612.3 the test instrument must be capable of producing a test voltage of 250, 500 or 1000V and deliver an output current of not less than 1mA at its normal voltage.

II. Earth fault loop impedance tester

The test instrument must be capable of delivering fault currents as high as 25A for up to 40 ms using the supply voltage. During the test, the instrument does an Ohm‟s law calculation and displays the test result as a resistance reading.

III. Inspection Requirements

Verify that selected elements associated with the applicant‟s program for inspection, test control, and controls of M&TE (as identified in an approved inspection plan) are in accordance with the applicant‟s approved QA Plan.

Elements chosen for inspection may include three or more of the following:

Verify that inspection requirements and acceptance criteria are contained in the applicable design documents approved by the responsible design organization. Verify that inspection activities are documented and controlled by instructions, procedures, drawings, checklists, travelers, or other appropriate means.

- Verify that tests required to verify conformance of an item to specified requirements, and to demonstrate satisfactory performance for service, are planned and executed. Verify that the characteristics to be tested and test methods to be employed are specified. Verify that test results are documented and their conformances with acceptance criteria are evaluated.
- Verify that the applicant has established controls for tools, instruments, gauges, and other M&TE used for quality-affecting activities. Verify that M&TE is controlled, calibrated (at specified periods), and adjusted to maintain accuracy within necessary limits.
- Verify that the applicant has established the requirements to identify the status of inspection and test activities. Verify that the status is indicated either on the items or in documents traceable to the items, where it is necessary to assure that required inspections and tests are performed, and to assure that items that have not passed the required inspections and tests are not inadvertently installed, used, or operated. Verify that the status is maintained through indicators (i.e., physical location and tags, markings, shop travelers, stamps, inspection records, computerized logs, or other suitable means). Verify that authority for application and removal of tags, markings, labels, and stamps is specified. Verify that status indicators provide for indicating the operating status of systems and components of the facility (i.e., tagging valves and switches) to prevent inadvertent operation.

1.5. Inspection Guidance

The inspector should refer to the applicant‟s approved QA Plan for specific requirements and commitments. Verify that the following inspection activities are documented and controlled by instructions, procedures, drawings, checklists, travelers, or other appropriate means:

a. Inspection Planning.

Verify that documented inspection planning includes the following:

1. Identification of each work operation where inspection is necessary to ensure quality;
2. Identification of documents that are used to perform the inspections;
3. Identification of the characteristics for inspection and the identification of when, during the work process, inspections are to be performed for those characteristics;
4. Identification of inspection or process-monitoring methods employed;
5. Sufficient information from the final inspection, to provide a conclusion regarding conformance of the item to specified requirements;
6. Identification of the functional-qualification level (category or class) of personnel performing inspections;
7. Identification of acceptance criteria;
8. Identification of sampling requirements;
9. Methods to record inspection results; and Selection and identification of the M&TE to be used to perform the inspection to ensure that the equipment is calibrated and is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

b. Selecting Inspection Personnel to Perform Inspections.

1. Determine that the individual who performs an inspection to verify conformance of an item to specified acceptance criteria is qualified to the requirements specified in the applicant‟s approved QA Plan.
2. Verify that inspections are performed by personnel other than those who performed or directly supervised the work being inspected. Verify that inspection personnel do not report directly to the immediate supervisor responsible for the work being inspected.

c. Inspection Hold Points.

1. If mandatory inspection hold points are used to control work, then verify that specific hold points are indicated in documents.
2. When applicable, verify that consent to waive hold points are documented and approved before to continuing work beyond the designated hold point.

d. In-Process Inspections and Monitoring.

1. If inspection of processed items is not practicable, then verify that indirect control is provided by the monitoring of processing methods, equipment, and personnel.
2. Verify that both inspection and process monitoring are conducted, when control is inadequate with only one method.
3. Verify that controls are established and documented for the coordination and sequencing of the work at established inspection points during successive stages of the process.

e. Final Inspection.

1. Verify that finished items are inspected for completeness, markings, calibration, adjustments, protection from damage, or other characteristics, as required to verify the quality and conformance of the item to specified requirements.
2. Verify that final inspections include a review of the results and resolution of nonconformance‟s identified by earlier inspections. If modifications, repairs, or

replacements of items are performed subsequent to the final inspection, then verify that appropriate re-tests or re-inspections are performed.

f. Accepting Items.

Verify that the acceptance of an item is documented and approved by qualified and authorized personnel.

g. . Inspection Documentation.

Verify that inspection documentation includes the following:

1. The item inspected, date of inspection, the name of the inspector, or the inspector‟s unique identifier, who documented, evaluated, and determined acceptability;
2. The name of the data recorder, as applicable, and the type of observation or method of inspection;
3. The inspection criteria, sampling plan, or reference documents used to determine acceptance;
4. Results indicating acceptability of characteristics inspected;
5. M&TE used during the inspection, including the identification number and the most recent calibration date; and
6. Reference to information on actions taken in connection with nonconformance.

Verify that the following test control activities are conducted and documented in accordance with the applicant‟s approved QA Plan:

a. Test Planning.

Verify that test planning includes the following:

1. Identification of documents to be developed to control and perform tests;
2. Identification of items to be tested, test requirements, and acceptance limits, including required levels of precision and accuracy;
3. Identification of test methods to be employed and instructions for performing the test;
4. Identification of test prerequisites addressing, calibration for instrumentation, adequacy of test equipment and instrumentation, qualifications of personnel, condition of test equipment and the item to be tested, suitably controlled environmental conditions, and provisions for data acquisition;
5. Identification of mandatory hold points and methods to record data and results; and
6. Selection and identification of the M&TE to be used to perform the test to ensure that the equipment is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

b. Performing Tests.

Verify that tests are performed in accordance with the applicant‟s QA procedures, and, as applicable, include the following:

1. Provisions for determining when a test is required, describing how tests are performed, and ensuring that testing is conducted by trained and appropriately qualified personnel.
2. Test objectives and provisions for ensuring that prerequisites for the given test have been met, adequate calibrated instrumentation is available and used, necessary monitoring is performed, and suitable environmental conditions are maintained.
3. Test requirements and acceptance criteria provided or approved by the organization

responsible for the design of the item to be tested, unless otherwise designated.

4. Test requirements and acceptance criteria based on specified requirements contained in applicable design or other pertinent technical documents.
5. Potential sources of uncertainty and error.

c. Use of Other Testing Documents.

Other testing documents (e.g., American Society for Testing and Materials specifications, vendor manuals, or other related documents containing acceptance criteria) may be used instead of preparing special test procedures. If the applicant uses other documents, then verify that the information is incorporated directly into the approved test procedure, or incorporated by reference in the approved test procedure.

d. Tests Results.

Verify that test results are documented and their conformance with acceptance criteria evaluated by a qualified individual within the responsible organization, to ensure that the test requirements have been satisfied.

e. Test Documentation.

Verify that test documentation includes the following:

1. Item or work product tested, date of test, names of tester and data recorders, type of observation, and method of testing;
2. Test criteria or reference documents used to determine acceptance;
3. Results and acceptability of the test;
4. Actions taken in connection with any nonconformance‟s noted;
5. The individual evaluating the test results; and M&TE used during the test, including the identification number and the most recent calibration date.

f. Qualification of Test Personnel.

Verify that the individual who directs a test to verify conformance of an item to specified acceptance criteria is qualified in accordance with the applicant‟s approved QA Plan. Verify that tests are directed by personnel other than those who performed or directly supervised the work being tested. Verify that test directors do not report directly to the immediate supervisor responsible for the work being tested.

Self-Check 1	Written Test

Direction: Answer the following questions accordingly

1. List the initial visual inspection of an installation checklist. (at least 4)
2. What is the aim/purpose of visual inspection?
3. What are the elements chosen for visual inspection?

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-2	Conduct appropriate functional test(s)

2.1. Testing of Medical devices

- **Visual Inspection**

The process of visual inspection is not clearly defined by IEC 60601, however visual inspections form a critical part of the general safety inspections during the functional life of medical equipment. In most cases, 70% of all faults are detected during visual inspection.
Visual inspection is a relatively easy procedure to make sure that the medical equipment in use still conforms to the specifications as released by the manufacturer and has not suffered from any external damage and/or contamination.
These can include the following inspections:

- Housing Enclosure – Look for damage, cracks etc.
- Contamination – Look for obstruction of moving parts, connector pins etc.
- Cabling (supply, Applied Parts etc) – Look for cuts, wrong connections etc
- Fuse rating – check correct values after replacement
- Markings and Labelling – check the integrity of safety markings
- Integrity of mechanical parts – check for any obstructions

2.2. Earth bond Testing

Earthbond Testing, also referred to as Ground bond Testing, tests the integrity of the low resistance connection between the earth conductor and any metal conductive parts, which may become live in case of a fault on Class I medical devices. Although many Class I medical devices are supplied with an Earth reference point, most if not all medical devices require multiple Earthbond tests to validate the connections of additional metal accessible parts on the enclosure.

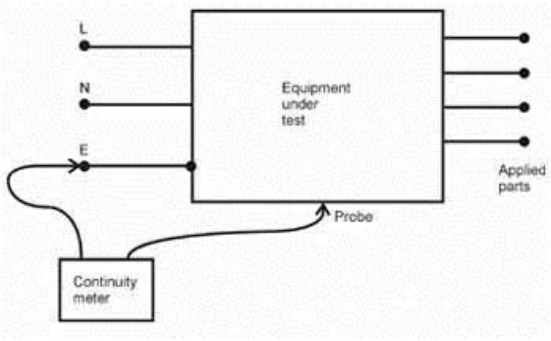


Figure1-Earth Bond Test

The test current is applied between the Earth pin of the mains supply plug and any accessible metal part (including Earth reference point) via a dedicated Earthbond test lead (clip/probe). The IEC 60601-1 (clause 8.6.4) requires a minimum test current of 25A AC or 1.5 times the highest rated current of the relevant circuit(s), whichever is greater. The open circuit voltage of the current source should not exceed 6V.
A test current of 25A AC is most commonly used. Due to the exposure of high current, some (parts of the) equipment could be damaged and thus requires a lower test current.

However, the Earthbond test is designed to stress the connection under fault conditions.

Faults in the detachable power cord account for 80-90% of all Earthbond failures, as most moulded power cables are prone to stress when the cables are dropped.
For fixed installations (i.e. MRI or X-RAY equipment) a Point-to-Point continuity measurement can be made. The resistance is then measured between two probes, where one would be connected to the incoming Earth reference point and one probe placed on metal accessible parts of the medical installation.
Test limits are set at 0.1 ohm for fixed power cords and 0.2 ohm for equipment with a detachable power cord. The table below gives a full overview of the IEC 60601-1 test limits. Prolonged use of testing at high currents can lead to a high probe temperature. Care should be taken to avoid touching the probe tip under these conditions.

2.3. Insulation Tests

IEC 60601-1 (second edition), clause 17, lays down specifications for electrical separation of parts of medical electrical equipment compliance to which is essentially verified by inspection and measurement of leakage currents. Further tests on insulation are detailed under clause 20, "dielectric strength". These tests use AC sources to test equipment that has been pre-conditioned to specified levels of humidity. The tests described in the standard are type tests and are not suitable for use as routine tests.
HEI 95 and DB9801 recommended that for class I equipment the insulation resistance be measured at the mains plug between the live and neutral pins connected together and the earth pin. Whereas HEI 95 recommended using a 500V DC insulation tester, DB 9801 recommended the use of 350V DC as the test voltage. In practice this last requirement could prove difficult and it was acknowledged in a footnote that a 500 V DC test voltage is unlikely to cause any harm. The value obtained should normally be in excess of 50MΩ but may be less in exceptional circumstances. For example, equipment containing mineral insulated heaters may have an insulation resistance as low as 1MΩ with no fault present. The test should be conducted with all fuses intact and equipment switched on where mechanical on/off switches are present.

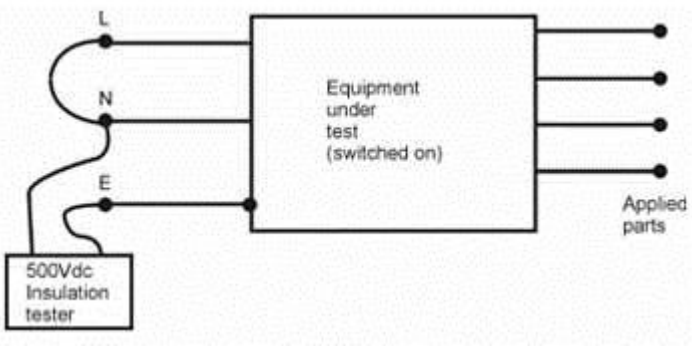


Figure 2-Insulation Resistance Test (Class I)

HEI 95 further recommended for class II equipment that the insulation resistance be measured between all applied parts connected together and any accessible conductive parts of the equipment. The value should not normally be less than 50MΩ. DB9801 Supplement 1 did not recommend any form of insulation test be applied to class II equipment.

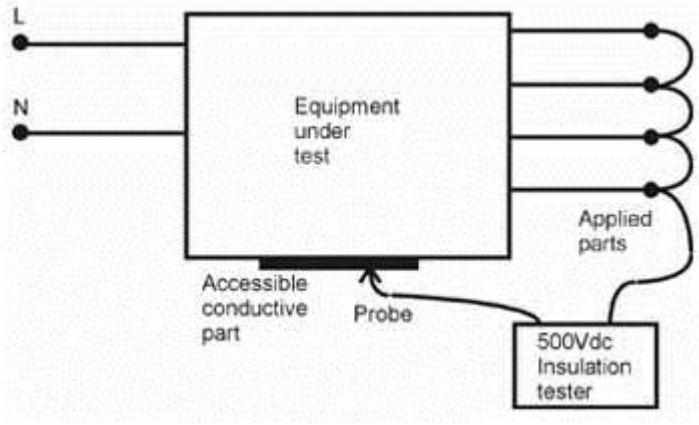


Figure 3-Insulation Resistance Test (Class II)

Satisfactory earth continuity and insulation test results indicate that it is safe to proceed to leakage current tests.

2.4. Single Fault Condition (SFC)

To maintain a Medical Device"s high level of protection during its operational life, a number of design features are taken into account to maintain the integrity of the Device's electrical safety. This is done by introducing conditions that could occur under normal use (i.e. reversed mains supply or voltage on signal input/output terminals - SIP/SOP) and conditions that can occur under a single fault condition (SFC).

IEC 60601-1 specifies a number of single fault conditions (SFC) under its clause 8.1. For the purpose of this précis, the only highlighted SFC are the interrupted Earth connection (Open Earth) and interruption of any of the supply conductors (Open Neutral).

Where a single fault condition is not applied, the equipment is said to be in "normal condition" (NC). However, it is important to understand that even in this condition, the performance of certain tests may compromise the means of protection against electric shock. For example, if earth leakage current is measured in normal condition, the impedance of the measuring device in series with the protective earth conductor means that there is no effective supplementary protection against electric shock.

Many electrical safety tests are carried out under various single fault conditions in order to verify that there is no hazard even should these conditions occur in practice. It is often the case that single fault conditions represent the worst case and will give the most adverse

results. Clearly the safety of the equipment under test may be compromised when such

tests are performed. Personnel carrying out electrical safety tests should be aware that the normal means for protection against electric shock are not necessarily operative during testing and should therefore exercise due precautions for their own safety and that of others. In particular the equipment under test should not be touched during the safety testing procedure by any persons.

IEC 60601-1 specifies that all leakage measurements should be carried out using normal and single fault conditions. A typical part of the electrical safety testing procedures is to perform the test as follows:

1. Normal Supply Voltage No (SFC)
2. Normal Supply Voltage Open Neutral
3. Normal Supply Voltage Open Earth
4. Reversed Supply Voltage No (SFC)
5. Reversed Supply Voltage Open Neutral
6. Reversed Supply Voltage Open Earth

In addition to these tests, some manufacturers might choose to include voltage on the signal input/ output terminals (i.e. communication ports such as USB or RS 232). As this test can be destructive, it is not commonly used other than during type testing of the medical electrical equipment.

2.5. Earth Leakage Test

The leakage current measuring device recommended by IEC 60601-1 loads the leakage current source with a resistive impedance of about 1 kΩ and has a half power point at about 1 kHz. The recommended measuring device was changed slightly in detail between the 1979 and 1989 editions of the standard but remained functionally very similar. The figure below shows the arrangements for the measuring device. The millivolt meter used should be true RMS reading and should have input impedance greater than 1 MΩ. In practice this is easily achievable with most good quality modern millimetres. The meter in the arrangements shown measures 1mV for each μA of leakage current.

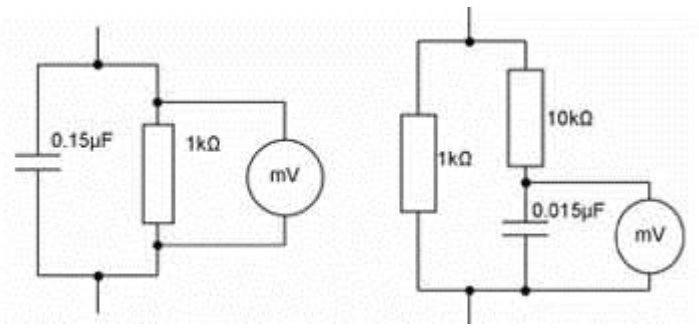


Figure 4-Earth Leakage Current Measuring Circuit

The Earth Leakage Test shows the current flowing through or via the insulation of the Medical Device into the protective Earth conductor. The Earth leakage test is important as it demonstrates the total leakage from the equipment under test / device under test. IEC 60601-1 specifies that the measurements are done under normal and reverse operation and single fault condition (neutral open circuit). The Earth leakage test is valid for Class I equipment with Types B, BF and CF applied parts. Appendix A shows the pass/fail limits as per IEC 60601-1 requirements.

Note - SFC 'Open Earth" cannot be performed as this would result in zero leakage measurements under all circumstances.

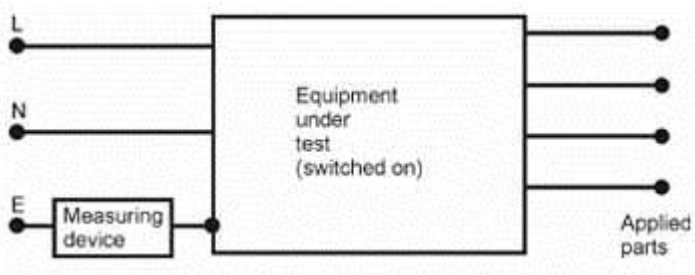


Figure 5-Measurement of Earth Leakage Current

Many safety testers offer the opportunity to perform the test under single fault condition, neutral conductor open circuit. This arrangement normally gives a higher leakage current reading. One of the most significant changes with regard to electrical safety in the 2005 edition of IEC 60601-1 is an increase by a factor of 10 in the allowable earth leakage current to 5mA in normal condition and 10mA under single fault condition. The rationale for this is that the earth leakage current is not, of itself, hazardous. Higher values of earth leakage currents, in line with local regulation and IEC 60364-7-710 (electrical supplies for medical locations), are allowed for permanently installed equipment connected to a dedicated supply circuit.

2.6. Enclosure Leakage Testing (Touch Current)

In general, Enclosure Leakage displays the current that would flow if a person came into contact with the housing (or any accessible part not intended for treatment or care) of the Medical Device. IEC 60601-1 specifies that the measurements are done under normal and reverse operation of the mains supply and single fault conditions Open Neutral circuit and Open Earth. The Enclosure Leakage Test is valid for both Class 1 and II equipment with Types B, BF and CF Applied Parts.

Many safety testers also allow the SFC's of interruption of live or neutral conductors to be selected. Points on class I equipment which are likely not to be protectively earthed may include front panel fascia"s, handle assemblies etc. The term "enclosure leakage current" has been replaced in the new edition of the IEC 60601-1standard by the term "touch current", bringing it into line with IEC 60950-1 for information technology equipment.

However, the limits for touch current are the same as the limits for enclosure leakage

current under the second edition of the standard, at 0.1 mA in normal condition and 0.5 mA under single fault condition. In practice, if a piece of equipment has accessible conductive parts that are protectively earthed, then in order to meet the new requirements for touch current, the earth leakage current would need to meet the old limits. This is due to the fact that when the touch current is tested from a protectively earthed point with the equipment protective earth conductor disconnected, the value will be the same as that achieved for earth leakage current under normal condition. Hence, where higher earth leakage currents are recorded for equipment designed to the new standard, it is important to check the touch current under single fault condition, earth open circuit, from all accessible conductive parts.
Appendix A shows the pass/fail limits as per IEC 60601-1 requirements.
Note - for Class II equipment, the Single Fault Earth Open tests are not required.
In the case of Class II devices, or fully insulated enclosures, this can be encapsulated by using aluminium foil of approximately 200 cm2. The enclosure leakage is measured by connecting the aluminium foil to the leakage tester.

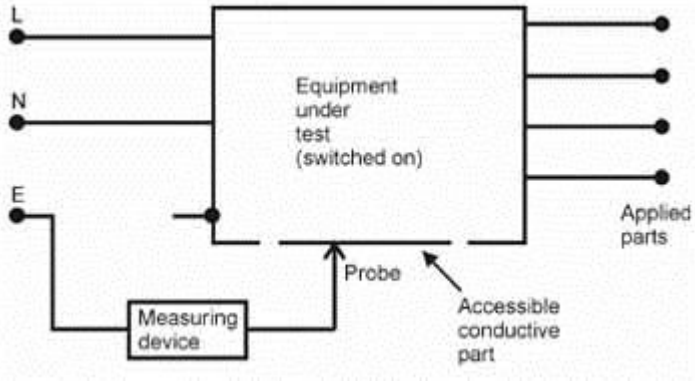


Figure 5-Measurement of Enclosure Leakage Current

2.7. Patient Leakage Current Testing

The Patient Leakage Current is the current flowing from the Applied Part via the patient to Earth or flowing from the patient via an Applied Part to Earth, which originates from an unintended voltage appearing on an external source. IEC 60601-1 specifies that the measurements be done under normal and reverse operation of the mains supply and single fault conditions Open Neutral circuit and Open Earth. The Patient Leakage Test is valid for both Class I and II equipment with Types B, BF and CF applied.
Appendix A shows the pass/fail limits as per IEC 60601-1 requirements.

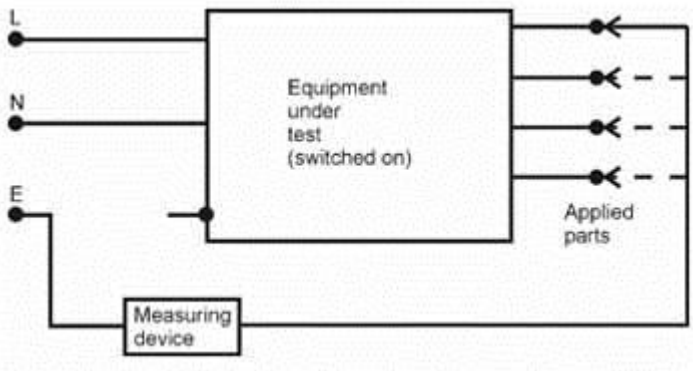


Figure 6-Measurement of Patient Leakage Current (Type CF)

Note for class II equipment, the single fault earth open tests are not required.
For type CF equipment the Patient Leakage Current is measured from each Applied Part separately however, for type B and BF equipment, the Patient Leakage Current is measured with all Applied Parts connected together.
Great care must be taken when performing patient leakage current measurements that equipment outputs are inactive. In particular, outputs of diathermy equipment and stimulators can be fatal and can damage test equipment.

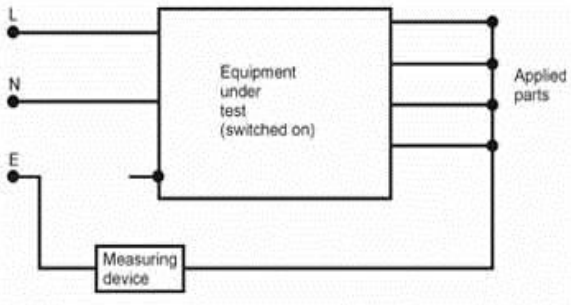


Figure 7-Measurement of Patient Leakage Current (Type B & BF)

2.8. The Patient Leakage F-Type Test (mains on applied parts)

The Patient Leakage F-Type Test (also known as mains on Applied Parts test) displays the current that would flow if a mains potential was applied to the Applied Part which was attached to a patient (i.e. a single fault condition). This test is applied only to type BF and CF equipment. This test involves applying a current limited mains potential (110% of mains input voltage) to the Applied Parts connections. Due to the requirements for IEC 60601-1 this test current can be in excess of 5mA under short circuit conditions and as such is hazardous to the user. Caution should be taken when conducting this test. Current limiting is via a limiting resistor in series with the measurement circuit. IEC60601-1 specifies that leakage current for type CF Applied Parts is measured from each of the patient connection

/ Applied Parts separately.

For type BF equipment the leakage current is measured with all parts of the same type Applied Parts connected together.
The F-type Leakage tests is valid for both Class 1 and II equipment and are measured under mains normal or reverse and source voltage normal or reverse conditions. Appendix A shows the pass/fail limits as per IEC 60601-1 requirements.

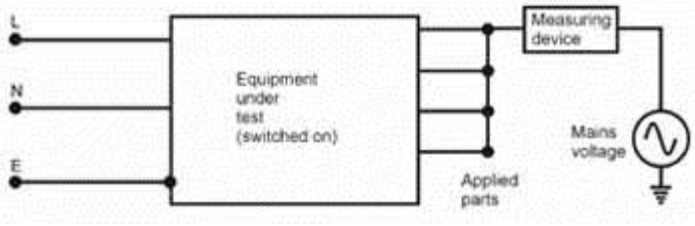


Figure 8-Measurement of Mains on Applied Parts

2.9. Patient Auxiliary Current

The Patient Auxiliary Current displays the leakage current that would flow between Applied Parts under normal and fault conditions. For these tests, current is measured between a single part of the Applied Part and all other Applied Parts connected together. This test should be repeated until all combinations have been tested. This is also referred to as Applied Part to All.

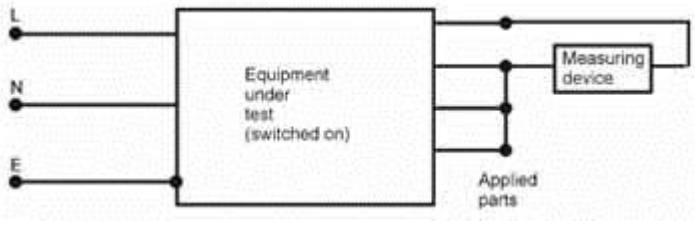


Figure 9-Measurement of Patient Auxiliary Current

IEC 60601-1 specifies that the measurements be carried out under normal and reverse operation of the mains supply and single fault conditions Open Neutral circuit and Open Earth. The Patient Auxiliary Leakage test is valid for both Class 1 and II equipment with Types B, BF and CF applied.
Note for class II equipment, the single fault earth open tests are not required.

Information Sheet-3	Clean and clear work site

3.1. Practice good housekeeping in the workplace

Workplace Housekeeping Program

To maintain a safe and healthy workplace, housekeeping must be a priority. According to the Canadian Centre for Occupational Health and Safety, poor housekeeping can present hidden hazards that may cause incidents, including tripping on loose objects in walkways, being hit by falling objects, and slipping on wet or dirty surfaces.

CCOHS recommends establishing a workplace housekeeping program that manages “the orderly storage and movement of materials from point of entry to exit.” The center advises training employees on how to safely work with the products around them. Also, integrate housekeeping responsibilities into jobs by having workers clean up as they go during shifts

by removing waste and unused materials and inspecting their work area to ensure cleanup was properly completed.

Additional tips include:

- Ensure all spills are immediately cleaned up. Replace worn, ripped and damaged flooring and place anti-slip flooring in areas that cannot continually be cleaned, such as an entrance.
- Maintain clean light fixtures to improve lighting efficiency.
- Keep aisles and stairways clear. Consider installing warning signs and mirrors to help improve sight lines in blind corners.
- Regularly inspect, clean and repair all tools. Do not use damaged tools.

Advantages to Maintaining a Clean Workplace

There are many „hidden" advantages to maintaining a clean workspace:

- There"s a direct correlation between a clean work environment and improved employee health. A clean environment can help reduce worker sick days.
- A regular cleaning program preserves and protects building assets such as carpets, floors, tile surfaces, equipment. It prevents excessive wear and extends lifespans.
- A sparkling workplace can be an excellent marketing tool, whether you"re trying to impress prospective clients, lease space or sell the building.
- A clean, healthy building plays extremely well with occupants, creating a welcoming atmosphere, often subconsciously encouraging hard work and collective effort.
- The appearance is one of the major elements that separates one building from another and brings added value.

3.2. Hazard Assessment

The Administrator will conduct a job hazard analysis (JHA) of *[insert work area]* for potential hazards. See the attached *Job Hazard Analysis Worksheet* for more information. From the JHA, the Administrator will develop hazard and exposure control measures to prevent injuries and illnesses to employees. Certain areas of the building will require different types of cleaning due to differences in the types of hazards. For example, areas requiring differential housekeeping attention include:

- Entryways and lobbies
- Bathrooms
- Hallways and corridors
- Kitchen and cafeteria
- Offices

- Warehouse

3.3. JHA Revision

The JHA will be revised or updated whenever new equipment or work processes are introduced to work areas or when reviews of accident records and reevaluation of selected personal protective equipment (PPE) and/or engineering controls warrant such revision.

3.4. Housekeeping Areas—Safe Work Practices

Supervisors and workers will implement the following safe work practices for housekeeping in all areas of the facility.

3.5. All Working Surfaces

- Keep all walking and working surfaces clean, sanitary, and orderly.
- Keep work surfaces dry.
- Clean up small spills immediately; report large spills to a supervisor.
- Ensure that all walking and working surfaces and passageways are free from protruding nails, splinters, holes, or loose boards.

❖ **Floors**

- Provide warning signs for wet floor areas.
- Clean up small spills immediately; report large spills to a supervisor.
- Use no-skid waxes and surfaces coated with grit to create nonslip surfaces in slippery areas such as toilet and shower areas.
- Immediately clean up all spilled hazardous materials or liquids according to hazardous material spill response procedures.
- Immediately repair, cover, or otherwise make safe any holes in the floor or other walking surface.
- Re-lay or stretch carpets that bulge or have become bunched to prevent tripping hazards.
- Promptly remove combustible scrap, debris, and waste, and discard them according to the waste disposal procedures.
- Keep toilets and washing facilities clean and sanitary.
- Eliminate uneven floor surfaces.

❖ **Wet Floors**

- Where wet processes are used, ensure that drainage channels are kept clear and that dry standing places such as mats are provided.
- Use waterproof footgear to decrease slip and fall hazards in areas that are frequently wet.
- Restrict or control access to wet floors or cover them with nonslip materials.

❖ **Aisles and Passageways**

- Keep aisles and passageways clear and marked as appropriate.
- Tape or otherwise anchor to the floor temporary electrical cords that cross aisles.
- Clean only one side of a passageway at a time.
- Ensure there is safe clearance for walking in aisles where motorized or

mechanical handling equipment is operating.

- Store materials or equipment in such a way that sharp projections will not interfere with or protrude into aisles or passageways.
- Clean up small spills immediately, and report large spills to a supervisor.
- Arrange aisles or walkways that pass near moving or operating machinery, welding operations, or similar operations so that employees will not be subjected to potential hazards.

❖ **Elevated Surfaces**

- Pile, stack, or rack material on elevated surfaces in a manner that will prevent the material from tipping, falling, collapsing, rolling, or spreading.
- Use dock boards or bridge plates when transferring materials between docks and trucks or railcars.

❖ **Entryways and Exits**

All entryways and exits will be kept clean, dry, and clear of all obstructions. Follow the housekeeping requirements in the *Fire Exits* section of this Plan.

❖ **Stairs**

All stairways will be kept clean, dry, and free of debris. No accumulation of any material will be allowed on stairs or in stairways or stairwells.

❖ **Lighting**

Ensure that all halls and stairwells are well lighted to help reduce accidents and promote security. Replace lightbulbs and/or fixtures as necessary to maintain adequate lighting at all times.

❖ **Fire and Explosion Prevention**

Flammable and combustible materials and residues will be controlled so that they do not cause or contribute to a fire emergency.

❖ **Maintenance of Ignition Sources**

Equipment and systems installed on heat- or ignition-producing equipment and processes will be maintained to prevent the accidental ignition of flammable and combustible materials.

❖ ***Dry Combustibles***

Keep combustibles such as paper, cardboard, wooden pallets, or rags in designated locations away from ignition sources. The accumulation of such material provides a place for a fire to start and spread quickly.

❖ ***Extension Cords***

- Electric extension cords will be inspected before each use and kept in good condition.
- Employees will not yank cords from electrical outlets.
- Tools and equipment that require grounding will be of the three-wire grounded-connection type.
- Never use extension cords to replace permanent wiring.
- If an extension cord is used for temporary wiring, it must be listed by

Underwriters Laboratories or another recognized testing laboratory.

- Avoid kinking or excessive bending of the cord; broken strands may pierce the insulated covering and become a shock or short-circuit hazard.

3.6. Flammable and Combustible Liquid Storage

❖ ***General Safe Work Practices***

- No open flames, smoking, sparks, or welding will be allowed in storage areas with flammable liquids.
- Electrical equipment must be explosion-proof if flammable or combustible liquid will be stored near such equipment.
- Keep flammable and combustible liquids away from direct sunlight and stored in a cool, dry place.
- The storage area must be well ventilated to prevent vapors from building up; the vents should be from floor to ceiling.
- Store oxidizers and other incompatible materials away from flammable and combustible liquids to prevent a dangerous reaction.
- Use secondary containment methods to make sure any spills are contained.
- Return flammable and combustible liquids to their storage location immediately after use.

❖ ***Containers***

Store flammable and combustible liquids in approved fire-resistant containers with self-closing lids. Ensure that such containers are grounded and bonded during any transfer of flammable or combustible liquids between containers. These containers prevent sparks and other ignition sources from igniting the liquids stored in them. Keep the containers closed when not in use.

❖ **Used rags.** Put rags soaked with flammable or combustible liquids in approved, closed containers. The containers must be kept closed to prevent vapor buildup.

❖ ***Reactive Materials***

Do not store reactive materials near one another. Reactive materials, when mixed, often create an exothermic reaction, which produces heat and could cause these materials to spontaneously combust.

3.7. Electrical and Hot Equipment

- Keep combustible materials, dust, and grease away from electrical equipment and hot machinery.
- Maintain a clear access to electrical panels at all times so that they can be opened quickly in case of an emergency that requires the power to a machine or the building to be shut down.

Fire Exits

- Always keep evacuation routes clear.
- Don"t store boxes or other items in aisles, hallways, or stairwells that lead

to emergency exits.

- Ensure that exit doors are kept clear on both sides so that they can be easily opened in an emergency.

Fire Extinguishers

- Fire extinguishers will not be used as hangers for coats, air hoses, electrical cords, or anything else.
- Access to extinguishers will be kept clear at all times.
- Extinguishers will always be kept visible. They will not be blocked by stacks of boxes, forklifts, or other items.

3.8. Combustible Dust

Combustible dusts that accumulate on surfaces can cause a deflagration, other fires, or an explosion. Combustible dusts are often either organic or metal dusts that are finely ground into very small particles, fibers, fines, chips, chunks, flakes, or a small mixture of these. These dusts include, but are not limited to:

- Metal dust, such as aluminum and magnesium
- Wood dust
- Coal and other carbon dusts
- Plastic dust and additives
- Bio solids
- Other organic dust, such as sugar, flour, paper, soap, and dried blood
- Certain textile materials

❖ ***Criteria for Dust Cleanup***

Immediate cleaning and collection of accumulated combustible dust is warranted whenever a layer of combustible dust 1/32-inch thickness (i.e., approximately the thickness of a typical paper clip) accumulates over a surface area of at least 5 percent of the floor area of the facility or any given room.

The 5 percent factor will not be used if the floor area exceeds 20,000 square feet (sq ft), in which case a 1,000 sq ft layer of dust is the upper limit. Accumulations on overhead beams, joists, ducts, the tops of equipment, and other surfaces should be included when determining the dust coverage area. Vertical surfaces will be included if the dust is adhering to them. Likely areas of dust accumulations within a plant are:

- Structural members
- Conduit and pipe racks
- Cable trays
- Floors
- Above the ceiling
- On and around equipment (leaks around dust collectors and ductwork)

❖ ***Procedures for Dust Cleanup***

Routinely remove accumulations of combustible dust from elevated surfaces, including the overhead structure of buildings. Accumulations will be removed and collected in dust collectors.

❖ ***Hot Work near Dust Collection Points***

The Administrator or designee will ensure that approved hot work permits are issued for any hot work in areas where hazardous levels of dust accumulations may occur. In addition, anyone who performs combustible dust collection operations near hot work on and around collection points and ductwork must receive written approval to perform such work from the issuer of the hot work permit. Dust collection operations will not be conducted while hot work operations are in progress.

❖ **Waste Recycling and Disposal**

The Administrator or designee will ensure that the following waste recycling and disposal procedures are implemented in all work areas where such waste is generated:

- Scrap materials will be collected and sorted for recycling or disposal.
- Scrap containers will be placed near areas where the waste is produced to encourage orderly waste recycling or disposal.
- All waste receptacles will be clearly labeled (e.g., recyclable glass, plastic, metal, toxic, flammable).
- All waste containers will be emptied.
- Covered metal waste can will be provided for oily or paint-soaked waste.

3.9. Hazardous Chemical Spill Control

The Administrator or designee will implement procedures for the cleanup of large and small hazardous chemical spills at the facility. Large spills will be managed according to the facilities

Spill Prevention Safety Plan.

Spill Prevention

Regularly cleaning and maintaining machines and equipment are ways to do this. Others are to use drip pans and guards where possible spills might occur.

Small Spills

The following procedure will be followed by all employees when a small chemical spill less than has occurred:

1. Notify *[insert name]*.
2. If toxic fumes are present, secure the area (with caution tape or cones) to prevent other personnel from entering.
3. Deal with the spill in accordance with the instructions described in the safety data sheet (SDS).
4. Small spills must be handled in a safe manner while wearing the proper PPE.
5. Use absorbent material to wipe up greasy, oily, or other liquid spills.
6. Absorbents must be disposed of properly and safely.

3.10. Electrical Parts and Equipment

Employees will not perform housekeeping duties near live electrical parts where there is a possibility of contact, unless adequate safeguards such as insulating equipment or barriers are provided. See the Electrical Safety Plan for information about safe work distances and other electrical hazard control procedures. Electrical equipment will be kept free of dust, debris, and grease.

❖ **Cleaning Materials**

Electrically conductive cleaning materials, including conductive solids such as steel wool, metalized cloth, and silicon carbide, as well as conductive liquid solutions, will not be used near energized parts unless written procedures authorized by the Administrator or designee that will prevent electrical contact are followed.

❖ **General Storage**

The Administrator or designee will ensure that the following general material storage procedures are implemented:

- Store or stack materials to allow a clear space of 3 feet or more under water sprinkler heads.
- Stack cartons and drums on a firm foundation and cross-tie them where necessary to reduce the chance of their movement.
- Do not allow stored materials to obstruct aisles, stairs, exits, fire equipment, emergency eyewash fountains, emergency showers, or first aid stations.
- All storage areas will be clearly marked.

3.11. Machines and Tools

Machines

- Keep the area around machines clear of combustibles, slip and trip hazards, or any other debris.
- Inspect machines before use.
- Ensure that all guards are in place and operating properly.
- Follow lockout/tag out procedures when servicing or repairing a machine.
- When done using the machine put away tools and clean up both the machine and the work area.

Hand and Power Tools

- Store blades and sharp tools carefully so that they do not create a hazard when not in use.
- Store new blades for band saws, circular saws, or utility knives in labeled boxes so someone doesn"t accidentally stick his or her hands inside and get cut.
- When it"s time to discard an old blade, cover the sharp edge with tape or cardboard and discard the blade directly into a metal trash container or Dumpster.
- Keep blades on utility knives sheathed or retracted when not in use.

3.12. PPE

The Administrator or designee will ensure the appropriate PPE is provided to and worn by employees performing housekeeping activities and that the PPE is in good condition.
PPE will not be used as a substitute for engineering, safe work practice, or administrative controls for preventing exposure to recognized physical or chemical hazards.
PPE for housekeeping operations include:

- Eye protection
- Gloves
- Proper shoes
- Dust masks
- Other items such as protective clothing, respirators, and hearing protection, depending on the hazards

Employees involved in housekeeping activities will implement the following PPE use and care procedures:

- Inspect PPE before each use, checking for signs of wear or damage.
- Keep PPE clean.
- Store PPE properly according to instructions on labels or received during training to prevent damage or contamination from dirt or chemicals.
- Replace PPE when it is worn out, damaged, or no loner provides the protection that is required.

When performing housekeeping tasks, employees will select the right equipment for the job, including the right PPE. Employees must consult with a supervisor concerning appropriate PPE when starting a new job or housekeeping task.

Inspections

Programs related to housekeeping will be regularly monitored to ensure a high standard of sanitation and safety in all work areas, as well as to identify deficiencies. The Administrator or designee(s) will conduct regular inspections of work areas to monitor hazards and ensure that housekeeping safe work practices are implemented.
The Administrator or designee(s) will develop housekeeping inspection schedules and checklists for each work area with specific hazards or work processes that differ from those found in the facility as a whole.

Frequency of Inspections

The frequency of inspections for each work area will be determined by identification of hazards and hazard control recommendations from hazard assessments, deficiencies identified in previous inspections, frequency of changes in work processes, and any other factors that may affect compliance with housekeeping requirements and policies.
At a minimum, inspections of all work areas will be conducted *[insert minimum frequency]*. Surprise inspections may be conducted at any time.

Inspection Documentation

Copies of inspection checklists or reports will be kept at *[insert location]*. Each report will be maintained for *[insert period of time]* after the date of the inspection.

The Administrator or designee will ensure that:

- All evacuation routes are clearly marked and unobstructed.
- Access to fire extinguishers and other emergency equipment is unobstructed.
- All emergency-related signs, placards, posters, notices, and markings are clearly visible and legible at all times.
- All used emergency and fire-fighting equipment is replaced.

Post-emergency cleanup operations will be conducted by personnel trained and authorized to perform specific cleanup tasks.

Training

[Manager XYZ] will provide housekeeping training to all employees at the time of hire and as needed thereafter.

Supervisors will provide safety meetings or talks to employees as a group every *[insert time & date]* and to individual employees who fail to follow safe procedures.

Training Records

Training will be documented with employee sign-in sheets, date of training, and the training session agenda.

Self-Check 2	Written Test

Part I: Enumeration

Direction: write/list down the following

1. PPE for housekeeping operations include
   a. _____
   b. _____
   c. _____
   d. _____
   e.
2. Cleaning materials used for housekeeping
   a. _____
   b. _____
   c. _____

3. waste recycling and disposal procedures

a. _____

b. _____

c. _____

d. _____

e. _____

4. Advantages to maintain clean workspace

a. _____

b. _____

c. _____

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-4	Record test results

4.1. Safe working procedures when testing

Whether you are carrying out the test procedure

(i) As a part of a new installation

(ii) Upon the completion of an extension to an existing installation

(iii) Because you are trying to discover the cause of a fault on an installation or

(iv) Because you are carrying out a periodic test and inspection of a building, you must always be aware of your safety, the safety of others using the building and the possible damage which your testing might cause to other systems in the building.

For your own safety:

- Always use „approved" test instruments and probes.
- Ensure that the test instrument carries a valid calibration certificate otherwise the results may be invalid.
- Secure all isolation devices in the „off" position.
- Put up warning notices so that other workers will know what is happening.
- Notify everyone in the building that testing is about to start and for approximately how long it will continue.
- Obtain a „permit-to-work" if this is relevant.
- Obtain approval to have systems shut down which might be damaged by your testing activities. For example, computer systems may „crash" when supplies are switched off. Ventilation and fume extraction systems will stop working when you

disconnect the supplies.

4.2. Requirements for safe working procedures

The following five safe working procedures must be applied before undertaking the fault diagnosis.

1. The circuits must be isolated using a „safe isolation procedure‟,
2. All test equipment must be „approved‟ and connected to the test circuits by recommended test probes as described by the Health and Safety Executive (HSE) Guidance
3. Isolation devices must be „secured‟ in the „off‟ position as shown in
4. Warning notices must be posted.
5. All relevant safety and functional tests must be completed before restoring the supply.

4.3. Record-keeping

In order for an eye care unit to manage its equipment effectively, it needs good maintenance and repair records. It is very difficult to manage the unknown!

A central maintenance and repair record will help you to keep track of the maintenance and repair work done. Ideally, this system should correspond to the eye unit's equipment inventory (mentioned on page 34); this means that you will have maintenance and repair records for each of the items listed in the inventory.

4.4. Record-keeping for maintenance

The preventative maintenance schedule for users can be accompanied by a weekly or monthly „tick sheet‟ near the item of equipment, with a space for each day so that users can date and sign it, thereby showing that they have carried out the required tasks. This may include a space for users to indicate what spare parts, such as bulbs, were used. On a regular basis, the list of spare parts used should be noted in the central maintenance and repair record so that more spare parts can be ordered.

The central maintenance and repair record can be used to keep track of all other maintenance, including maintenance done by the in-house team, by vendors, or by service agents. The information captured should include the date, the equipment reference number, what was done, who did the work, and when next maintenance is due.

Self-Check 3	Written Test

Part II: Enumeration

Direction: Write/List down the following

1. Safe working procedures when testing
   a) _____
   b) _____
   c) _____
   d) _____
2. Requirements for safe working procedures while undertaking fault diagnosis
   a) _____
   b) _____
   c) _____
   d) _____
   e) _____

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-5	Report test results

5.1. Technical Report Writing

Definition

Technical report today deals with an important aspect of every activity. In any industry and business today, everybody is expected to write a technical report on what he/she performed because it is in the main means of communication between department peoples and professionals.

In technical report, people express what they found, performed, and analyzed the problem they solved, the procedure and material used, the status of their performance, summaries of work and some recommendations. Thus, technical report writing is a process of producing technical reports, which comprises of the above components.

Anybody who produces technical report should know how to communicate with people to get reliable data, interpret data and analyze data, it is expected to know what medium of communication (oral, observation, letter, etc…) used to exchange data, how to document this data and generate the final report about the occurrence. So technical report writing is a practical repetitive activity of employees/students as part of jobs.

5.2. Purpose of technical report writing

Technical report writing has three basic purposes:

- To inform (receive and transfer data, activities done, procedures used, result of work)
- To instruct (directions to use equipment and for performing duties, provide technical support, descriptions…. etc)
- To perused (to tell reason why does follow rules/procedures, convince work to be done, to inform bottlenecks of the process).

5.3. Types of Report

There are many cases to classify technical report such as subject matter, functions, frequency of issuance, type and formality of forms, length…but, traditionally there are two descriptive categories

1. Informational report and
2. Analytic report

1. The Informational Report

Presents information without criticism evolution and recommendation It provides

- Detailed account of activities
- No attempt to provide solution to problems
- Information on present and past events

Example inventory report, sales report, progress report

2. The Analytic Report

It is a report goes beyond informational reports since it presents an analysis and interpretation of the fault in addition to the facts. The conclusion and recommendations are the most important and interesting parts of the report. The analytical report serves as bases for the solution of an immediate problems or a guide to future happenings.

It is valuable and commonly used instruments for all types of activities to report by applying different techniques

5.4. Procedures of Report Writing

Report writing is reconstruction of in written form of purpose full analysis of a problem.

Report writing goes through 4 steps of doing

1. Preliminary analysis and planning
2. Gathering of data [investigating the problem] situations
3. Organizing data and
4. Develop report

Self-Check 4	Written Test

Part I: Answer the following questions accordingly

1. Define technical report

   _____

   _____

   _____

   _____

   _____.

2. List the purposes of technical report writing
   a. _____
   b. _____
   c. _____
3. List types of report
   e) _____
   f) _____
4. Steps in preparing report writing
   a. _____
   b. _____
   c. _____
   d. _____

Operation Sheet 1	Techniques of Inspecting and testing the repaired instrumentation and control devices

1.1. Techniques for Inspect and test the repaired instrumentation and control devices:

Step 1- inspect to ensure safe operation.
Step 2- inspect to ensure that the testing conducted on the device conforms to the manufacturer‟s instruction/manual.
Step 3- clean and clear of all debris and left in safe condition in accordance with company procedures
Step 4- Test and record control devices history result on cards
Step 5- Report and complete according to company requirements.

LAP Test Method	Practical Demonstration
LAP Test Title/Activity 1	Clean up work area

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instructions:

Task 1. You are required to perform housekeeping on your workshop:

a. You will be given the necessary tools
b. Return all maintenance tools and equipment"s
c. Clean all tools, materials and equipment"s
d. You are required to re-arrange all chairs, etc…
e. You are required to wear PPE

Task 2. Request your teacher for evaluation and feedback

Reference Books

1. "Physics for Scientists and Engineers" by F. Beuche;
2. http://medical-dictionary.thefreedictionary.com;
3. http://www.uth.tmc.edu/anes/Assets/powerpoint/Electrical-Safety.pps ;
4. http://www.medtek.ki.se/medicaldevices/
5. http://www.bassengineering.com/e_effect.htm;
6. http//howstuffworks.com ;
7. http://www.mddionline.com/article/leakage-current-standards-simplified

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