Federal Democratic Republic of Ethiopia
Ministry of Health

BIOMEDICAL ENGINEERING
TRAINING MANUAL ON
OPERATING ROOM MEDICAL DEVICES

PARTICIPANT'S TRAINING MANUAL

July, 2019

Addis Ababa, Ethiopia

Forward

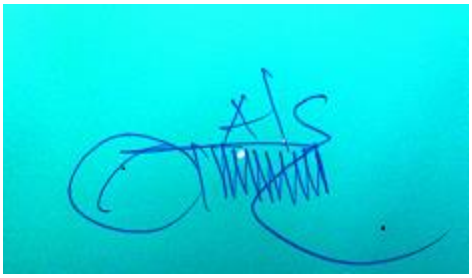
Modern healthcare services are very much dependent on the use of proper medical devices for diagnosis and treatment. The majority of these devices and equipment are manufactured in developed countries and needs skilled man power to manage and use them lifelong. Because they are applied on human being they need rigorous care and handling for the sake of patient safety and utilize them effectively and efficiently. Even with normal and careful use, they are subject to malfunction.

It is important to take good care of them and employ timely preventive maintenance to keep them working last long and decrease downtime. The proper handling and maintenance of these devices can be achieved by deploying the well trained and competent Biomedical Engineers/ Technicians to the respective health facilities. In line with this, it is also important to provide continuous on job training to build their capacity and introduce them to a new technology. Therefore, this training package is developed to provide TOT for biomedical education training provider institute instructors as well as professional who are working at health facilities to fill their Knowledge, attitude and skill gaps on some selected operation room medical devices.

APPROVAL STATEMENT OF THE MINISTRY

The Federal Ministry of health of Ethiopia has been working towards standardization and institutionalization of In-Service Trainings (IST) at national level. As part of this initiative the ministry developed a national in-service training directive and implementation guide for the health sector. The directive requires all in-service training materials fulfill the standards set in the implementation Guide to ensure the quality of in-service training materials. Accordingly, the ministry reviews and approves existing training materials based on the IST standardization checklist annexed on the IST implementation guide.

As part of the national IST quality control process, this operating room medical devices IST training package has been reviewed based on the standardization checklist and approved by the ministry in November, 2019.



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List of acronyms and abbreviation

BP- Blood Pressure

CO_2 - Carbon dioxide

ECG- Electrocardiography

$EtCO_2$ - End-tidal carbon dioxide

FiO_2 - Fraction of inspired oxygen

HR- Heart Rate

I: E - Inspiratory and expiratory ratio

IBP- Invasive Blood Pressure

MV- Minute volume

O_2 - Oxygen

PH - potential of hydrogen

N_2O -Nitrous oxide

NIBP- Non Invasive Blood Pressure

PEEP- positive End-expiratory pressure

TV- Tidal volume

cm H_2O - centimeter of water

CMV- Control Mandatory Ventilation

ACMV- Assist Control Mandatory Ventilation

SIMV- Spontaneous Intermittent Mandatory Ventilation

CPAP - Continuous Positive Airway Pressure

Ppeak, Ppause, Pmean - Pressure peak, pressure pause, pressure mean

PEEPH- Positive End Expiratory Pressure High

PEEPL - Positive End Expiratory pressure Low

BPM - Breath Per Minute

RR - Respiration rate

LPM - Litter Per minute

PSI - Pound Per Square Inch

SPO_2- Blood oxygen saturation level

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Introduction to the manual

The Federal Ministry of Health's Growth and Transformation Plan (GTP) indicates that by 2018, 16 specialized governmental hospitals, 80 general hospitals, 800 primary hospitals, and 3,200 health centers will be established. Additionally, there are more than 200 private hospitals and diagnostic centers operating in the country. The FMOH reports that these healthcare facilities will need 4,000 newly trained biomedical equipment technicians and 600 biomedical engineers. Ensuring that existing technicians and engineers are equipped with adequate skills is also a challenge. Ethiopia lacks systems to manage the lifecycle of emerging healthcare technologies and medical devices, but has developed a plan to address this.

The current biomedical engineering programs at JU IT and AAU IT, and the vocational biomedical technician program at AATPC, HBC, KPC and other newly merging regional TVET Colleges are tasked with producing technicians and engineers to meet the very high demands for trained professionals throughout Ethiopia. Program gaps include a lack of adequate hands-on, practical training opportunities and laboratory/industrial skills for students, and an acute shortage of academically/industrially/vocationally trained faculty and staff. The existing faculty and staff lack access to modern biomedical training equipment, modern training methodologies, as well as evidence-based information on biomedical devices that is in line with international standards and best practices. This deprives students/trainees of standardized protocols and training in devices maintenance and management and leads to an unstructured career path for students.

The HRH Project through its close working relation with those institutes has made discussions with teaching staff's and biomedical departments to gather the information regarding the training demand and discussed with the FMoH, HR directorate and decided to develop these standard training packages for the purpose of conducting technical update training on some selected medical devices. The HRH project, Core biomedical Engineers coordinate this training package development activity in collaboration with FMoH technical experts, we hope this will be a good opportunities for faculty, staff, and HTM personnel's to fill the skill gap on the selected medical devices and as a result improves the faculty teaching learning process.

The following are the core competency of this training:

- Apply the operation principles of some selected Operation Room (OR) medical devices
- Identify the basic components of the selected OR devices

- Apply the proper handling and safe use of OR medical devices
- Perform appropriate troubleshooting procedures for each equipment
- Perform preventive and corrective maintenance as per the manufacturer manual
- Perform performance test and calibration as demanded

Course Syllabus

Course description

This 10 days course is designed to equip participants with appropriate knowledge, skill and attitude required for maintenance and care of operation room (OR) medical equipment. It covers the fundamental concepts, techniques and attitudes for troubleshooting, maintaining and safe handling of operation room (OR) medical devices.

1. Course Goals:

To provide the trainee with basic knowledge, skills and attitudes regarding the maintenance and proper utilization of operating room medical devices.

2. Trainee Learning Objectives

At the end of this training, participants will be able to**:**

- Explain the purpose and clinical application of the selected operation room equipment
- Explain the principle of operation for the selected operation room equipment
- Identify the basic components of the selected operation room equipment
- Follow the safe handling procedures of the equipment
- Apply appropriate troubleshooting procedures
- Perform preventive and corrective maintenance as per the manufacturer manual
- Apply performance test and calibration as demanded

3. Training/Learning Methods

- Interactive lectures
- Group discussion
- Demonstration and coaching
- Video and simulation
- Role play and modeling
- Facility visit with mentoring

4. Training Materials and Equipment

- Participant manual
- Facilitator's guide
- Power point presentation

- Service manuals
- WHO maintenance guidelines
- Selected OR medical devices
- E-learning materials
- Simulators
- Tool kits
- Learning guides and checklist

5. Certification Criteria

Trainee who has completed and passed (score ≥70%) at the end of course performance evaluation will be provided certificate of participation/completion.

6. Participant Selection Criteria

- BSc. in Biomedical Engineering
- Biomedical Engineering Technicians
- Any BSc. holder or technicians working on maintenance of medical devices

7. Trainer Selection

- The facilitators of this course will be a consultant who have developed this course (TWG)
- TOT on OR medical devices
- Basic training on OR medical devices and training facilitation skill
- Has a minimum of BSc Degree in Biomedical Engineering and relevant practical experience on the OR Medical devices preferably at health facility level.

8. Course Venue

Accredited in-service training centers with functional internet service

Course Duration: 10 days

9. Course Composition

- 20-25 trainee
- 4 trainers

10. Methods of Evaluation

- **Participant**
  - Formative

- Pre-test
- Group exercises/ demonstration using checklists

- Summative
  - Knowledge assessment (30 %)
  - Practical assessment (70%)

- **Course evaluation**
  - Daily Evaluation
  - Daily trainers feedback meeting
  - End of course evaluation

11. Course Schedule

Date	**Activity**	**No. of days**	**Time per day**	**Total Time**
Day 1 & Day 2	CRC Electro Surgical Unit	2	8hrs	14hrs
Day 3	Suction machine	1	8hrs	8hrs
Day 4 - 6	Anesthesia machine	2.5	8 hrs	20hrs
Day 7	Autoclave	1.5	8hrs	12 hrs
Day 8 +	Patient monitor	1.5	8hrs	12hrs
Day 9 - 10	ECG machine	1.5	8hrs	12hrs
			Total	**80hrs**

Chapter 1
Caring, Respectful and Compassionate Healthcare Service

Chapter description: This chapter is designed to equip healthcare professionals and senior management in health facilities to increase core competencies of compassionate, respectful, holistic, scientifically and culturally acceptable care for patients and their families.

Chapter objective: By the end of this chapter the participants will be able to:

- Describe Compassionate, respectful and Caring(CRC) healthcare service delivery

Enabling Objectives: By the end of this chapter participants will be able to:

- Describe Compassionate, respectful and caring (CRC)
- List principles of health care Ethics
- Discuss components of compassionate care
- Explain principles of respectful care
- Discuss characteristics of Compassionate leader

Chapter Outline

1.1. Introduction to CRC
1.2. Healthcare Ethics
1.3. Compassionate care
1.4. Respectful care
1.5. Compassionate leader

1.1 Introduction to Compassionate, Respectful and Caring (CRC)

Individual reflection

What are Compassionate, Respect and Caring (CRC)?

Time: 15 min

1.1.1 Definition of CRC

Compassion (ሩህሩህ)

Is a feeling of deep sympathy and sorrow for the suffering of others accompanied by a strong desire to alleviate the suffering? Therefore, we can say it is being sensitive to the pain or suffering of others and a deep desire to alleviate the suffering.

Respectful (ተገልጋይን የሚያከብር)

Is the kind of care, in any setting, which supports and promotes, and does not undermine a person's self-respect, regardless of any differences?

Caring (ተንከባካቢ)

Caring is an intensification of the affective dimension of empathy in the context of significant suffering. It is coupled with effective interventions to alleviate that suffering.

Compassionate, respectful and caring (CRC) - means serving patients, being ethical, living the professional oath, and being a model for young professionals and students. It's a movement that requires champions who identify with their profession and take pride by helping people.

- Why CRC a transformational agenda

Time Allowed :10 minutes

1.1.2 Why CRC a Transformation agenda?

Helping health professionals' to become compassionate and respectful practitioners remains a major challenge for the healthcare. Compassionate and respectful care is not only morally and financially essential, but it is required in many countries through national legislation and/or national health policy.

The notion that healthcare services must be expanded beyond the prevention of morbidity or mortality is only one aspect of the agenda. It must encompass respect for patients' basic human rights, including respect for patients' autonomy, dignity, feelings, choices, and preferences. It must include choice of companionship wherever possible.

Taken from the United Nations human rights declaration, 'All human beings are born free and equal in dignity and rights.' The Ethiopian constitution of human rights article 25 and 26 states that the rights to equality and privacy.

In the Ethiopian health system, there are many health professionals who have dedicated their entire career to public service and are respected by the public they serve. However, a significant proportion of health professionals see patients as just 'cases' and do not show compassion. Lack of respect to patients and their families is also a common complaint.

A three-year report of the Ethics Committee and relevant documents in Addis Ababa showed that 39 complaints were related to death of the patient and 15 complaints were about disability. The committee verified that 14 of the 60 claims had an ethical breach and/or negligence and other study also indicated that forwarding bad words, shouting on patients, mistreatment, insulting and hitting of clients are some of unethical practices showed by the health professionals.

Studies showed the need for CRC

- Lack of role models in many health facilities.
- Measuring the worth of a profession by how much it pays.
- Senior physicians cancel their outpatient clinics without informing their patients.
- Elective surgeries get cancelled.
- Admitted patients are by default getting the care they need from relatives.
- Nurses, for various reasons, have limited their role to providing injections and securing IV lines.
- Proper counseling during dispensing of drugs is also becoming a rarity.
- The quality of lab tests and the quality assurance process that lab professionals have to take before issuing results is not practiced as expected.
- Lack of compassion, respect and care is the common source of grievances in health facilities.

1.1.3 The Benefits of CRC

Table 1.1: The benefits and beneficiaries of Compassionate and Respectful Care

Beneficiaries	Who	How
First	**Patients**	• When health professionals are compassionate, patients are less anxious • Adherence to medical advice and treatment plans • Compassionate care correlates positively with both prevention and disease management. Diabetic patients, for example, demonstrate higher self-management skills when they self-report positive relationships with their providers • Hostile emotional states in patients delay the healing processes • Quality of health professionals –patient communication with increased physical functioning, emotional health and decreased physical symptoms of pain in patients
Second	**Health Professionals**	• Health care Professionals satisfaction with their relationships with patients can protect against professional stress, burnout, substance abuse and even suicide attempts • Burnout is strongly associated with poorer quality of care, patient dissatisfaction, increased medical errors, lawsuits and decreased expressions of compassion • Participation in a mindful communication associated with short-term and sustained improvement in well-being and attitudes associated with patient care • A major predictor of patient loyalty • When health professionals are compassionate, they achieve earlier and more accurate diagnoses because the patient is better able to reveal information when he or she feels emotionally relaxed and safe • Respect from the client/patients • Health professionals will find their work more meaningful and gratifying
Third	**Students**	• Good role modeling is essential for students • Increased motivation to be CRC health professionals
Fourth	**Health care facilities**	• Patient satisfaction will rise • Quality of health care will be improved • Lower malpractice suits • Staff will be more loyal to their hospital or health care system • Patient adherence to treatment will rise • Resources can be conserved • Greater employee satisfaction and reduced employee turnover.

1.1.4 National Strategy and Approach of CRC

The development of caring, respectful and compassionate health workers requires a multi-pronged approach in order to make CRC as a culture, self-driven inner motive and a legacy that the current generation of practitioners leaves to their successors.

NATIONAL STRATEGY AND APPROACHES FOR CRC

- ***Reforming the recruitment of students for health science and medicine programs.***
- ***Improving the curriculum of the various disciplines.***
- ***Ownership and engagement of the leadership at all levels of the system.***
- ***Inspirational leadership that aims to create an enabling environment.***
- ***National, regional and facility level ambassadors.***
- ***An advocacy campaign through mass media will also be launched to project positive images of health professionals.***
- ***Patients and the general public will also be engaged in this movement.***
- ***An annual health professional recognition event will be organized***
- ***Putting in place a favorable legislative framework to reinforce CRC which would include regulation on patients' rights and responsibilities (PRR)***
- ***Measurement of health care providers on CRC***
- ***Comprehensive projects will be designed.***
- ***Conducting national assessment related to CRC.***
- ***Provision of continuous CRC trainings.***
- ***Engagement and ownership of professional associations.***
- ***Experience sharing from national and international best practices.***

1.2 Healthcare Ethics

1.2.1 Principles of healthcare ethics

Individual reflection

- ❖ What is ethics?
- ❖ What is healthcare ethics?

Time: 5 Minutes

Ethics:

Ethics is derived from the Greek word *ethos*, meaning custom or character. Ethics is the study of

morality, which carefully and systematically analyze and reflect moral decisions and behaviors, whether past, present or future. It is a branch of philosophy dealing with standards of conduct and moral judgment.

Healthcare ethics:

It is a set of moral principles, beliefs and values that guide us to make choices about healthcare. The field of health and healthcare raises numerous ethical concerns, including issues of health care delivery, professional integrity, data handling, use of human subjects in research and the application of new techniques.

Ethical principles are the foundations of ethical analysis because they are the viewpoints that guide a decision. There are four fundamental principles of healthcare ethics.

1. Autonomy
2. Beneficence
3. Non-maleficence
4. Justice

1. Autonomy

Autonomy is the promotion of independent choice, self-determination and freedom of action. Autonomy implies independence and ability to be self-directed in one's healthcare. It is the basis of self-determination and entitles the patient to make decisions about what will happen to his or her body.

Case one:

A 49-year-old client with diabetic finding came with right foot second finger gangrene to a hospital. The surgeon decided that the finger should be removed immediately. But the patient refused the procedure.

Question: How should the surgeon handle this case?

Time: 5 Minutes

2. Beneficence

Beneficence is the ethical principle which morally obliges health workers to do positive and rightful things. It is "doing what is best to the patient". In the context of professional-patient relationship the professionals are obliged to always and without exception, favor the wellbeing and interest of their patients.

Case two:

Ms. X was admitted to adult surgical ward with severe excruciating right flank pain with presumptive diagnosis of renal colic. Nurse Y was the duty nurse working that day. The physician who saw her at OPD did not write any order to alleviate the pain.

Question: What should the attending nurse do for Ms. X?

Time: 5 Minutes

3. Non-maleficence

The principle refers to "avoid doing harm". Patient can be harmed through omitting or committing interventions. When working with clients, healthcare workers must not cause injury or distress to clients. This principle of non-maleficence encourages the avoidance of causing deliberate harm, risk of harm and harm that occurs during the performance of beneficial acts. Non-maleficence also means avoiding harm as consequence of good.

Case Three:

Mr "X" is admitted to internal medicine ward with cardiac failure. The physician admitted Mr "X" and prescribed some medication which should be given regularly by the ward nurse. A nurse in charge of the ward does not give a patient medication timely and appropriately.

Question: What should the ward nurse do for Mr "X"

Time: 5 Minutes

4. Justice

Justice is fair, equitable and appropriate treatment. Justice refers to fair handling and similar standard of care for similar cases; and fair and equitable resource distribution among citizens. It is the basis for treating all clients in an equal and fair way. A just decision is based on client need

and fair distribution of resources. It would be unjust to make such decision based on how much he or she likes each client.

Example:

- Resource scarcity is the common issue in healthcare settings. For example, there may be only one or two neurosurgeons and many patients on the waitlist who need the expertise of these neurosurgeons. In this case we need to serve patients while promoting the principle of justice in transparent way. Example, the rule of first come first serve could be an appropriate rule.
- Justice requires the treatment of all patients equally, irrespective of their sex, education, income or other personal backgrounds.

1.2.2 Confidentiality and informed consent

Confidentiality

Confidentiality in healthcare ethics underlines the importance of respecting the privacy of information revealed by a patient to his or her health care provider, as well the limitation of healthcare providers to disclose information to a third party. The healthcare provider must obtain permission from the patient to make such a disclosure.

The information given confidentially, if disclosed to the third party without the consent of the patient, may harm the patient, violating the principle of non-maleficence. Keeping confidentiality promotes autonomy and benefit of the patient.

The high value that is placed on confidentiality has three sources:

- ***Autonomy****:* personal information should be confidential, and be revealed after getting a consent from the person
- ***Respect for others****:* human beings deserve respect; one important way of showing respect is by preserving their privacy.
- ***Trust****:* confidentiality promotes trust between patients and health workers.

The right of patient to confidentiality

- All identifiable information about a patient's health status, medical condition, diagnosis, prognosis and treatment and all other information of a personal kind must be kept confidential, even after death. Exceptionally, family may have a right of access to information that would inform them of their health risks.
- Confidential information can only be disclosed if the patient gives explicit consent or if

expressly provided for in the law. Information can be disclosed to other healthcare providers only on a strictly "need to know" basis unless the patient has given explicit consent.

- All identifiable patient data must be protected. The protection of the data must be appropriate to the manner of its storage. Human substances from which identifiable data can be derived must also be protected.

Exceptions to the requirement to maintain confidentiality

- Routine breaches of confidentiality occur frequently in many healthcare institutions. Many individuals (physicians, health officers, nurses, laboratory technicians, students, etc.) require access to a patient's health records in order to provide adequate care to that person and, for students, to learn how to practice care provision.
- Care providers routinely inform the family members of a deceased person about the cause of death. These breaches of confidentiality are usually justified, but they should be kept to a minimum and those who gain access to confidential information should be made aware of the need not to spread it any further than is necessary for descendants benefit. Where possible, patients should be informed ahead that such a breach might occur.
- Many countries have laws for the mandatory reporting of patients who suffer from designated diseases, those deemed not fit to drive and those suspected of child abuse. Care providers should be aware of the legal requirements to be able to disclose patient information. However, legal requirements can conflict with the respect for human rights that underlies healthcare ethics. Therefore, care providers should look carefully at the legal requirement to allow such an infringement on a patient's confidentiality and assure that it is justified.

Case four:
An HIV-positive individual is going to continue to have unprotected sexual intercourse with his spouse or other partners.
Question:
1. How do you manage such an individual?
2. Discuss situations that breach confidentiality.
Time: 5 Minutes

Ethiopia Council of ministers' regulation 299/2013, Article 77 Professional Confidentiality

Informed Consent

Informed consent is legal document whereby a patient signs written information with a complete information about the purpose, benefits, risks and other alternatives before he/she receives the care intended. It is a body of shared decision making process, not just an agreement. Patient must

obtain and being empowered with adequate information and ensure that he/she participated in their care process.

For consent to be valid, it must be voluntary and informed, and the person consenting must have the capacity to make the decision. These terms are explained below:

A. ***Voluntary***: the decision to either consent or not to consent to treatment must be made by the person him or herself, and must not be influenced by pressure from medical staff, friends or family. This is to promote the autonomy of the patient.

B. ***Informed***: the person must be given all of the information in terms of what the treatment involves, including the benefits and risks, whether there are reasonable alternative treatments and the consequences of not doing the treatment. This will help to avoid harm—patients may harm themselves if they decide based on unwarranted and incorrect information.

C. ***Capacity***: the person must be capable of giving consent, which means they understand the information given to them, and they can use it to make an informed decision.

General principle of informed consent

Consent should be given by a patient before any medical treatment is carried out. The ethical and legal rationale behind this is to respect the patient's autonomy and their right to control his or her life. The basic idea of personal autonomy is that everyone's actions and decisions are his or her own.

The principles include:

1. Information for patients
2. Timing of consent process
3. Health Professionals responsibility for seeking consent
4. Decision making for incompetent patients
5. Refusal of treatment

Ethiopia Council of minister's regulation 299/2013, Article 52. Patient's informed consent

1.2.3 Preventive ethics in the aspect of CRC

What is preventive ethics?

Preventive Ethics is a systematic application of ethical principles and values to identify and handle ethical quality gaps, dilemmas, challenges and errors to appropriately and fairly. It could

be carried out by an individual or groups in the health care organization to identify prioritize and systematic address quality gaps at the system level.

Why is preventive ethics important for CRC healthcare workers?

First and foremost, the CRC health workforce, patients, families and the community at large should have a common understanding that the experience of illness and the practice of medicine lead to situations where important values and principles come to conflict and ethical dilemmas and challenges arise everywhere. Moreover, the CRC health worker should always understand the context in which She/he operates (like the services, the clients, the providers, values, norms, principles, culture, religions, socio-economic-geographic…) as the way in which ethical dilemmas are handled vary from case to case and place to place.

Preventive ethics helps the CRC health workforce to predict, identify, analyze, synthesize and manage ethical dilemmas, challenges and errors to make the appropriate and fair decisions. Hence, preventive ethics enhances honesty and transparency between healthcare workers, patients, families and relevant others to make a deliberated joint decision. Moreover, it inspires mutual understanding and trust amongst the healthcare provider, recipient and the community at large.

Preventive ethics brings all efforts together productively and leads to the satisfaction of clients, providers and the community even if when the decisions are sometimes painful and outcomes are negative.

1.2.4 Ethics and law as enablers of CRC

The Relation between Ethics and Law

Individual reflection

- What is the relationship between ethics and law?

Time: 5 Minutes

Ethics as discussed in the previous sessions, is considered as a standard of behavior and a concept of right and wrong beyond what the legal consideration is in any given situation.

Law is defined as a rule of conduct or action prescribed or formally recognized as binding or enforced by a controlling authority. Law is composed of a system of rules that govern a society

with the intention of maintaining social order, upholding justice and preventing harm to individuals and property. Law systems are often based on ethical principles and are enforced by the police and Criminal justice systems, such as the court system.

Ethics and law support one another to guide individual actions; how to interact with clients and colleagues to work in harmony for optimum outcome; provision of competent and dignified care or benefits of clients/ patients. Ethics serves as fundamental source of law in any legal system; and Healthcare ethics is closely related to law. Though ethics and law are similar, they are not identical.

Often, ethics prescribes higher standards of behavior than prescribed by law; and sometimes what is legal may not be ethical and health professionals will be hard pressed to choose between the two. Moreover, laws differ significantly from one country to another while ethics is applicable across national boundaries.

The responsibilities of healthcare professionals and the rights and responsibilities of the patient is stipulated in legal documents of EFMHACA like regulation 299/2013, directives and health facility standards.

1.3 Principles and Standards of Compassionate Care

1.3.1 Qualities of compassionate care

Compassion can be defined as: "sensitivity to the suffering of self and others with a deep wish and commitment to relieve the suffering".

Developing more compassion can be a way to balance emotions to increase the well-being of patients, healthcare professionals and facilitation of healthcare delivery. For patients, compassion can help prevent health problems and speed-up recovery. Compassion can improve staff efficiency by enhancing cooperation between individuals and teams and between patient and healthcare professionals.

Individual reflection

- **Can compassion be trained and learned?**

  Time Allowed: 5 Minutes

Qualities of Compassionate Care

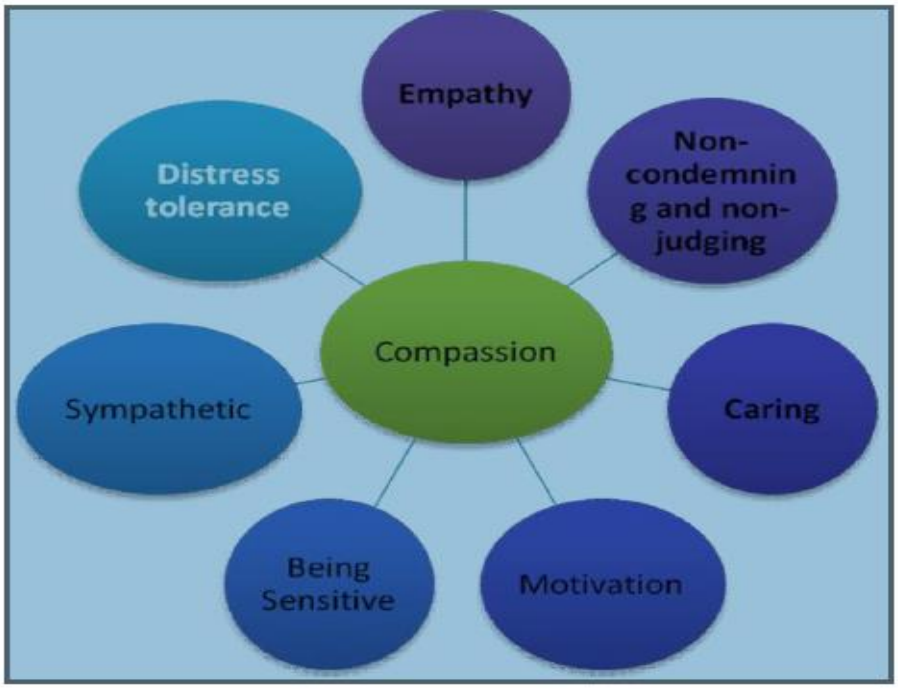


Figure 1.1: Qualities of compassion

Role play on qualities of compassionate care:

Instructions:

One participant will take the role of a healthcare provider and another participant will take the role of a mother [with limited mobility] of a sick child with a feeding problem. Other participants should observe and note the discussion.

Roles

Healthcare provider

A mother (with limited mobility) of a sick child:

Situation:

A mother with limited mobility brings her 3-month-old baby girl with cough and fever to the outpatient clinic. The healthcare provider seemed tired. By the time the mother enters the examination room, he was talking with his subordinate about last night's football game. He had already noticed her but did not let her to sit. Her child was crying and she was trying to quiet her.

All of a sudden the healthcare provider shouted loudly at the mother to quiet her child or they would have to leave.

While waiting and calming her child, the mother told the healthcare

provider that her child is very sick and needs an urgent care. While facing to his friend, the healthcare provider told the mother that he would see her child in five minutes.
After waiting for 10 minutes, the healthcare provider started to examine the child and felt sad about the condition of the child; apologized to her for having let her wait so long. The healthcare provider evaluated the child gently, gave the child a proper treatment, reassured the mother, and the child went home better.

Discussion Questions

Did the health provider demonstrate the characteristics of compassion?

If not, what are the areas /conversation that show poor characteristics of compassion?

If yes, what are the areas /conversation that show good characteristics of compassion?

Time allowed: 30 minutes

1.3.2 Elements of compassionate care

According to researches the key elements of compassionate care has categories, each contains theme and subthemes.

1. **Virtue:** It is described as ‘‘good or noble qualities embodied in the character of the health care provider
2. **Relational space:** is defined as the context and content of a compassionate encounter where the person suffering is aware of and is engaged by, the virtues of the health care provider.
   The category of relational space comprised two themes.
   - Patient awareness which describes the extent to which patients intuitively knew or initially sensed health care provider capacity for compassion.
   - Engaged care giving which refers to tangible indicators of health care provider compassion in the clinical encounter that established and continued to define the health care provider-patient relationship over time.
3. **Virtuous Response:** It is the “Enactment of a virtue toward a person in suffering,’’ and it is both an individual category and an overarching principle of care that functions as a catalyst to the three core categories of compassionate care giving: ‘‘**seeking to understand,**

relational communicating, and attending to needs'' The category of virtuous response contain three broad themes within it:

- **Knowing the person** refers to the extent to which healthcare providers approached their patients as persons and view their health issues and suffering from this point of view.
- **Seeing the person as priority** involves healthcare providers' ability to priorities patient needs, setting aside their own assumptions and healthcare system priorities in the process.
- **Beneficence** refers to healthcare providers wanting the best for the patient, informing the three more targeted core categories of compassionate care giving.

4. **Seeking to Understand:** refers to healthcare providers trying to know the patient as a person and his or her unique needs.

   The need to understand a person's desires and tailor his or her care is identified by most patients as a fundamental feature of compassion.

   - Seeking to Understand the Person.
   - Seeking to Understand the needs of the Person

5. **Relational Communication:** is an important element of compassion identified by patients consisting of verbal and nonverbal displays conveyed by the healthcare provider's engagement with the person suffering.

   There are four specific themes and associated subthemes that convey compassion within clinical communication:

   - **Demeanor**(''being'')
   - **Affect** (''feeling for'')
   - **Behaviors** (''doing for'')
   - **Engagement** (''being with'')

Attending to Needs

It refers to ''a timely and receptive desire to actively engage in and address a person's multi-factorial suffering''. Attending to patients' needs has three interrelated themes:

- **Compassion-Related Needs:** refers to the dimensions of suffering that patient feel compassion: physical, emotional, spiritual, familial and financial.
- **Timely** refers to addressing suffering in a ''timely'' manner.
- **Action** refers to the initiation and engagement of a dynamic and tangible process aimed at alleviating suffering. Compassion is more action.

1.3.3 Principles of compassionate care

Individual reflection

- **What are the principles of compassionate care?**

  Time Allowed: 5 Minutes

The universal principles of compassion will help us know one another in a more meaningful way where we discover one another respectfully. They create the conditions that allow a person who is suffering to experience the healing power of compassion.

1. **Attention:** is the focus of healthcare provider. Being aware will allow the healthcare provider to focus on what is wrong with a patient; or what matters most to the patient.

2. **Acknowledgement:** is the principle of what the healthcare professional says. The report of the examination or reflection on the patient's message. Positive messages of acknowledgment are buoyant; they let someone know that you appreciate them as a unique individual.

3. **Affection:** is how healthcare providers affect or touch people. Human contact has the ability to touch someone's life. It is the quality of your connection, mainly through warmth, comfort, kindness and humor. Affection brings joy and healing.

4. **Acceptance**: is the principle of being with mystery – how you stand at the edge of your understanding or at the beginning of a new experience, and regard what is beyond with equanimity. It is the quality of your presence in the face of the unknown, in the silence. Like the sun in the north at midnight, acceptance welcomes the mysteries of life and is at peace with whom we are and where we are, right now. It is the spirit of Shalom.

- The principle of acceptance is: being at peace with the way things are allows them to change.

1.3.4 Threats to compassionate care

There are factors preventing compassion and compassionate behavior for individual members of staff, teams and units and health facility. Most research discusses compassion at the individual level. In general, the most common threats for compassionate care are:

- **Compassionate fatigue:** Physical, emotional and spiritual fatigue or exhaustion resulting from care giving that causes and a decline in the caregivers' ability to experience joy or feel and care for others.
  - A form of burnout, a kind of "secondary victimization" what is transmitted by clients or patients to care givers through empathetic listening.
- **Unbalanced focus between biomedical model (clinical training) and person:** Effective clinical care is clearly fundamentally important, but human aspects of medicine and care must also be valued in training and in terms of how to be a good healthcare professional.
- **Stress, depression and burnout:**
  - **Self-reported stress** of health service staff is reported greater than that of the general working population.
  - **Burnout** (or **occupation burnout)** is a psychological term referring to general exhaustion and lack of interest or motivation to work.
- **Overall health facility context:** Attention by senior managers and health facility boards to achieve financial balance that affects priorities and behaviors of staff in health facility.

Addressing Threats of compassion

- Overcoming compassion fatigue
- Developing an inner compassionate self
- Compassion to yourself
- Teaching compassion to professionals through, training and education
- Dealing with staff stress and burnout
- Dealing with wider health facility context

1.4 Respectful care

1.4.1 Definition of Concepts of Respectful and Dignified Care

1. Can you share us your experience with regard to respect and dignity in the health care setting?
2. What does respectful care mean to you?

Time Allowed: 10 minutes

Definition of Dignity (ልእልና)

The word dignity originates from two Latin words: 'dignitus' which means merit and 'dignus' meaning worth. It is defined from two perspectives:

- Dignity is a quality of the way we treat others.
- Dignity is a quality of a person's inner self.

Types of Dignity

There are four types of dignity: dignity of human being, personal identity, merit and moral status.

1. Dignity of human being

This type of dignity is based on the principle of humanity and the universal worth of human beings their inalienable rights-which can never be taken away.

2. Dignity of personal identity

This form of dignity is related to personal feelings of self-respect and personal identity, which also provides the basis for relationships with other people.

3. Dignity of merit

This is related to a person's status in a society.

4. Dignity of moral status

This is a variation of dignity of merit, where some people have a personal status because of the way they perceived and respected by others. (**N.B.** Refer to Hand-out 3.1 for details.)

Attributes of Dignity

There are four attributes of dignity:

1. **Respect:** self-respect, respect for others, respect for people, confidentiality, self-belief and believe in others

2. **Autonomy:** having choice, giving choice, making decisions, competence, rights, needs, and independence
3. **Empowerment**: Feeling of being important and valuable, self-esteem, self-worth, modesty and pride
4. **Communication (may be verbal or non-verbal):** explaining and understanding information, feeling comfort, and giving time to the patients / families

Definition of Respect (አክብሮት)

- It is a term which is intimately related to dignity
- It is probably the most important action verb used to describe how dignity works in practice.

The action meanings of the word respect are:

- Pay attention to
- Honoring
- Avoiding damage e.g. insulting, injuring
- Not interfering with or interrupting
- Treating with consideration
- Not offending

People can vary by their skills, educational background, gender, age, ethnicity, and experiences. But, as human being, all are entitled to get dignified and respectful care. Every human being must respect others and get respect from others. Therefore, dignity is brought to life by respecting people:

- Rights and freedoms
- Capabilities and limits
- Personal space
- Privacy and modesty
- Culture
- Individuals believes of self-worth
- Personal merits
- Reputation
- Habits and values

Dignity and respect in the health care setting

Treating clients with dignity implies treating them with courtesy and kindness, but it also means:

- Respecting their rights

- Giving them freedom of choice
- Listening and taking into consideration what they say and
- Respecting their wishes and decisions, even if one disagrees

Treating clients with dignity implies being sensitive to clients' needs and doing one's best for them, but it also means:

- Involving them in decision making
- Respecting their individuality
- Allowing them to do what they can for themselves and
- Giving them privacy and their own personal space

1.4.2 Principles of Respectful Care

Individual reflection

❖ Think of a person who gave you the most respectful care/service.

- Describe the situation?
- What are the qualities of that person?
- What did you value most?

Time: 5 Minutes

The principles of respectful care guide actions and responsibility of care providers in ensuring dignified care for their service users. Dignified care has seven core principles.

- Recognize diversity and uniqueness of individuals
- Uphold responsibility to shape care
- Meaningful conversation
- Recognize the care environment
- Recognize factors affecting dignity
- Value workplace culture
- Challenge dignity barriers

1.4.3 Characteristics of Disrespectful Care

The situation where you received disrespectful care?

1. Describe the incident?
2. What was your reaction?

Time: 5 Minutes

The seven categories of disrespect and abuse

Category	Example
Physical Abuse	Slapping, pinching, kicking, slapping, pushing, beating,
Non-consented care	Absence of informed consent or patient communication, forced procedures
Non-confidential care	Lack of privacy (e.g. Laboring in public or disclosure of patient information
Non-dignified care	Intentional humiliation, rough treatment shouting, blaming, treating to withhold services laughed at patients, provider did not introduce themselves, patients not called by their names throughout the interaction.
Discrimination based on specific patient attributes	Discrimination based on ethnicity, age, language, economic status, education level, etc.
Abandonment of care	Women left alone during labor and birth Failure of providers to monitor patients and intervene when needed
Detention in facilities	Detention of patients/family in facility after delivery, usually due to failure to pay

1.4.4 Factors affecting Respectful Care Provision

Individual reflection

1. What do you think hinders you from providing respectful care in your health facility?
2. What are the factors that facilitate provision of respectful care in your health facilities?

Time: 5 Minutes

Different Factors have a significant impact on hindering or facilitating the provision of respectful care service. These factors can be broadly classified in to three major groups; Health care environment, staff attitude & behavior and patient factors

Positive attributes of the physical environment which helped health professional to provide dignified care are related to aspects maintaining physical and informational privacy and dignity, aesthetically pleasing surroundings and single sex accommodation, toilet and washing facilities. Aspect of the environment that maintain physical and informational privacy are listed below

- **Environmental privacy** (for example curtains, doors, screens and adequate separate rooms for intimate procedures or confidential discussions (auditory privacy).
- **Privacy of the body**: covering body, minimizing time exposed, privacy during undressing and clothing are some of the enabling factors to ensure bodily privacy done by health professionals.
- **Aesthetic aspects** of the physical environment (for example space, color, furnishing, decor, managing smells); and the provision of accommodation, toilet and washing facilities
- **Managing peoples in the environment:** such as other patients, family and ward visitors/public contribute positively to maintain dignity in the health
- **Adequate mix and proficient Staffing**: adequately staffed with appropriate number and skill mix, as high workload affects staff interactions, and have strong leaders who are committed to patient dignity.

Physical environment which hinders health professional form providing respectful care are related to the overall health care system, lack of privacy, restricted access to facility /service and lack of resources. Aspect of the environment that hinders the provision of respectful care are listed below,

- **The healthcare System:** Shortage of staff, unrealistic expectations, poorly educated staff, 'quick fix' attitude, low wage, pay 'lip service' to dignity, low motivation, lack of respect among professionals, normalization/tolerance of disrespectful care, lack of role model, management bureaucracy and unbalanced staff patient ratio and skill mix.
- **Lack of privacy:** Lack of available single rooms, bath rooms and toilets without nonfunctional locks, use of single rooms only for infectious cases and lack of curtains or screens
- **Restricted access to facility/service:** Badly designed rooms, inadequate facilities (e.g. toilets, bath rooms), Cupboards with drawers that do not open, toilet and bath rooms shared between male and females.

- **Lack of resource:** Run out of hospital, gowns and pyjamas, Lack of medical equipment and supplies

The A, B, C, of respectful health care, is a tool designed to consider the attitudes and behaviors of health care providers

A –Attitude

Ask yourself:

- How would I be feeling if I was this person?
- Why do I think and feel this way?
- Are my attitudes affecting the care I provide and, if so, how?
- Are my personal beliefs, values, and life experiences influencing my attitude?

Action to be taken

- Reflect on these questions as part of your everyday practice.
- Discuss provider attitudes and assumptions and how they can influence the care of patients with the care team.
- Challenge and question your attitudes and assumptions as they might affect patient care
- Help to create a culture that questions

B- Behavior

- Introduce yourself. Take time to put the patient at ease and appreciate their circumstances.
- Be completely present. Always include respect and kindness.
- Use language the patient/family can understand

C-Communication

- Communication revolving around the patient's needs.
- Patient centered communication with defined boundaries
- Objectivity is an important attribute when assessing the clients' needs

Ten Mechanisms to mitigate threats to respectful care -

1. Support clients with same respect you would want for yourself or a member of your family
2. Have a zero tolerance of all forms of disrespect
3. Respect clients' right to privacy
4. Maintain the maximum possible level of independence, choice, and control
5. Treat each client as an individual by offering personalized care
6. Assist clients to maintain confidence and a positive self esteem
7. Act to alleviate clients' loneliness and isolation
8. Listen and support clients to express their needs and wants
9. Ensure client feel able to complain without fear of retribution
10. Engage with family members and care givers as care partners?

1.5 Compassionate Leader

1.5.1 Quality of Compassionate Leadership

Group exercise

Discuss in a group of 4-5 and share your experience to the larger group.

- What does it mean for you to lead, and manage?
- Can you give an example of a leader whom you know in your professional or personal life? What makes him or her good leader for you?
- Do you know of any individuals in high positions or authority who demonstrate compassionate, respectful and caring practices when they deal with their staff and clients?

Duration: 20 minutes

Brief description of leadership theories

Introduces transactional, transformational, and servant leadership theories. It will also provide a better understanding of qualities of CRC leaders, which will enable participants to provide better service and increase awareness of CRC leadership.

- **Transformational leaders**: lead employees by aligning employee goals with their goals. Thus, employees working for transformational leaders start focusing on the company's well-being rather than on what is best for them as individual employees.
- **Transactional leaders**: ensure that employees demonstrate the right behaviors because the leader provides resources in exchange.

- **Servant Leadership**: defines the leader's role as serving the needs of others. According to this approach, the primary mission of the leader is to develop employees and help them reach their goals. Servant leaders put their employees first, understand their personal needs and desires empower them and help them develop their careers.

1.5.2 Characteristics of compassionate leaders

- **'In-tune' feeling**: Their actions abide by their words – and they always have the time to engage with others.
- **Manage their moods**: They know feelings affect others and they use positive emotions to inspire, not infect others with negative feelings.
- **Put people before procedures**: They are willing to set aside or change rules and regulations for the greater good.
- **Show sincere, heartfelt consideration**: They genuinely care for the well-being of others and have a humane side that puts other people's needs before theirs.
- **Are mindful**: They are aware of their own feelings and their impact on others. They are also attentive and sympathetic to the needs of others.
- **Are hopeful**: They move others passionately and purposefully with a shared vision that focuses on positive feeling of hope.
- **Courage to say what they feel**: They communicate their feelings, fears, even doubts which builds trust with their employees.
- **Engage others in frank, open dialogue**: They speak honestly with humility, respect and conviction, and make it safe for others to do the same.
- **Connective and receptive**: They seem to know what other people are thinking and feeling.
- **Take positive and affirming action**: They carry out compassion. They do not just talk about it; they make a promise, act on it and keep it.

What does compassionate leadership do for the organization?

- Positively affects sufferers, clients, employees
- Increases people's capacity for empathy and compassion
- Promotes positive relationships
- Decreases the prevalence of toxic viral negative emotions and behavior
- Increases optimism and hope
- Builds resilience and energy levels
- Counteracts the negative effects of judgment and bias

Self-evaluation of compassionate behavior

Good leaders can evaluate their own behavior using different methodologies. The self-assessment of compassionate leaders should be conducted every six months to enhance self-compassion through mindfulness.

Mindfulness begins with self-awareness: knowing yourself enables you to make choices how you respond to people and situations. Deeper knowledge about yourself enables you to be consistent, to present yourself authentically. You will learn and practice different ways to develop mindfulness and explore how it can contribute to developing compassionate leadership practices through:

- Enhancing attention and concentration
- Increasing creativity and flexibility
- Working efficiently in complex systems and uncertain environments
- Creating meaning and purpose
- Making effective and balanced decisions
- Responding effectively to difference and conflict
- Acting with compassion and kindness
- Enhancing relationships and partnerships
- Enabling genuine and courageous action
- Working ethically and wisely
- Developing cultural intelligence

1.6 Systems Thinking for CRC

Group activity in healthcare system thinking

Discuss in a group of 4-5 and share your experience to the larger group.

- Discuss concepts of Health System and how it relates with your Health Facility /Hospital and Health Center/ functions.
- Take your Health Facility/Hospital and Health Center/ and list the various department/core processes/support processes. Using a systems thinking approach, discuss how they interact with each other?
- Take in to account the CRC concepts and identify gaps you may have experienced in your facilities?

Duration: 20 minutes

System: A system is a set of interacting or interdependent components forming an integrated whole.

Health System: A health system consists of all the organizations, institutions, resources and people whose primary purpose is to improve health.

Fully functional health system: A point which various management systems and subsystems are connected and integrated to provide the best possible health services to all the intended beneficiaries of those services.

Management systems: The various components of the overall health system that managers use to plan organize and keep track of resources. Management systems are run by people living in different contexts.

Integrate CRC into Existing System

Integration of new initiatives into existing system has paramount importance in expediting the process of implementation and ensuring sustainability of CRC in a health system. Integration can be done using "AIDED" model.

Assess: Understand the capacity of the unit structure, especially in regards to the availability of resources, as well as human resource; also to assess the level of human capability when integrating and sustaining the CRC by determining the level of support the unit requires before or after carrying out CRC.

Innovate: Design and package the CRC to fit with the existing quality of unit structure and their environmental context to spread the CRC throughout the hospital departments.

Develop: Build upon existing knowledge of main stakeholders and opinion leaders by encouraging hospital policies, organizational culture, and infrastructure to support the implementation of principles of CRC.

Engage: Use existing roles and resources within the hospital units to introduce, translate, and integrate CRC principles into each employee's routine practices.

Devolve: Capitalize on existing organizational network of index user groups to release and spread the innovation to new user groups.

1.6.1 Organizational culture

Organizational culture consists of the values and assumptions shared within an organization. Organizational culture directs everyone in the organization toward the "right way" to do things. It frames and shapes the decisions and actions of managers and other employees. As this definition points out, organizational culture consists of two main components: shared values and assumptions.

1. ***Shared Values:*** are conscious perceptions about what is good or bad, right or wrong. Values tell us what we "ought" to do. They serve as a moral guidance that directs our motivation and potentially our decisions and actions.
2. ***Assumptions:*** are unconscious perceptions or beliefs that have worked so well in the past that they are considered the correct way to think and act toward problems and opportunities.

Five key systems influence the hospital's effective performance with respect to improving the safety and quality of patient care, as well as sustaining these improvements. The systems are:

1. Using data
2. Planning
3. Communicating
4. Changing performance
5. Staffing

Leaders create and maintain a culture of safety and quality throughout the hospital. Rationale

- CRC thrives in an environment that supports teamwork and respect for other people, regardless of their position in the organization.
- Leaders demonstrate their commitment to CRC and set expectations for those who work in the organization. Leaders evaluate the culture on a regular basis.
- Leaders encourage teamwork and create structures, processes, and programs that allow this positive culture to flourish. Disruptive behavior that intimidates others and affects morale or staff turnover can be harmful to patient care.
- Leaders must address disruptive behavior of individuals working at all levels of the organization, including management, clinical and administrative staff, licensed independent practitioners, and governing body members.

Creating an organizational culture of empowering employees for CRC

Having empowered employees is the aim of many leaders. Literature has reported that creating an organizational culture will empower employees to increase customer satisfaction levels, as well as to improve employee morale and productivity.

Employee empowerment encourages communication, participation in shared decision-making and enabling physicians and staff to reach their full potential by creating and optimal healing environment.

There are many different ways to build employee empowerment and engagement, but all share six fundamental actions to promote CRC on the part of leadership:

Share information and communication: Sharing information with employees is important because it not only helps to build trust; it gives employees important information to allow them to make the best possible decisions in critical situations when providing CRC services.

Create clear goals and objectives: Inspire employees to embrace the mission or changes of the organization by appealing to their innate desire to help patients and provide an efficient CRC service. Great leaders share important information in a structured and consistent manner.

Teach, accept and encourage: If you empower employees to make decisions that will help keep customers happy, then you have to be willing to allow them to make mistakes and learn from those mistakes.

Reward Self-Improvement: Create an environment that celebrates both successes and failures. A good leader celebrates successes; and employees who take risks for the benefits of patients/client;

also, a good leader will assist employees to develop a plan for growth and reward them as they advance.

Support a learning environment: Listen to the voice of physicians, nurses and other staff to understand key barriers, issues, and opportunities to allow them to have a voice in crafting solutions for CRC challenges.

Create a clear role of autonomy: Enable frontline workers to execute change by supplying resources (education, funding, access to other skill sets within the health facility, etc.) and removing obstacles themselves.

1.6.2 Leading CRC Health Teams

Group activity

Discuss in a group of 4-5 and share your experience to the larger group.

- What principles do you think of when implementing CRC?
- Do you think there are differences between your current "leading" style and leading based on CRC? If yes, list the differences.

Duration: 10 minutes

Health facility leaders have intersecting roles as public servants, providers of health care, and managers of both healthcare professionals and other staff.

- **As public servants**, health facility leaders are specifically responsible for maintaining the public trust, placing duty above self-interest and managing resources responsibly
- **As healthcare providers**, health facility leaders have a fiduciary obligation to meet the healthcare needs of individual patients in the context of an equitable, safe, effective, accessible and compassionate health care delivery system.
- **As managers**, leaders are responsible for creating a workplace culture based on integrity, accountability, fairness and respect.

Ethical healthcare leaders apply at least the following six specific behavioral traits:

1. **Ethically conscious:** Have an appreciation for the ethical dimensions and implications of one's daily actions and decisions or, as described by author John Worthily, the "ethics of the ordinary" (reference?).
2. **Ethically committed:** Be completely devoted to doing the right thing.

3. **Ethically competent:** Demonstrate what Rush worth M. Kidder, president and founder of the Institute for Global Ethics, calls "ethical fitness," or having the knowledge and understanding required to make ethically sound decisions (reference).
4. **Ethically courageous:** Act upon these competencies even when the action may not be accepted with enthusiasm or endorsement.
5. **Ethically consistent:** Establish and maintain a high ethical standard without making or rationalizing inconvenient exceptions. This means being able to resist pressures to accommodate and justify change inaction or a decision that is ethically flawed.
6. **Ethically candid:** Be open and forthright about the complexity of reconciling conflicting values; be willing to ask uncomfortable questions and be an active, not a passive, advocate of ethical analysis and ethical conduct.

Problem solving in healthcare

Steps of Scientific Problem Solving Skills

1. Define the problem
2. Set the overall objective
3. Conduct a root cause analysis
4. Generate alternative interventions
5. Perform comparative analysis of alternatives
6. Select the best intervention
7. Develop implementation plan and implement plan
8. Develop evaluation plan and evaluate

Best Practice Identification

Criteria to select best practices

- **New/Novel idea-** not much practiced in other hospitals in Ethiopia
- **Effectiveness:** has brought empirical change to the implementation of CRC specifically to patient satisfaction and quality of service provision. The practice must work and achieve results that are measurable.
- **Relevant/impact:** improved CRC and quality of patient experience (Explain the relevance of the innovation using a clear baseline and current performance of CRC)
- **Diffusible:** implemented at low cost in other facilities or implemented innovation in other hospitals.
- **Sustainable:** Innovation is easy to understand, easy to communicate and works for long time.

- **Political commitment:** The proposed practice must have support from the relevant national or local authorities.
- **Ethical soundness:** The practice must respect the current rules of ethics for dealing with human populations.

By definition, "Best Practices" should be "new/novel", "effectiveness" and "relevance".

Monitoring and Evaluation of CRC Health Team

Potential focus areas where leaders focus to evaluate their CRC staff

- **Quality of work**: Provide accuracy and thorough CRC service
- **Communication and interpersonal skills**: listening, persuasion and empathy to clients/patients and teamwork and cooperation in implementing CRC
- **Planning, administration and organization**: setting objectives, and prioritizing CRC practice
- **CRC knowledge**: knowledge based training, mentoring, modeling and coaching
- **Attitude**: dedication, loyalty, reliability, flexibility, initiative, and energy towards implementing CRC
- **Ethics**: diversity, sustainability, honesty, integrity, fairness and professionalism
- **Creative thinking**: innovation, receptiveness, problem solving and originality
- **Self-development and growth**: learning, education, advancement, skill-building and career planning

Summary

- *Dignity of human being is the basis for healthcare delivery*
- *Clients should be treated as human being not as cases*
- *Disrespect and abuse is a problem in Ethiopia.*
- *Zero Tolerance to Disrespectful care shall be a motto for all health workers in the health facilities.*
- *Improving the knowledge of ethics is important to boost the ethical behavior in practice*

Chapter 2
Electrosurgical Unit

Chapter Allocated Time: 14hrs

Chapter Description:

This chapter is designed to develop the necessary knowledge, skills and attitude of the learners to the standards required in operating room equipment maintenance for biomedical engineers and technicians. It covers basic working principles, purposes, and main components, troubleshooting techniques and safety procedures for electrosurgical unit.

Chapter Objective:

By the end of this session, the participants will be able to know how to handle, install, and maintain electrosurgical unit

Enabling objectives

After completion of this module the participant is able to:

- Describe uses/purpose of Electrosurgical unit (ESU)
- Identify types of Electrosurgical unit
- Describe working principles of Electrosurgical unit
- Describe basic parts and components of ESU
- Follow troubleshooting techniques for ESU
- Differentiate types of maintenance in ESU
- Apply maintenance report techniques

Chapter Outline:

2.1 Introduction

Electro-surgery generator units (ESUs) are a crucial piece of equipment in the majority of operative settings and are the most useful and common instruments used by surgeons today. An ESU uses an AC source that operates at a radio frequency (RF) in the range between 300 kHz and 3MHz.The rate of the frequency depends on the heating effect of a high frequency electrical current which flows through the sharp edge of a wire loop or band loop or a point of a needle into the tissue. Electro-surgery, also known as surgical diathermy which means through heat, was first developed by William Bovie in 1926, and is a treatment method involving the production of electrically induced heat through the passage of high frequency AC currents through biological tissue. This technique allows the high frequency current to cut or coagulate the tissue, minimizing blood loss and shortening operating times. The principle of heat production via current passing into tissue can be adjusted to produce a variety of tissue effects such as coagulation, cutting, desiccation and fulguration. This section discusses about the purposes/clinical applications, working principles, basic components, troubleshooting, and maintenance procedures/techniques, and the safe handling of a general electrosurgical unit.

The term "electrocautery," or "cautery," is often, and incorrectly, used to describe all types of electrosurgical devices. Its use is only appropriate to describe the simple direct current cautery device. The cautery is useful in ophthalmic surgery and other a very minor procedure in which very little bleeding is encountered. Its use is limited because it cannot cut tissue or coagulate large bleeders. It is further limited because the target tissue tends to stick to the electrode.

2.2 Purpose and clinical application of electrosurgical unit

Individual activity 2.1:

- For what types of clinical Service we use Electrosurgical Unit?

Time: 15 min.

ESU's are used for surgical cutting or to control bleeding by causing coagulation (homeostasis) at the surgical site. They deliver high-frequency electrical currents and voltages through an active electrode, causing desiccation, vaporization, or charring of the target tissue.

ESU's are a useful tool in all aspects of the surgical arena: from the most basic wart removal, spider veins, or hair removal in a doctor's office; to the most intricate open heart, orthopedic, and transplant procedures. An ESU, by definition, is a generator capable of producing a cutting and/or coagulating clinical effect on tissue by the use of alternating current at a high frequency (RF - radio frequency, also known as radio surgery). Voltages and currents may vary depending on the desired clinical effect.

2.3 Working principle of electrosurgical unit

Learning activity 2.2:

- Discuss with two groups the mono-polar and bipolar operation modes of ESU.
- What are the electrosurgical waveforms and their tissue effects?

Time: 15 min.

Basic principles of electricity that impact patient care and outcomes of electro-surgery Include [1, 2].

- Electricity follows through the path of least resistance,
- Electricity will always seek to return back to an electron reservoir (e.g., electro-surgery unit or earth ground), and
- A closed circuit must be established in order for electricity to flow.

Why electro-surgery generators do not shock patients is a common question. The answer is because of the higher frequencies at which electro-surgery generators operate. Electro-surgery generators take 60 Hz current and ramp it up to the radio frequency range. Radio frequency current alternates so rapidly between the positive and negative poles that cells do not depolarize, or react to the current. Neuromuscular stimulation ceases at about 100,000 Hz.

Electro-surgery generators typically operate in the 200 kHz to 3.3 megahertz (MHz) range (see Fig. 2.1). That is well above the range where neuromuscular stimulation or electrocution could occur.

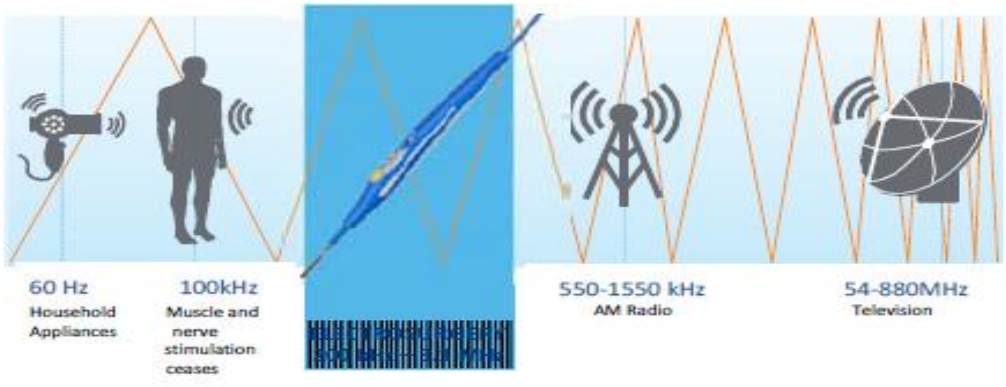


Figure 2.1: Sample standard monitor/screen of a patient monitoring system [Courtesy of (Wu et.al Complications and…])

2.3.1 Operation Modes of Electrosurgical unit

2.3.1.1 Mono-polar Electro-surgery

The most frequently used method of delivering electro-surgery is mono-polar, because it delivers a greater range of tissue effects. In mono-polar electro-surgery, the generator produces the current, which travels through an active electrode and into target tissue. The current then passes through the patient's body to a patient return electrode where it is collected and carried safely back to the generator (Figure 2.2). This is the intended pathway for the electrical current. The type of mono-polar generator used, along with appropriate surgeon and nursing interventions can help to ensure that this is the path the current takes through the patient.

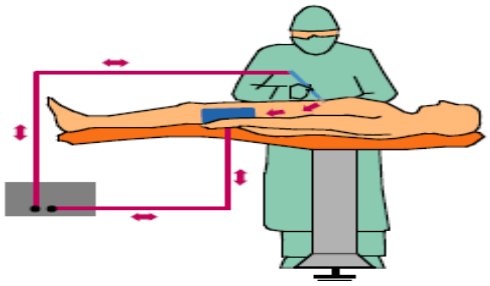


Figure 2.2: Mono-polar Circuit [Courtesy of (Gallagher et.al Electro-surgery…)]

2.3.1.2 Bipolar Electro-surgery

Bipolar electro-surgery is the use of electrical current where the circuit is completed by using two parallel poles located close together. One pole is positive and the other is negative. The flow of current is restricted between these two poles. These are frequently tines of forceps, but may also be scissors or graspers. Because the poles are in such close proximity to each other, low voltages are used to achieve tissue effect. Most bipolar units employ the cut waveform because it is a lower voltage waveform, and achieves hemostasis without unnecessary charring. Because the current is confined to the tissue between the poles of the instrument and does not flow through the patient, a patient return electrode is not needed (see Figure 2.3). Bipolar is a very safe type of electro-surgery. There are some disadvantages to the use of bipolar, especially in the micro bipolar mode. Bipolar cannot spark to tissue, and the low voltage makes it less effective on large bleeders (Mitchell, 1978). However, there are newer bipolar systems that incorporate a "macro" or bipolar "cut" mode that has higher voltage and is designed for use with the new generation of bipolar cutting instruments. Bipolar, especially micro bipolar, has been widely used in neurosurgery and gynecologic surgery. It may be safer to use when there is a question about the efficacy of using more powerful mono-polar electrosurgical units (e.g., with pacemakers, implanted automatic cardiac defibrillators).

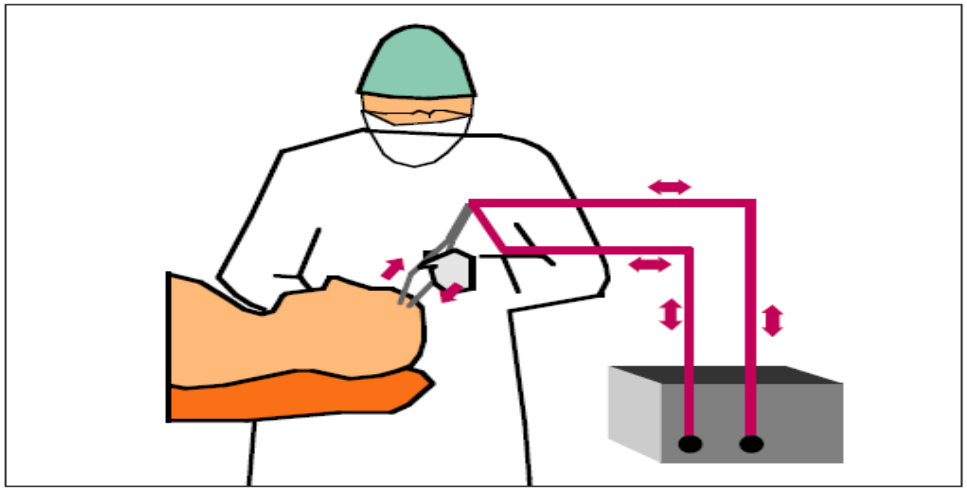


Figure 2.3: Bipolar Circuit [Courtesy of (Gallagher et.al Electro-surgery…)]

2.3.2 Electrosurgical Waveforms and their Tissue Effects

ESUs can be programmed to function in several modes with distinct tissue characteristics. The generator output can be varied in two ways: the voltage can be altered to drive more or less current through the tissues, or the waveform can be modified which influences the tissue effect. The tissue effect associated with the different electrosurgical current waveforms is dependent on the size and shape of the electrode and the output mode of the generator. There are three types of current waveforms: cutting, coagulation, and blended currents, see Figure 2.4 [5, 6, 7, 8].

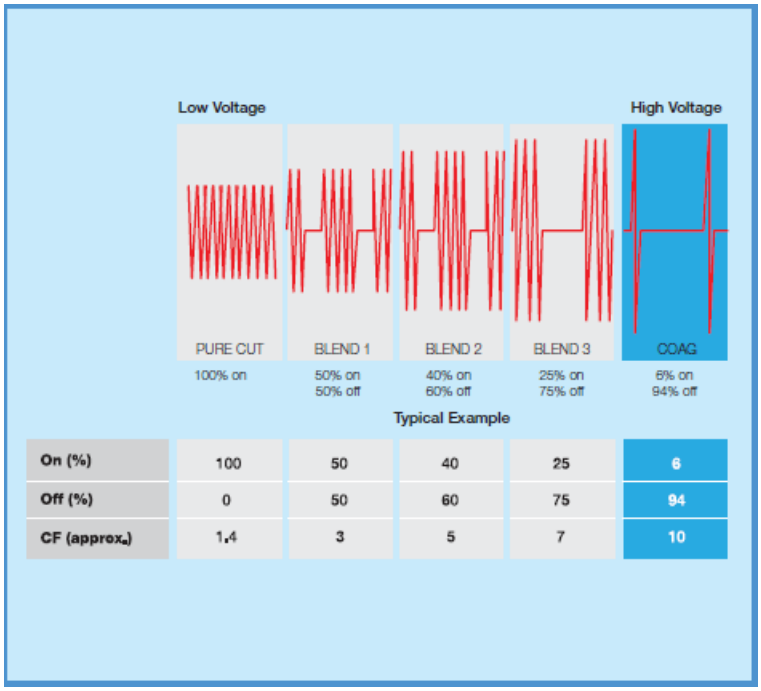


Figure 2.4: Pure cutting current, blend 1-3, coagulation current [Courtesy of (www.boss.net.au/clinical/studynotes/genper01.htm)]

Cutting Currents

Cutting currents use an uninterrupted sinusoidal waveform with high average power, high current density and a CF of 1.4, see Figure 2.4. The use of electric sparks allows for precise cutting and focused heat which minimizes widespread thermal damage. The electrode should be held slightly away from the tissue to create a spark gap and discharge arc at specific locations which produces a sudden and localized heating effect over a short period of time which causes extreme heating and vaporization of intracellular fluid that bursts cells. A fine, clean incision is created through the biological tissue with minimal coagulation (hemostasis) or extensive thermal damage and the continuous current does not allow for tissue cooling.

Coagulation Currents

Coagulation currents are characterized by high voltage intermittent bursts of dampened sine waves which drive the current through the tissue and relatively low current which reduces the duty cycle to 6%, Figure 2.4. Coagulation currents typically have a CF of around 10. Coagulation is electrical sparking over a wide area therefore less heat is produced resulting in evaporation and relatively slow dehydration which seals blood vessels while keeping cells intact. "The coagulation current is operated with the power setting between 30 to 50 W with voltage spikes as high as 9000 V at 50 W" [10] . In between bursts of current, the heat dissipates into the tissues reducing the cutting effect whilst enhancing the coagulation during the 94% off cycle.

Desiccation is a direct contact form of coagulation where 100% of the electrical energy is converted into heat within the t issue, not seen with other current waveforms. It uses low current density over a broad area which causes dehydration of cells without the need for an electrical spark.

Fulguration is a non-contact form of coagulation, producing a spark gap and electric discharge arc to mediate the tissue as the air between the probe and tissue ionizes. A spray effect at various regions causes shallow tissue destruction

Blended currents

A blended current is a modification of the duty cycle and operates at voltages between those of cutting and coagulation with a CF usually in the range of 3 to 10. Blended currents allow for tissue division whilst maintaining a variable degree of homeostasis which is defined by the off period. Although the total energy remains the same, the ratio of voltage and current is adjusted to increase hemostasis by interrupting the current and increasing the voltage, to deliver a waveform in intermittent bursts. Three blends are shown in Figure3.4. Modifications and reductions to the duty cycle through progressive blends produce less heat and as the interval between bursts progressively increases, greater coagulation is produced. However, as homeostasis increases, the cutting ability of the blended current decreases [5, 6, 7, 8]. The rate at which heat is produced is the dominant factor and only variable in determining whether a waveform vaporizes or coagulates biological tissue. Surgeons have the option to combine the cut and coagulate currents to produce different tissue effects. Coagulation can be performed with the cutting current by using the

electrode in direct contact with the tissue and this requires less voltage than the coagulation waveform. However power settings may need to be adjusted and electrode size varied to achieve the desired surgical effect [5].

2.4 Basic components of electrosurgical unit

Learning activity 2.3:

- **List the major components of electrosurgical unit and discuss their functions.**

The major components of electrosurgical unit are:

2.4.1 Power unit

2.4.2 RF output Board

2.4.3 Memory Board

2.4.4 Logic Board / Relay Board

2.4.5 Front Panel

2.4.6 Display Board

2.4.7 Audio Tone Generator

2.4.8 Isolation Board

2.4.1 Power unit:

The power supply generates -5VDC, +15VDC, -15VDC, supplied to all units. It is power supply. The 5VDC panel control and Display generated voltage for measure the current drawn the supply of +5VDC, VDC, +24VDC, which is basically like a low voltage VDC are used for the front Display. It also monitors the diagnostic purpose to from power supply

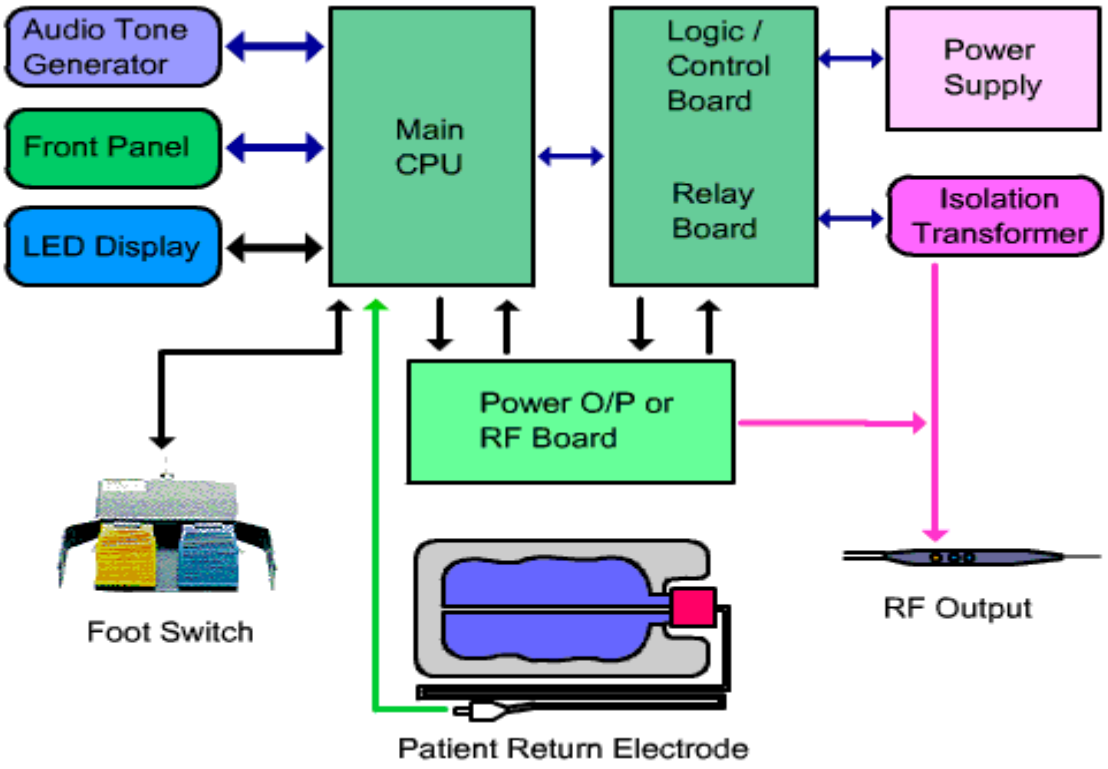


Figure 2.5: General Block Diagram [Courtesy of (http://www.srmuniv.ac.in/sites/default/files/downloads/esu.pdf)]

2.4.2 RF output Board

It has a power amplifier assembly, which comprises Bipolar, Mono-polar, CUT/ COAG and BLEND waveform. The output circuit is fully isolated. It generates the output as per front panel Main Board and Logic Control Board. It generates the Switch mode pulse pattern generator, Drive circuit for output switching power MOSFETS and High Frequency filtering components.

In enhanced type generator, the output power is managed and controlled according to patient's tissue impedance.

2.4.3 Memory Board

The function of this board is to accept operating mode control signal from front panel, rear panel and foot switch. It checks and identifies that which connector is in use and monitors its continuity. An interfaced Front Panel switch signal decodes and passes information to Display. It has a microprocessor, used together with EPROM as program memory and RAM. The analog to digital conversion of signal to convert the commands received from front panel and fed to logic board. It also generates the audible command whenever any fault occurs during self-test and operation. It detects all front panel operation and acts as per instruction.

2.4.4 Logic Board / Relay Board

The board is mainly interfaced with Main Board or sometimes all functions of Main Board are incorporated. It is a liaison between front panel and output required. All signals reinter-related to this board. It gives the power output command to RF or Power output board and monitors the output. It has relay board too, which activates according to finger switch or foot switch control.

2.4.5 Front Panel

It consists of membrane keyboard, Power switch, Patient Return Electrode, Mono-polar, Bipolar connector. Front panel also interfaces with Display Board and Power Supply Board. The Power Supply Switch supplies the AC mains current to the Electrosurgical Unit.

2.4.6 Display Board

It is located in the Front Panel Assembly. It contains RF indicator lamp, seven segments LED, and Mono-polar / Bipolar mode of surgery. The RF indicator lamps are used for visual indication of presence of RF power during activation. The improper attachment of Patient Return Electrode is visually indicated by Patient Return LED. It also contains LED driver circuit and Seven Segment Display, which indicates the Bipolar, Mono-polar, Cut, Coagulation power settings.

2.4.7 Audio Tone Generator

It receives the command from Main board, which activates the Audio oscillator circuit. Audio circuitry gets ON at time of activation of high frequency, any malfunction or Fault of ESU, improper or loose attachment of patient Return Electrode and Power up. It activates with signals provided by micro-controller and gives high and low tone.

2.4.8 Isolation Board

The patient interface board is interfaced with the Main Board. It has several different functions, which is concerned with patient connected parts and provides the patient isolation voltage. It monitors the patient plate continuity, plate voltage, BIPOLAR forceps switch, CUT / BLEND, and COAG finger switches and patient earth monitor. It monitors the high frequency leakage current. This board passes the Active electrode signals to main board and continuously monitors the patient plate continuity. If any break occurs in plate lead or not plugged IN, the related signal activates and passes to main board to generate audible signal.

2.4.9 ESU Electrodes

There are two types of Electrodes used in Electro-surgery.

I) Active Electrodes

The mono-polar active electrode is typically a small flat blade with symmetric leading and trailing edges that is embedded at the tip of an insulated handle. The edges of the blade are shaped to easily initiate discharge arcs and to help the surgeon manipulate the incision; the edges cannot mechanically cut tissue.

Since the surgeon holds the handle like a pencil, it is often referred to as the "pencil." Many pencils contain in their handle one or more switches to control the electrosurgical waveform, primarily to switch between cutting and coagulation. Other active electrodes include needle electrodes, loop electrodes, and ball electrodes. Needle electrodes are used for coagulating small tissue volumes like in neurosurgery or plastic surgery. Loop electrodes are used to resect nodular structures such as polyps or to excise tissue samples for pathologic analysis.

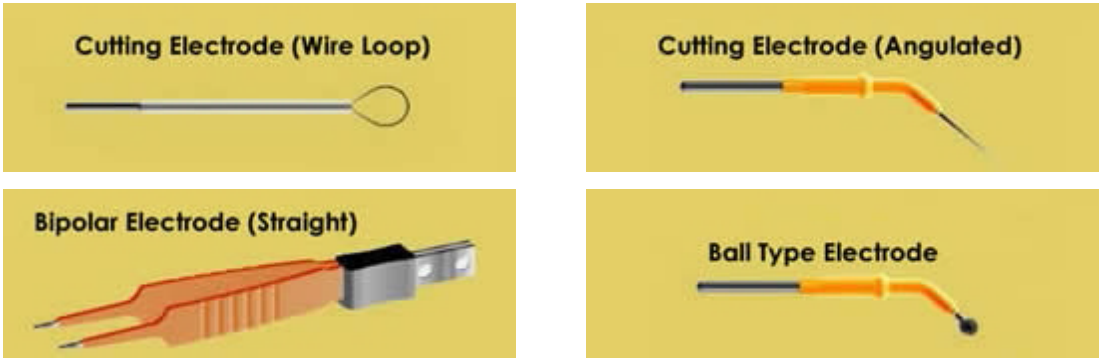


Figure 2.6: Examples of active electrodes [Courtesy of (http://www.srmuniv.ac.in/sites/default/files/downloads/esu.pdf).]

II) Dispersive Electrodes

The main purpose of the dispersive electrode is to return the high-frequency current to the electrosurgical unit without causing harm to the patient. This is usually achieved by attaching a large electrode to the patient's skin away from the surgical site. The large electrode area and small contact impedance reduce the current density to levels where tissue heating is minimal. Since the ability of a dispersive electrode to avoid tissue heating and burns is of primary importance, dispersive electrodes are often characterized by their heating factor. Electrode failures and subsequent patient injury can be attributed mostly to improper application, electrode dislodgment, and electrode defects rather than to electrode design.

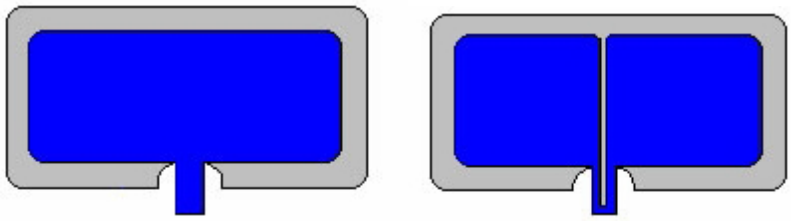


Figure 2.7: Examples of dispersive electrodes [Courtesy of (http://www.srmuniv.ac.in/sites/default/files/downloads/esu.pdf)]

2.5 Safe Handling of Electrosurgical Unit

Learning activity 2.4:

List the appropriate safe handling procedures for each of the following electrosurgical system.

- Active Electrode
- Patient returns Electrode
- Patient Safety
- Electrical Safety

Generally in using/operating, troubleshooting, or maintaining any components of electrosurgical unit system, both users and technicians have to apply and follow the appropriate safe handling procedures as per the manufacturer's service manual. In this sub section a general guidelines and procedures for safe handling of electrosurgical unit are listed.

2.5.1 General Safety

High Frequency (Sometimes referred to as radio frequency or HF) surgery can result in serious injuries to patient if carelessly or incorrectly applied. HF surgical instrument should be used on patient exclusively by personnel familiar with feature and operation of the equipment.

In order to prevent accidental injuries due to fault, failure to equipment or its accessories, the equipment and its accessories should be regularly checked for proper and safe operation.

Electrodes and cables are to fasten carefully.

2.5.1.1 Hazardous electrical out put

- Electrosurgical unit is recommended to use only by qualified medical personnel. To avoid burns, do not touch active electrodes.

- Do not operate in explosive atmosphere
- To avoid explosion, do not operate unit in an explosive atmosphere.
- Prevent Electro-surgery use in the presence of flammable gases, flammable liquids, or flammable object.

2.5.2 Electrical Safety

- Electrosurgical units may cause interference with improperly shielded medical equipment.
- **Use proper power cord.**
  Use only a power cord in a good condition with properly grounded receptacle.
- **Use the proper fuses**
  To avoid fire hazard, use only fuses of correct type, voltage rating and current rating as specified. Remove the power cord during replacement of fuse.
- Do not touch the active electrode to grounded metal parts or to the patient plate for function proving.
- The cables to HF-electrodes should be as short as possible and must be arranged without loops so that they touch neither the patient nor other cables. Only cables recommended by the manufacturer should be used.
- Foot switches used in explosion hazard areas must be explosion proof.

2.5.3 Patient Safety

- Ensure that there is no air gap between patient's body and patient return electrode.
- Ensure that no small-surface area contact is made between the patient and any of the metal parts of the treatment chair, table, saline water stand, which conduct ground potential. Heat may be generated at such points leading to undesired burns.
- The patient plate shall be reliable in good contact with the patient's skin for the whole operation;
- If patient plate is fastened at limbs, be careful that it doesn't affect the supply of blood.
- The return path of the HF-current shall be as short as possible and in longitudinal or diagonal direction of the body. It should not go transversely through the body, especially at the thorax.

- The patient with pacemaker should be treated and consulted through cardiology department as the high frequency may affect or damage to the pacemaker. Outpatient with pacemakers should not be treated using a HF generator.
- Avoids skin to skin contact, such as fingers touching the patient's leg, when ESU is activated.

2.5.4 Patient returns Electrode safety precautions

- Discard the disposable packages that have expired.
- Use 'Patient Return Electrode' according to the manufacturer's documented instruction.
- Inspect patient return electrode before each use for wire breakage or fraying.
- Select appropriate size patient return electrode for patient (i.e., neonate/infant, pediatric, adult).
- Do not cut patient return electrode to accommodate patient size.
- Shave, clean and dry at application site as needed.
- Place patient return electrode on positioned patient on a clean, dry skin, convex area in close proximity to operative site.
- Avoid bony scar tissue, skin over an implanted metal prosthesis, hairy surfaces, pressure points, tissue, and areas where fluid may pool.
- Apply finger pressure to adhesive border of the electrode and massages entire pad areato ensure adequate contact with the patient's skin.
- Follows manufacturers' guidelines for alarm system, check prior to use.
- Check patient return electrode connections to confirm that they are clean, intact, and can make effective contact.
- Remove patient return electrode gently to protect skin.

2.5.5 Active Electrode Safety Precautions

- Avoid coiling, bundling, or clamping of active and patient return electrodes.
- Avoid wrapping the active electrode cord around a metal instrument.
- Remove all metal patient jewelry to prevent current diversion and to avoid contact with other metals.
- Place active electrodes in a non-conductive holster designed to hold electrosurgical pencils and similar accessories, when they are not in use.

- Keep active electrode freeform debris
- Record placement of patient returns electrode, identification number of unit, and settings used.
- Inspect insulation on reusable and disposable electrodes before and after use

2.6 Troubleshooting techniques

Generally troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device. So that one has to first perform the appropriate troubleshooting techniques to identify the problem before conducting a repair to any components of electrosurgical unit. In this section troubleshooting techniques for detecting the major failures of electrosurgical unit is discussed.

2.6.1 Preparatory Steps of Troubleshooting Technique

Before directly the conducting trouble shooting technique one has to first perform the following tasks:

- Receive maintenance request from users or organization
- Gather information about the equipment problem
- Ask users about the history of the device.
- Prepare:
    - Appropriate PPE (personal protective equipment)
    - Cleaning material
    - Multimeters to check electrical parameters
    - Mechanical and electrical tool kits to trouble shoot
    - Service manual
    - Checklists to check qualitative and quantitative data
    - Blower to remove dusts on the interior and exterior part of the device
- **Physical inspection**
    - Smell for burning cables and components
    - Hearing for abnormal noise ,
    - Looking at physical breakage of system components
    - Inspect cables

2.6.2 Troubleshooting Procedures to Detect Major System Component Failures

- Check the Electrosurgical Unit (ESU) for physical damage.
- Verify all accessories cords are connected properly.
- Check the condition of power cord, it should not be frayed, damaged, crack or exposed of any wire otherwise replace the same immediately.
- Check the fuse of ESU. It should be firmly fitted inside the fuse socket. Also check for any corrosion and damages if so replace the same rating of fuse as mentioned in manual and on ESU
- Disconnect the power cord and check for Footswitch receptacle damage or obstruction. If found replace the rear panel or rear panel connector.
- Check for the firm contact of Bipolar Instrument receptacle on front panel for obstruction and damage. If found replace the front panel or front panel connector.
- Check for the firm contact of Mono-polar instrument receptacle on front panel for any obstruction and damage. If found replace the front panel or front panel connector.
- Check the patient return electrode receptacle for any broken pins and obstruction. If found replace the front panel or front panel connector.
- Check RF output Board
- Check Memory Board, Logic Board / Relay Board, Display Board, Audio Tone Generator and Isolation Board.

2.7 Maintenance Procedure for ESU

2.7.1 Corrective Maintenance

Table 2.1: Corrective Maintenance for Electrosurgical Unit

No	Symptom	Possible Cause	Remedy
1.	• The ESU cannot Turned On • No voltage reaching the machine.	• Blown fuse • Power cord may be defective • Circuit breaker has blocked	• Replace fuse with the some rating. • Check point by point all switch and line connections
2.	Monopolar Mode use Cutting or coagulation output only not available	• Electrode holder /finger switch may be defective • Monopolar foot switch may be defective	• Replace with new one • Repair the defective unit.

3.	Both outputs /cutting/coagulation are not available	• Electrode holder /finger switch may be defective • Monopolar foot switch may be defective	• Replace with new one • Repair the defective unit.
4.	Bipolar Mode use Bipolar output is not available	• Bipolar foot switch may be defective • Accessories may be defective	• Replace with new one • Repair the defective unit
5.	Patient electrode alarm activated	• Patient electrode cord is not connected • Patient electrode defective	• Check connection • Replace with new one
6.	Over load alarm	• Load exceeds the pre-set value	• Decrease the output pre-setting
7.	Grounding alarm activates	• Protection ground cable not connected • Protection ground cable defective /disconnected	• Check connection • Repair
8.	Generator is on, but could not complete self-test	• An alarm condition exists • Software malfunction • Loose or disconnected internal cables • Faulty low voltage power supply • Damaged control board connectors and /or malfunctioning control board • Shorts or disconnects on power supply/RF board • Faulty power switch • Malfunctioning front panel	• Check the display for an alarm number • Turn off, then turn on the generator • Check and correct all internal connections • Check the low voltage power supply • Remove the control board and inspect the connector to the power supply /RF board and to the display board for damage, poor seating, etc. if the problem persists, replace the control board. • Check the power supply board for shorts or disconnect • Replace the power switch. • Replace the front panel assembly
9.	Generator is on and accessory activated, but generator does not deliver output	• Malfunctioning footswitch or hands witching instrument • Incompatible foots with	• Turn off the generator. Check and correct all accessory connections. Turn on the generator. Replace the accessory if it continues

		• Footswitch connected to monopolar 1 footswitch receptacle is being used for instrument connected to monopolar 2 instrument receptacle • Power set too low • An alarm condition exists • Blown fuse on power supply/RF boar • Control board malfunction • High voltage power supply malfunction	to malfunction. • Use only a covidien footswitch • Connect the footswitch to the monopolar 2 footswitch receptacle • Increase the power setting • Check the cut display for an alarm number • Check the high voltage power fuse and replace if necessary • If the indicator bar does not illuminate and the tone does not sound, replace the control board. • If high voltage is not present on the power supply/ RF board, troubleshoot the high voltage power supply.
10.	Activation and/or alarm tones do not sound, speaker is malfunctioning	• Poor connection or damaged footswitch board • Faulty connections or speaker on footswitch board • Audio signal malfunction on control board	• Check connection. If indicated, replace the footswitch board • Replace the footswitch board • Replace the control board
11.	Black or confusing LED display	• Faulty ribbon cable between control board and display board • Incorrect display modes communicated through the control board • Display board malfunction	• Check/connect ribbon cable that connects the display board to the control board • Replace the control board • Replace the display board
12.	Modes buttons do not function correctly when pressed	• Faulty ribbon cable between control board and display board. • Incorrect modes communicated through the control board • Faulty ribbon cable between the front panel	• Check/ connect ribbon cable that connects the display board to the control board. • Replace the control board • Check/correct the ribbon that connects the display board to the front panel.

		and the display board	
13.	Continuous monitor interference	• Faulty chassis-to – ground connection • Electrical equipment is grounded to different objects rather than a common ground. The generator may respond to the resulting voltage differences between grounded objects. • Malfunctioning monitor	• Check and correct the chassis ground connections for the monitor and, if applicable, for the generator. Check other electrical equipment in the room for defective grounds. • Plug all electrical equipment into line power at the same location • Replace the monitor
14.	Interference with other devices only when generator is activated	• Metal-to metal sparking • High setting used for fulguration • Electrically inconsistent ground wire in the operating room • If interference continues when the generator is activated, the monitor is responding to radiated frequencies.	• Check all connection to the generator, patient return electrode, and accessories. • Use lower power setting for fulguration or select the desiccate mode • Verify that all ground wires are as short as possible and go to the same grounded metal. • Check with the manufacturer of the monitor
15.	Pacemaker interference	• Intermittent connections or metal-to-metal sparking • Current traveling from active to return electrode during monopolar electrosurgery is passing too close to pacemaker	• Check all connections to the generator. It may be necessary to reprogram the pacemaker • Use bipolar instruments, if possible. If you must use a monopolar instrument, place the patient return electrode as close as possible to the surgical site.

Learning activity 2.5:

Arrange yourself in a group where each group can have a maximum of five persons. Then within your group perform a troubleshooting activity on the following system components of electrosurgical unit.

- Power unit
- Patient return electrode receptacle
- Mono-polar instrument receptacle
- Bipolar instrument receptacle
- Alarm systems

After finishing the troubleshooting identify the system failures/problems (if there is any) of the device.

2.7.2 Preventive Maintenance

Learning activity 2.6:

What are the major preventive maintenance procedures that are commonly applied for electrosurgical unit?

Preventive maintenance is a scheduled and planned maintenance technique whose aim is to prevent failures on the equipment/devices. For any device the schedule and preventive maintenance techniques must be performed as per the manufacturer's service manual.

The common preventive maintenance techniques on electrosurgical unit, that have to be applied periodically to prevent system component failures, are:

- **Chassis / Housing**: Check Exterior of unit for cleanliness and general physical condition. Be sure that plastic housings are intact, that all hardware is present and fitting are firm and tight, and that there are no signs of spilled liquids.

- **Mount / Fasteners** : If the device is mounted on a stand or cart, examine the condition of the mount. If it is attached to a wall or rests on a shelf, check the security of this attachment.
- **AC Plug / Receptacles**: Check AC power plug for damage. Attempt to wiggle the blades to check that they are secure. Shake the plug for loose screws. If any damage is suspected, open the plug and inspect it. Check the fuse and fitting position.
- **Line Cord**: Inspect the cord for damage & excessive bending. If damaged, replace the entire cord. Verify the minimum power cord length before cutting the defective position.
- **Strain Relief:** Examine the strain relief at both ends of the line cord. Be sure that they hold the cord securely.
- **Circuit Breaker / Fuse**: If the device has an external circuit breaker, check that it operates freely. If the device is protected by an external fuse, check its value and type against that marked on the chassis andensure that a spare is provided.
- **Connectors:** Examine all cables of the ESU for proper fittings and firm contact of connectors.
- **Probes:** Confirm that probes for their physical condition. For disposable probes check expiry date.
- **Controls / Switches**: Examine all controls and switches for physical condition, secure mounting, and correct motion. Look for loose connections. Check for proper alignment, as well as positive stopping. Confirm the functioning of each switch and controls proper functioning.
- **Indicators / Displays:** Confirm the operation of all indicators on the unit that all segments of a digital display function and functioning of Alarms.
- **Audible Signal:** Operate the device to activate any audible signals.
- **Labeling:** Check for necessary labels, and instruction cards are present.
- **Dispersive Electrode cable continuity**: Check the patient return electrode continuity and any alarm functioning on removal.
- **Accessories (Footswitch):** To check the physical integrity, connection and proper operation of allaccessories related to ESU

2.8 Summary

- An ESU uses an AC source that operates at a radio frequency (RF) in the range between 300 kHz and 3 MHz.
- ESU's are used for surgical cutting or to control bleeding by causing coagulation (homeostasis) at the surgical site.
- There are two operation modes of electrosurgical unit, i.e. mono-polar and bipolar.
- There are three types of current waveforms: cutting, coagulation, and blended currents.
- The major components of electrosurgical unit include: Power unit, RF output Board, Memory Board, Logic Board / Relay Board, Front Panel, Display Board, Audio Tone Generator, Isolation Board.
- There are two types of Electrodes used in Electro-surgery: active electrodes and dispersive electrodes.
- Safe handlings of electrosurgical unit include: General Safety, hazardous electrical output safety, electrical Safety, patient Safety, .patient returns electrode safety precautions, active Electrode safety precautions.
- Troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device.
- One should follow different steps to perform both preventive and corrective maintenance on electrosurgical unit which is one of operation medical equipment.

Chapter 3
Suction Machines

Chapter Allocated Time: 8hrs

Chapter Description:

This chapter is designed to develop the necessary knowledge, skills and attitude of the learners to the standard required in operating room equipment maintenance for biomedical engineers and technicians. It covers basic working principles, purposes, and main components, troubleshooting techniques and safety procedures for electrosurgical unit

Chapter objective

By the end of this session, the participants will be able to know how to handle, install, and maintain suction machine.

Enabling objectives: By the end of this chapter the participants will be able to:

- Describe purpose and clinical uses of suction machine.
- Describe the working principles of suction machine.
- Describe basic parts and components of machines
- Demonstrate and apply safety maintenance procedure of suction machine.
- Demonstrate basic preventive and corrective maintenance procedure of suction machine.
- Follow troubleshooting techniques for suction machine
- Apply maintenance report techniques

Chapter Outline:

3.1 Introduction

The existence of a vacuum force was first discovered by Otto von Guericke in 1650 in an experiment where air molecules were removed from a sealed container. Once removed, the container's space became a vacuum. Not long after this discovery, the vacuum pump was invented to help chemists better understand the properties of gases. An empty container allowed chemists to refill it with different gases and study them in their pure forms, without the interference of air gases. Since then, vacuum technology has developed to the point where the full effects of this force can be utilized within a variety of applications.

Suctioning is a procedure that removes excess secretions from the mouth and throat (oropharynx), from the nose and throat (nasopharynx), and from the windpipe (trachea) using a mechanical aspiration device (Suction machine).

3.2 Purpose and clinical application of Suction Pumps

Learning activity 3.1:

➲ What are the clinical purposes of suction machine?

Time: 15min

Suction machines (also known as aspirators) are used to remove fluids from the airway or respiratory support system and infectious materials from wounds. The device creates a negative pressure (vacuum) that draws fluids through disposable tubing that is connected to a collection bottle. The fluids are trapped in the collection bottle for proper disposal. It is for use on the order of a physician only. Suction pump conveys the following clinical application:

- ✓ Breast pumps are utilized to extract milk from the breasts of a lactating woman. Breast pumps may be manual devices powered by hand or foot movements or electrical devices powered by mains electricity or batteries.
- ✓ Negative pressure Wound therapy Pump (NPWT) are utilized to treat patients with Stage III or IV pressure ulcer, neuropathic/diabetic ulcer, venous insufficiency or arterial ulcer, or a chronic ulcer of mixed etiology. These wounds should have exudate, size and depth to require this specialized therapy. The technique is also known as vacuum assisted closure (VA.C).

- ✓ Bodily Fluids suction pump are utilized for the removal of surgical fluids, tissues, bodily fluids or infectious materials from wounds during surgery. Healthy people also use a suction pump with tubing and catheters to clear and manage their own secretions. Individuals who have a compromised swallowing or coughing mechanismneed to have these secretions removed by a respiratory therapist or registered nurse. It is recommended that a clinical professional monitor patients using suction pumps.

3.3 Working principle of Suction Machine

Learning activity 3.2:

➲ **Discuss briefly the working principle of suction machine.**

Time: 20min

Suction is generated by a pump. This is normally an electrically powered motor, but manually powered versions are also often found. The pump generates a suction that draws air from a bottle. The reduced pressure in this bottle then draws the fluid from the patient via a tube. The fluid remains in the bottle until disposal is possible. A valve prevents fluid from passing into the motor itself (See Figure 3.1).

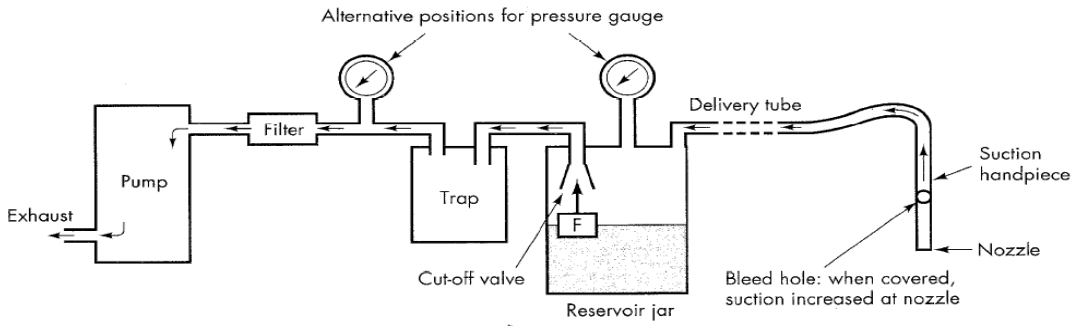


Figure 3.1: Working Principle of Suction Machine [Courtesy of (Medical equipment maintenance...)]

3.4 Types of Suction Pumps

Today, there are three main types of vacuum pumps: compressed air pumps, electromechanical pumps and entrapment pumps.

3.4.1 Compressed air pumps

These types of pumps work to increase the pressure of a gas by decreasing the space that it occupies. They do this by forcing gas molecules through a small space, like a nozzle. When compressed gas is introduced into a high pressure environment, it creates a vacuum effect.

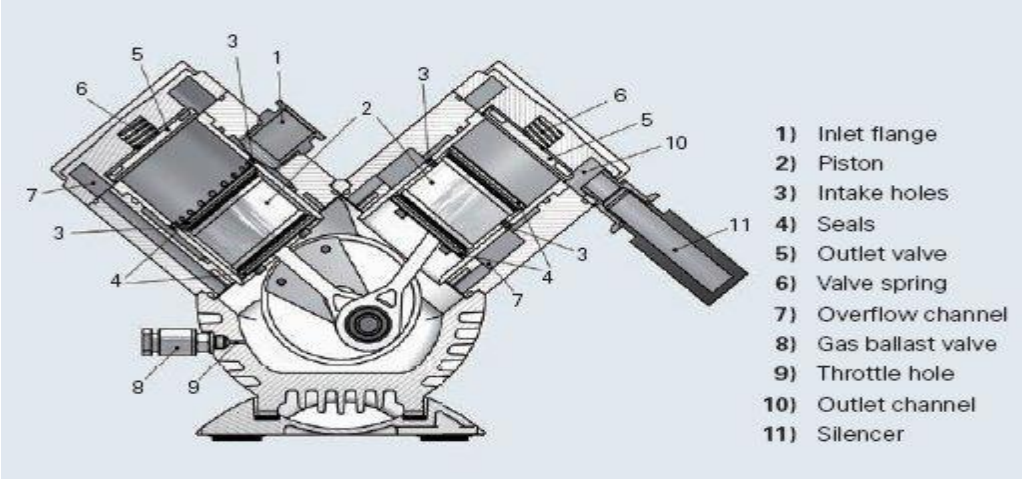


Figure 3.2: Compressed air pumps with its main parts [Courtesy of (http:// rice 360.wildapricot.org.)]

3.4.2 Electromechanical pumps

These kinds of pumps trap air inside moving mechanical parts--like rotors--then force it through a pump device. This process creates a vacuum effect. These are motorized devices that require electricity to run.

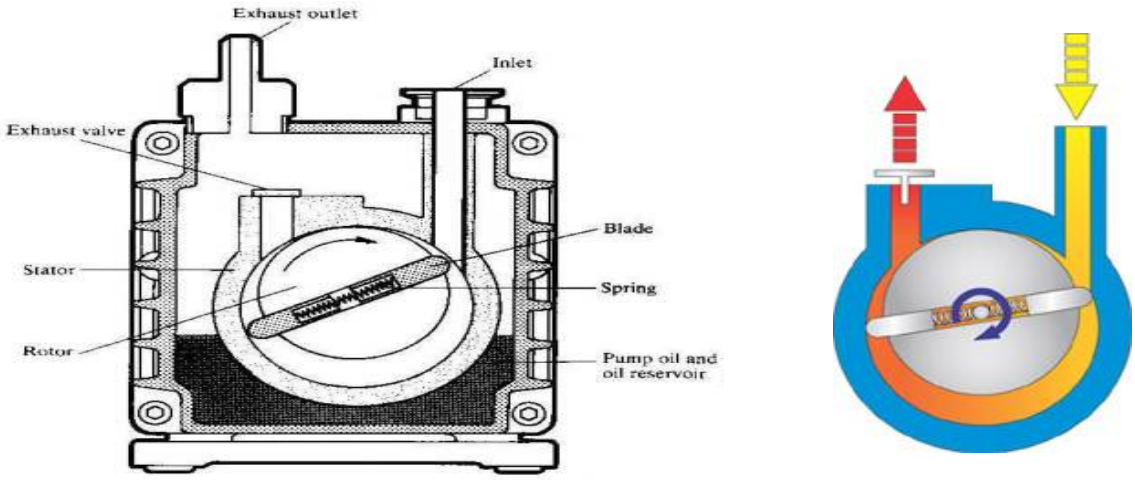
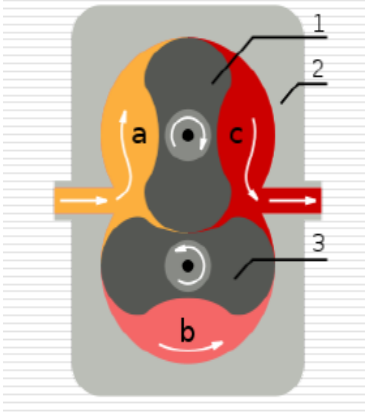


Figure 3.3: Electromechanical pumps with its main parts [Courtesy of (http:// rice 360.wildapricot.org.)]

3.4.3 Entrapment pumps

These are designed to catch gases and confine them in a sealed space, or chamber. All three methods have been adapted for use in various applications.



1. 1. Rotor
2. Casing
3. Rotor
a. Low pressure gas in
b. Fluid compressed in rotor void
c. Higher pressure gas out

Figure 3.4: Entrapment pumps with its main parts [Courtesy of (Daniel K. http:// rice 360.wildapricot.org.)]

3.5 Basic components of Suction Machine

Learning activity 3.3:

- **List the major components of suction unit and discuss their functions.**

Time: 20min

The major components of Suction machine are:

- Collection Container
- Vacuum Gage
- Connection Tubing
- Power Unit
- Patient Tubing
- Filter Cartridge

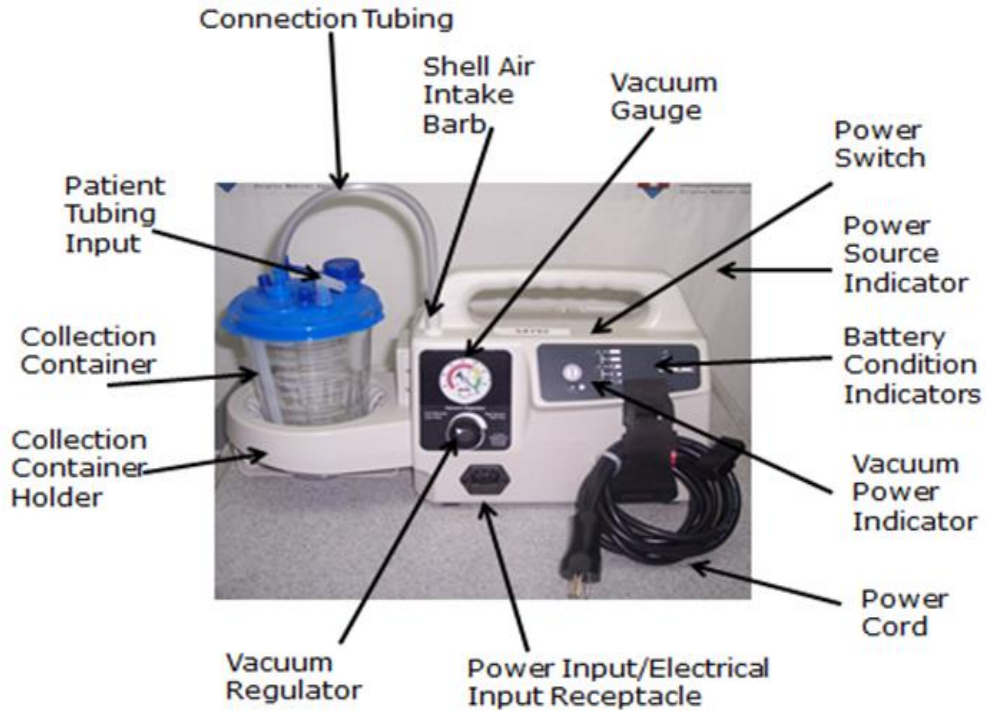


Figure 3.5: Major Components of Suction Machine [Courtesy of (Smith…http:// rice 360.wildapricot.org)]

3.5.1 Collection Container

The collection container is used to collect the fluid which came from the peasant and it consists:

Cut off valve: uses to cut off the fluid when the collection container is full. There are two types of cut of valves:

1. **Manual cut off valve:** is found at the top and the valve has piston which move up and down, this piston has floater on the tip. When the fluid reaches the safe full level to collect bottle, the suctioning will stop sucking automatically (float shut-off).
2. **Automatic flow valve**: is found at the top and it has two wires with electronic circuit. When the sputum reaches the safe full level of collection bottle the wire in the bottle will short by the fluid and the suction machine will stop sucking automatically (float shut-off).

3.5.2 Vacuum Gage

- Adjust the vacuum level from 0 to 520 mm Hg by turning the vacuum adjust knob (clockwise to increase vacuum and counter-clockwise to decrease vacuum). Referring to the vacuum gauge while setting the desired level of vacuum.
- To accurately read the gauge, block the patient end of the hose or cap off the collection bottle and allow the gauge to reach a stable vacuum reading.

3.5.3 Connection Tubing:

- It is a flexible tube which uses to connect the collection bottle bacteria filter and pressure adjusting valve.

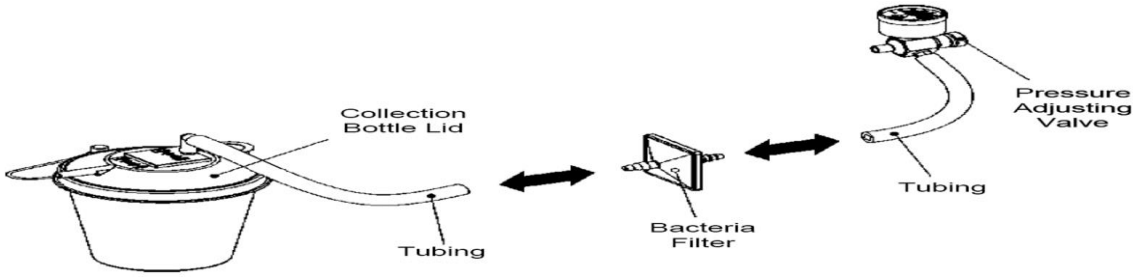


Figure 3.6: Connecting tubing of suction machine [Courtesy of (Daniel K. http:// rice 360.wildapricot.org.)]

3.5.4 Power Switch and Unit

- Power switch located on the side of the unit is in the off position before connecting the unit to a power source.
- Before use, check the specification label on the side of the suction unit to ensure that the voltage and current indicated on the unit correspond with the voltage and current available. Power switch has two positions on/off.
- Power unit consists of power supply, power distribution board and battery as shown on Figure 3.8.

Figure 3.7: Power switch of suction machine [Courtesy of (Daniel K. http:// rice 360.wildapricot.org.)]

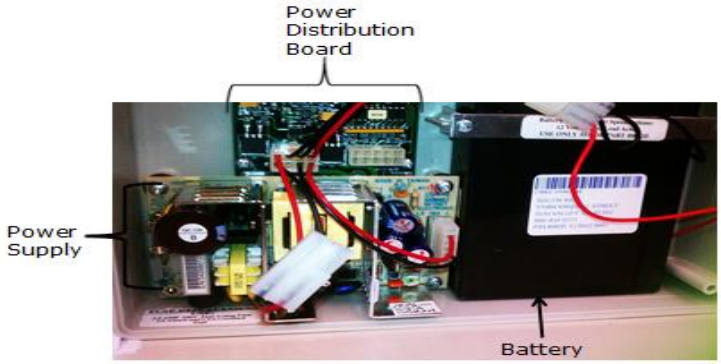


Figure 3.8: Power unit of suction machine [Courtesy of (Smith…http:// rice 360.wildapricot.org)]

3.5.5 Patient Tubing

- Patient tube is a flexible tube which uses to inter fluid in to the collection bottle.
- Tubing should be rinsed thoroughly after every use by running hot tap water through it
- Followed by a solution of one part vinegar to three parts hot water.
- Rinse with hot tap water and air dry.
- Keep the outer surface of the tubing clean by wiping with a clean, damp cloth.

3.5.6 Bacteria filter:

- Bacteria filter should be replaced every two month. If overflow occurs, change the filter immediately.
- Remove filter by disconnecting it from tubing connected to pressure adjusting valve and tubing connected to collection bottle lid assembly.
- Replace with a new PROBASICS bacteria filter and connect to above two tubing.

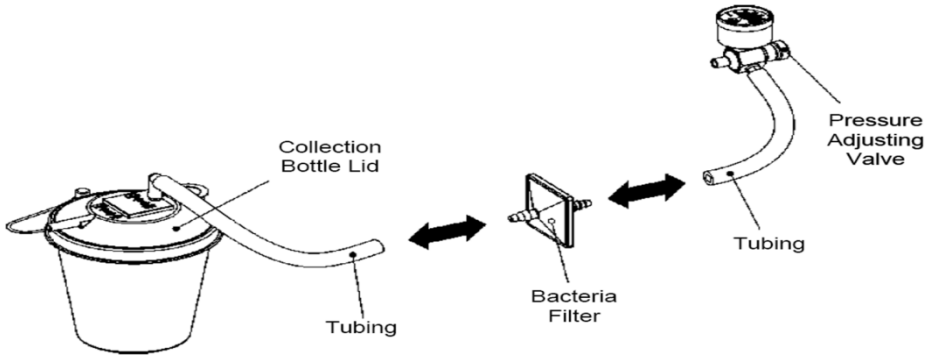


Figure 3.9: Bacteria filter of suction machine [Courtesy of (Daniel K. http:// rice 360.wildapricot.org.)]

3.6 Safe Handling of Suction Machine

Learning activity 3.4:

List the appropriate safe handling of suction machine.

Time: 10min

- The technicians that maintain the suction unit should always wear protective gloves.
- The chances of coming in contact with those bacteria are very high if gloves are not worn.
- They should also wash their hands immediately after maintaining the suction machine.
- The waste in collection bottle may cause respiratory infection which must be handled according to medical waste disposing regulation.

- Operator must wear gloves and medical class mask before cleaning the collection bottle, tubing and handle the wasting unit and/or accessories**.**

3.6.1 Electrical Safety

If the overload protector shuts off the motor frequently, you may have a low voltage situation. Low voltage can also be suspected when:

1. The motor does not get up to full power or speed.

2. Other motor operated appliances fail to operate properly. Too many motor operated appliances on same circuit. The motor of this compressor has a thermal overload protector.

- If the motor overheat, the overload protector will shut off the motor.
- If this occurs, turn the ON/OFF switch to the OFF position and allow the motor to cool (approximately 5 minutes). Restart compressor.
- If the compressor fails to start, wait an additional 5 minutes before attempting to restart.
- If this fails, inspect the fuses on your suction unit. If the unit still does not restart, tray to fix the problem.

3.7 Troubleshooting techniques

Learning activity 3.5:

Time: 1:30hrs

Arrange yourself in a group where each group can have a maximum of five persons. Then within your group perform a troubleshooting activity on the following system components of suction machine.

- Power unit, motor, battery, filter, tubing
- After finishing the troubleshooting identify the system failures/problems (if there is any) of the device.

Generally troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device. So that one has to first perform the appropriate troubleshooting techniques to identify the problem before conducting a repair to any components of suction unit. In this section troubleshooting techniques for detecting the major failures of suction machine is discussed.

3.7.1 Preparatory steps of troubleshooting technique

Before directly the conducting trouble shooting technique one has to first perform the following tasks:

- Receive maintenance request from users or organization
- Gather information about the equipment problem
- Ask users about the history of the device.
- Prepare:
    - Appropriate PPE (personal protective equipment)
    - Cleaning material
    - Multimeters to check electrical parameters
    - Mechanical and electrical tool kits to trouble shoot
    - Service manual
    - Checklists to check qualitative and quantitative data
    - Blower to remove dusts on the interior and exterior part of the device
- Physical inspection
    - Smell for burning cables and components
    - Hearing for abnormal noise ,
    - Looking at physical breakage of system components
    - Inspect cables

3.7.2 Troubleshooting procedures for component failures

a) Power unit checkup:

- Check power switch is on.
- Check mains power is present at socket using equipment known to be working.
- Check for leaks or wire causing fuse to blow and correct this.
- Check power cord for damage

b) Motor runs, but no vacuum checkup:

- Verify tubing connection security
- Check for leaks or tubing kinks
- Ensure that float shut-off is not activated
- Check for bottle leaks and cracks

c) Low vacuum checkup

- Check system for leaks

d) Motor overheats and motor overload protector shuts off motor checkup

- Inspect fuse

e) Suction fault checkup

- Open the equipment and verify internal tubing connection
- Open the equipment and verify internal tubing bends
- Open the equipment ,disconnect the tubing and check the pump

f) Checkup for battery indicator

- Check power cord connections and that battery is installed

g) Vacuum indicator checkup

- Check as the tubes are Straighten / untwist

h) Filter checkup

- Check the floating valve

i) Fluid flow checkup

- Check as the valve is clean
- Check for damaged tube

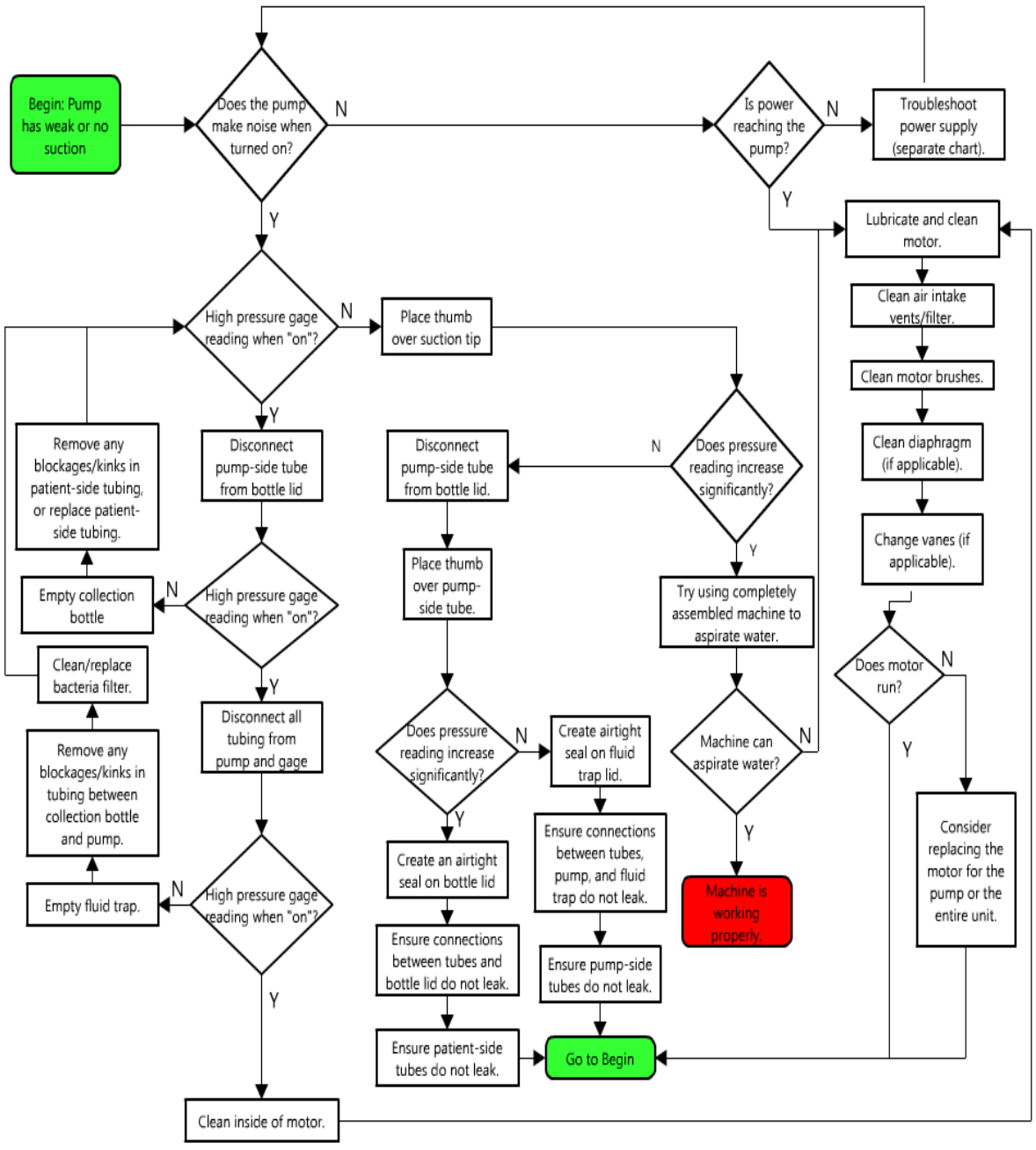


Figure 3.10: Basic Trouble-shooting of suction machine [Courtesy of (Smith…http:// rice 360.wildapricot.org)]

3.8 Maintenance procedure

Learning activity 3.6:

Time: 5min

What are the major types' of maintenance procedures that are commonly applied for medical devices in general?

3.8.1 Preventive maintenance

Learning activity 3.7:

What are the major preventive maintenance procedures that are commonly applied for suction unit?

Time: 10min

Preventive maintenance is a scheduled and planned maintenance technique whose aim is to prevent failures on the equipment/devices. For any device the schedule and preventive maintenance techniques must be performed as per the manufacturer's service manual.

The common preventive maintenance techniques on suction machine, that have to be applied periodically to prevent system component failures, are:

- Clean filters
- Clean air vents
- Disinfect jars, tubing, other components that come into contact w/ patient fluids between each use in solution of water, detergent, and disinfectant
- When applicable, check the canister to determine if the expiration date has passed. If the expiration date has passed, replace the canister.
- Change bacteria filter if wet or discolored
- Check collection bottle/jar for cracks, chips, and other damage
- Make sure there is a sufficient supply of bacterial filters
- Check that float valve moves freely
- Clean or replace air intake filter
- Clean brushes on motors as necessary
- Inspect power cord and plug
- Test the health of the battery
- Determine if the gauge is properly calibrated
- Ensure vacuum works over full range of suction pressures if there is a control/knob Verify that overflow valve (float valve) works properly when container is filled with water
- Grounding resistance between chassis and ground pin should not exceed 0.5 ohms
- Verify that the unit is not damaged and that it is clean.

- Verify that the feet are not damaged or missing.
- Using an independent vacuum gauge verify that the unit provides a maximum vacuum level.
- Check the airflow.
    - Connect tubing from the patient port of the canister to a calibrated airflow meter.
    - Ensure the regulator gauge is adjusted to the high setting (fully turned clockwise and turn the device on. The reading on the calibrated airflow meter should be as per the manufacturer rate.
    - If the device does not produce the set rate, check to ensure all tubing connections are tight, the canister lid is securely fastened to the canister and all the port covers on the canister lid are secure.
    - If your device does not produce at least the minimum set rate airflow, check the airflow before the canister, at the union barb fitting at the top of the device. The airflow at the union barb fitting should be at least the minimum set value.

3.8.2 Corrective maintenance

Table 3.1: Corrective maintenance for suction machine

No	Symptom	Possible Cause	Corrective solution
1.	Machine is not running.	• No power from mains socket. • Fuse blown • Electrical cable fault	• Check power switch is on. ○ Check mains power is present at socket using equipment known to be working. ○ -Check point by point all switch and line connections • Check for leaks or wire causing fuse to blow and correct this. ○ Replace fuse with correct voltage and current rating. Test operation. • Try cable on another piece of equipment.
2.	Poor fluid flow, pressure gauge Low	• Tube /seal / bottle leaking or disconnected • Air outlet valve blocked • Control valve stuck	• Close different tubes by bending. When pressure gauge changes, leakage point has been passed. Replaced damaged tube or seal. • Clean outlet valve • Operate control valve through full range.
3.	Poor fluid flow, pressure gauge High	Blocked filter or tube	Disconnect each tube one at a time. When air flow is stopped, blockage has been passed. Replace filter or unblock tube.
4.	Filter	Floating valve broken	Change filter, clean or replace floating valve

	discoloured		
5.	Electrical shocks	Wiring fault	Check point by point all switch and line connections
6.	Manual suction is jammed	Internal slider stuck	Perform greasing
7.	Suction fault	• Internal tubing are not properly connected • Internal tubing are choked • Pump fault	• Open the equipment and verify internal tubing connection. • Open the equipment and verify internal tubing bends • Open the equipment ,disconnect the tubing and check the pump
8.	Motor runs, no vacuum	• Tubing failure • Bottle failure	• Verify tubing connection security • Check for leaks or tubing kinks • Ensure that float shut-off is not activated • Check for bottle leaks and cracks
9.	Low Vacuum	• Blockage in piping • Faulty system valve • Inlet filter element clogged • Liquid in the pump • Clearance opened up	• Clean piping and strainers. • Check valve operation and settings. • Check inlet filter. • Pump liquid from the pump. • Check clearances and the pumps for wear.
10.	Excessive noise	• Excessive or insufficient seal liquid to pump • Coupling misalignment • Defective bearing • Cavitation	• Adjust seal flow rate. • Realign coupling. • Replace bearing. • Add non condensable gas load
11.	Pump will not start	• Motor and/or control wiring faulty • Pump seized or damaged due to product build-up	• Check wiring and connections for correct rotation. • Remove buildup by solvent soaking or disassemble the pump to clean and repair it.
12.	Blinking LED	• Low battery capacity	• Replace battery.
13.	Vibration	• Coupling misalignment • Pump or motor not properly anchored • Rotor imbalance • Improperly mounted pump	• Realign coupling. • Anchor pump or motor properly. • Balance rotor. • Make sure mounting surface is level.

3.9 Summary

Chapter summary:

- Suctioning is a procedure that removes excess secretions from the mouth and throat (oropharynx), from the nose and throat (nasopharynx), and from the windpipe (trachea) using a mechanical aspiration device (Suction machine).
- Suction machines (also known as aspirators) are used to remove fluids from the airway or respiratory support system and infectious materials from wounds.
- Suction is generated by a pump. This is normally an electrically powered motor, but manually powered versions are also often found. The pump generates a suction that draws air from a bottle. The reduced pressure in this bottle then draws the fluid from the patient via a tube. The fluid remains in the bottle until disposal is possible. A valve prevents fluid from passing into the motor itself.
- The major components of Suction machine include: Collection Container, Vacuum Gage, Connection Tubing, Power Switch, Patient Tubing and filter Cartridge.
- There are many procedures we should follow whenever we operate and maintain a suction machine.
- Troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device.
- One should follow different steps to perform both preventive and corrective maintenance on Suction machine which is one of operation medical equipment.

Chapter 4

Anesthesia Machine

Duration: 20 hours

Chapter description:

This chapter is designed to develop the necessary knowledge, skills and attitude of the learners to the standard required in operating room equipment maintenance for biomedical engineers and technicians. It covers basic working principles, purposes, and main components, troubleshooting techniques and safety procedures for anesthesia machines.

Chapter objective

By the end of this session, the participants will be able to maintain anesthesia machines.

Enabling activities

- Explain the purpose and clinical application of anesthesia machine.
- Describe the principle of anesthesia machine
- Identify the basic components and their function
- Identify gas source for anesthesia machine
- Perform appropriate troubleshooting procedure
- Perform basic maintenance procedures.

Chapter outlines

4.1 Introduction to anesthesia machine

Learning Activity 4.1:

Duration: 15 Min

- Discus about the anesthesia machine.

Anesthesia machine is one of the basic equipment of hospitals and main equipment in operating rooms. It's life-supporting equipment and its basic function is to ventilate the patient and accurately transmit volatile anesthetics to make the patient in an appropriate state of general anesthesia. At the same time, it monitors the patient and the working state of itself to guarantee the patient's life safety. Anesthesia machine has a complex structure which comprises gas source, gas mixing system, anesthetic gas vaporizer, breathing circuit, ventilator, exhaust gas emission system and information communication systems.

The word anesthesia came from the Greeks and actually means "without feeling." So we can define anesthesia as a state of insensibility to most external stimuli, such as pain.

When anesthesia is given so that the patient loses consciousness, it is called general anesthesia. There are at least four different types of anesthesia that are encountered in the developing world.

General anesthesia

Is the induction of a balanced state of unconsciousness, accompanied by the absence of pain sensation, and the paralysis of skeletal muscle over the entire body. It is induced through the administration of anesthetic drugs and is used during major surgery and other invasive surgical procedures.

General anesthetics may be gases or volatile liquids that evaporate and are inhaled along with oxygen and other atmospheric gases. The amount of anesthesia produced by inhaling a general anesthetic can be adjusted rapidly, if necessary, by adjusting the anesthetic-to-oxygen ratio that is inhaled by the patient. General anesthesia is administered by inhalation, intravenously, intramuscularly, rectally or via the stomach.

State of "General Anesthesia"

1) Analgesia
2) Amnesia, loss of consciousness
3) Skeletal muscle relaxation
4) Inhibition of sensory and autonomic reflexes

Local anesthesia

Local anesthesia is where a specific area is "numbed" such as in a dentist's office so that the patient is awake and may feel some limited pain.

Saddle block anesthesia

Is where the patient is conscious and the area of the body that would touch a saddle is affected. This is accomplished by injecting an anesthetic agent low in the dural sac and is common for childbirth. Spinal anesthesia is where an anesthetic agent is injected beneath the membrane of the spinal cord. There is no sensation below that point until the agent wears off.

4.1.1 Type of Anesthetic agents

4.1.1.1 General anesthetics (inhalation)

- Liquid: Isoflurane, Desflurane, sevoflurane, halothane(Halogenated inhalation)
- Gas: Nitrous oxide (N_2O)(intravenous)

4.1.1.2 Local anesthetics

- Ester group, Amide group

4.2 Purpose and Clinical application of Anesthesia machine

Anesthesia machine is a medical device designed to provide an accurate and continuous supply of medical gases (such as oxygen and nitrous oxide), mixed with an accurate concentration of anesthetic vapor (such as isoflurane) to a patient It delivers the medical gases to a patient at a safe pressure and flow. Modern machines incorporate a ventilator, suction unit, and patient-monitoring devices.

4.2.1 Clinical application and functions of anesthesia machine

- Anesthesia machine is a life saving equipment
- For Ventilation system
- Supply set mixtures of gases and anesthetic agent vapors to the patient.
- Deliver levels of oxygen necessary to sustain life.
- Provide basic patient monitoring such as measuring breathing rate and volume and the percent of oxygen delivered to the patient by integrated Patient Monitoring or isolated one.
- Safely remove waste and excess gas from the machine.
- create artificial breathing environment for patient

- It ensures that the patient does not feel pain and minimizes patient discomfort
- It provides the surgeon with favorable conditions for the work.

An anesthesia system comprises four basic subsystems: a gas supply and control circuit, breathing and ventilation circuit, a scavenging system, and a set of system function and breathing circuit monitors (e.g., inspired 0_2 concentrations, breathing circuit integrity). Vaporizers add a controlled amount of anesthetic vapor to the gas mixture.

An automatic ventilator is generally used to mechanically deliver breaths to the patient. The ventilator forces the anesthesia gas mixture into the patient's breathing circuit and lungs and, in a circle breathing system, receives exhaled breath from the patient as well as fresh gas.

A scavenging system captures and exhausts waste gases to minimize the exposure of the operating room staff to harmful anesthetic agents. Scavenging systems remove gas by a vacuum, a passive exhaust system, or both.in some anesthesia systems are a number of monitors and alarms that indicate levels and variations of several physiologic variables and parameters associated with cardiopulmonary function and/or gas and agent concentrations in breathed-gas mixtures. Manufacturers typically offer a minimum combination of monitors, alarms, and other features that customers must purchase to meet standards and ensure patient safety. To meet the minimum standard, anesthesia machines must monitor 0_2 concentrations, airway pressure, and either the volume of expired gas or the concentration of expired CO_2. Stand-alone monitors may be used to track other essential variables such as electrocardiogram, temperature, and blood pressure.

4.3 Types of anesthesia machine:

The classification is based on ventilation system and oxygen supply source that the anesthesia machine delivers.

4.3.1 Anesthesia Machine with Manual Resuscitator

Figure 4.1: Anesthesia with manual resuscitator

Basic features:

1. Oxygen concentrator
2. Manual operated bellows

2. Anesthesia Machine with Ventilator

1. Manual/ automatic ventilation
2. Patient monitoring modules and displays

4.3.2 Anesthesia Machine with Ventilator

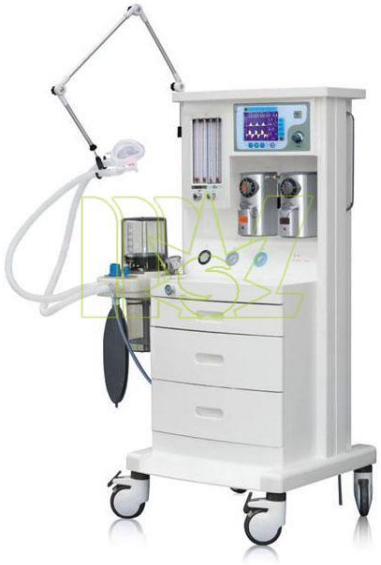


Figure 4.2: Anesthesia Machine with Ventilator

4.4 Features of anesthesia machine

Components of Anesthesia machine– Front view:

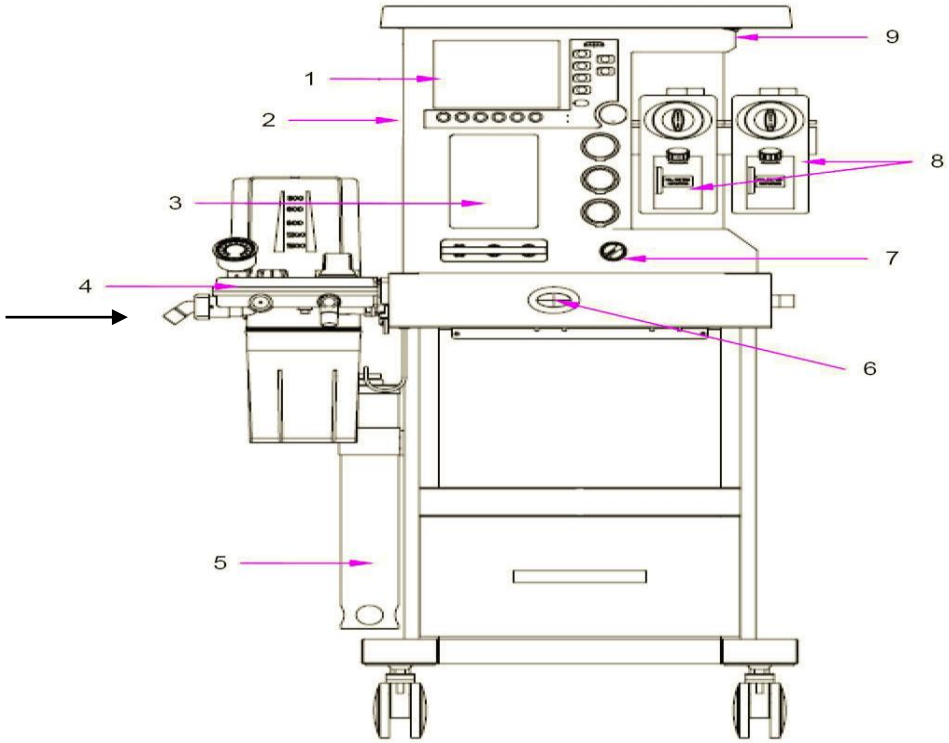


Figure 4.3: Anesthesia machine front view

1. LCD screen
2. Frame
3. Gas flow meter
4. Absorber system
5. Anesthetic gas scavenging system (AGSS) assembly
6. O_2 flush button
7. System power switch
8. Vaporizer
9. Flow meter light switch

Components of Anesthesia machine– Rear view:

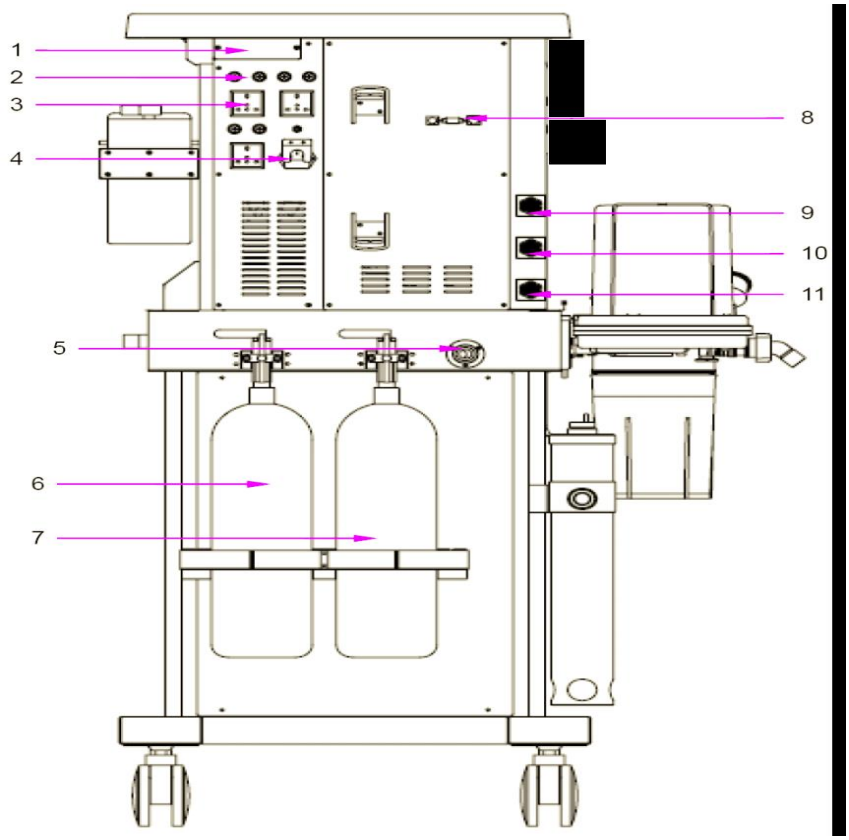


Figure 4.4: Anesthesia machine– Rear view

1. Battery box
2. Fuse box
3. Auxiliary power receptacle
4. Main power socket
5. AGSS interface outlet
6. O_2 cylinder
7. N_2O cylinder
8. Data communication port
9. O_2 inlet, from pipeline
10. N_2O inlet, from pipeline
11. Air inlet, from pipeline

Components of Anesthesia machine breathing System:

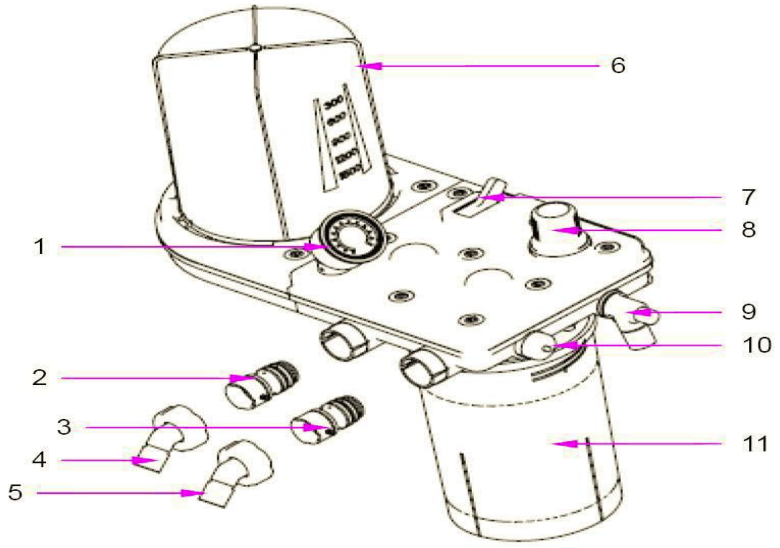


Figure 4.5: Anesthesia machine Breathing System

1. Patient Manometer (Pressure Gauge)
2. Flow sensor, Expiratory
3. Flow sensor, Inspiratory
4. Expiratory port
5. Inspiratory port
6. Bellows housing (chamber)
7. Bag/Ventilator selector (switch)
8. APL valve (POP-Off)
9. Manual bag port (Reservoir bag)
10. O_2 Sensor
11. Soda lime canister

4.5 Gas supply components for anesthesia machine

- Central Gas supply
- Oxygen Cylinder supply
- Oxygen concentrator supply
- Air Compressor supply

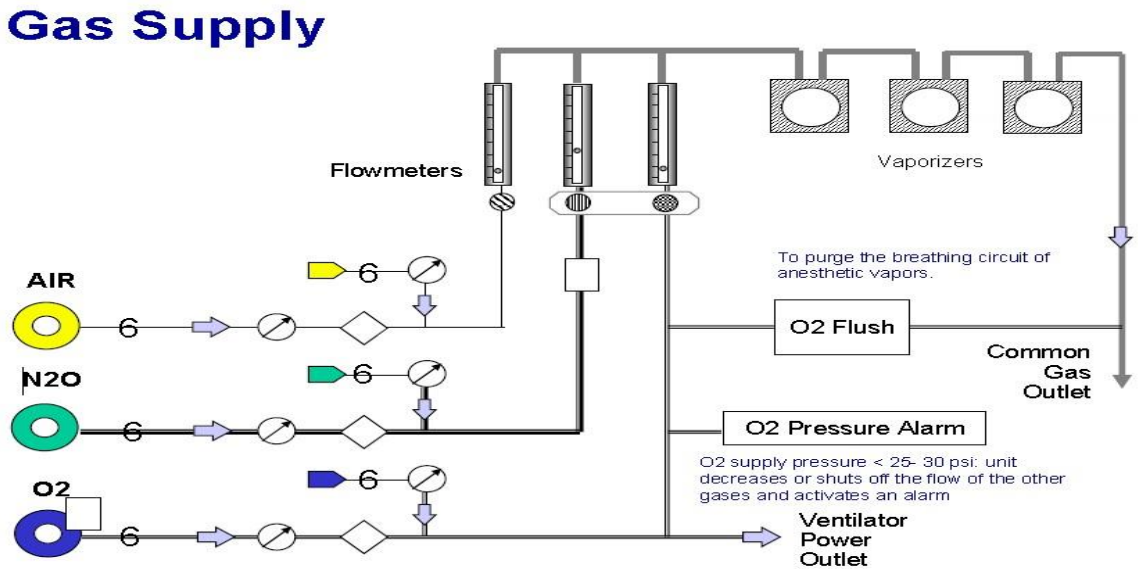


Figure 4.6: Gas supply system

Figure 4.7: Medical Gas Supply Facility Room

Learning activity 4.2:

Duration: 15min

Group Discussion

Identify the pressure circuit of an anesthesia machine as High-pressure, Intermediate-pressure, Low pressure region and categorize the following list

- cylinder pressure regulators ,oxygen pressure-failure device ,ventilator power inlet ,vaporizers ,check valves, cylinder pressure gauge ,common gas outlet, flow meter tubes ,oxygen flush valve

The pressures within the anesthesia machine can be divided into three curcuit

- High-pressure circuit
- Intermediate pressure circuit
- Low pressure circuit

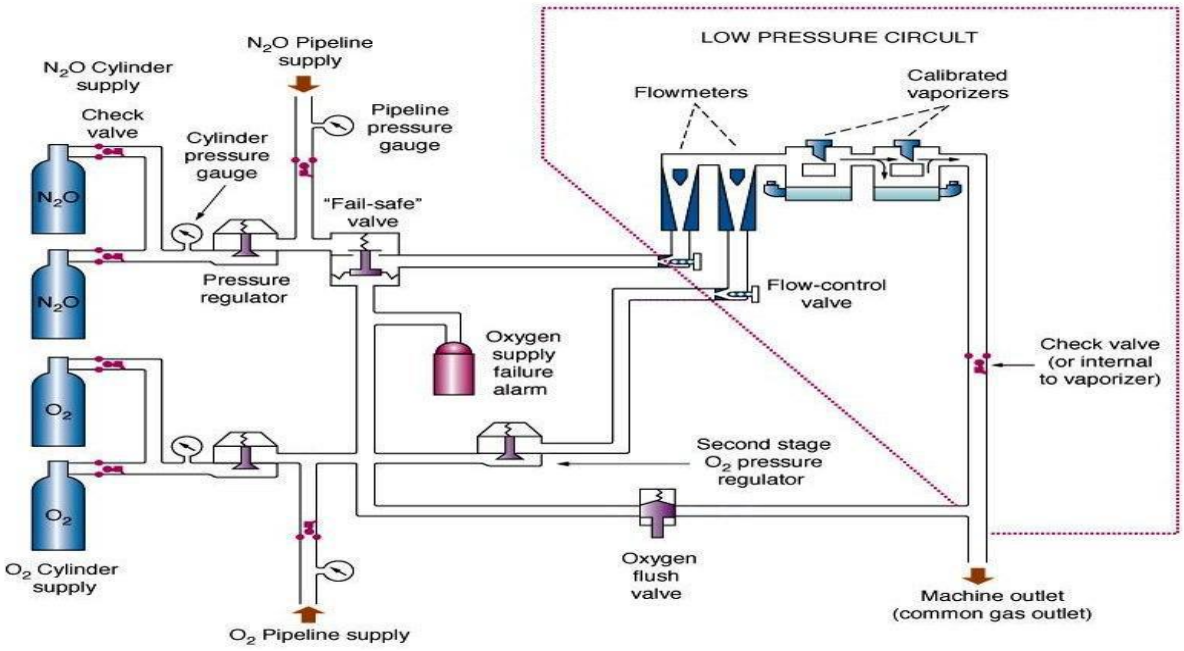


Figure 4.8: Anesthesia machine pressure circuit

The high-pressure circuit consists of those parts which receive gas at cylinder pressure 1900-2200psi

- hanger yoke (including filter and unidirectional valve)
- yoke block
- cylinder pressure gauge
- cylinder pressure regulators

Figure 4.9: Central gas supply for oxygen

2. **Intermediate** receives gases at low, relatively constant pressures (40 Psi, pipeline pressure/pressure downstream of a cylinder regulator)

Figure 4.10: Pipeline inlets, pipelines, 50psi and pressure gauges

- ventilator power inlet
- oxygen pressure-failure device (fail-safe) and alarm
- oxygen and nitrous oxide second-stage regulators
- oxygen flush valve (35 – 70 L/min)

3. **Low circuit:** Includes components distal to the flow meter needle valves 16-22psi
   - flow meter tubes
   - vaporizers
   - check valves (if present)
   - common gas outlet

Table 4.1: Color Code for Cylinder Hose connection

GAS	USA	INTERNATIONAL
OXYGEN	**Green**	**White**
Carbon dioxide	**Gray**	**Gray**
Nitrous oxide	**Blue**	**Blue**
Helium	**Brown**	**Brown**
Nitrogen	**Black**	**Black**
Air	**Yellow**	**White and Black**

Figure 4.11: Color code for different gasses

Yoke system: O_2/N_2O cylinder attached to the anesthesia machine

Figure 4.12: Yoke system

4.5.1 Safety system

1. **Gas cylinder's pin index safety system**

It is the point of exit for the gas. It sits on the inner part of the hanger yoke system. Available in various sizes **"E"** cylinders holds 660 L of oxygen and is attached to the anesthesia machine. **"H"** cylinders hold 6900 L of oxygen and stand separate from the machine.

A full tank of oxygen has a pressure of 1900-2200 psi. The volume in liters can be determined by multiplying the psi by 0.3 for an E tank and 1.7 for an H tank.

$$\text{Volume (L)} = \frac{\text{0.3 or 1.7 x psi on gauge}}{\text{L/min to be delivered}}$$

- This formula will allow you to know how long your tank will last.
- Actual amount in tank is displayed when the tank is turned on.
- Check this gauge before an anesthesia machine begins its process!!
- Change when the pressure is no lower than 100 psi.

2. **Pressure regulators:** Used to reduce cylinder gas pressure to 40 Psi before the gas flows to the machine
3. **Pressure gauge:** Used to indicate the contents of gases in a cylinder Color Coded of gases
4. **Pressure Reducing Valve:**
    - Reduces the high and variable pressures found in a cylinder to a lower and more constant pressure found in the anesthesia machine.
    - Regulates the pressure of the gas leaving the tank and going into the anesthesia machine.
    - Allows a constant flow of gas into the machine, despite pressure changes within the tank
    - Reduces the pressure of oxygen that leaves the tank at 2200 psi to a safer 45-50 psi.
5. **Unidirectional Valves:**

Unidirectional valves are one-way valves that allow the flow of fresh gas to enter the inhalation valve and exit the exhalation valve. Valve is either a rigid disk or a flap that flutters as gas flows past it.

Inhalation valve opens as patient inhales; anesthetic enters the hose, then the end tracheal tube and the patient.CO2 and anesthetic gases are then exhaled, travel down the hose and through the unidirectional exhalation valve. This valve prevents the expired gases from traveling back to the patient before the CO2 is removed.

6. **Flow meter:**

Read a gas flow meter

- Float - read at the top
- Ball - read in the middle

Function

- Measure the flow of gases.
- It prevent low oxygen Concentration

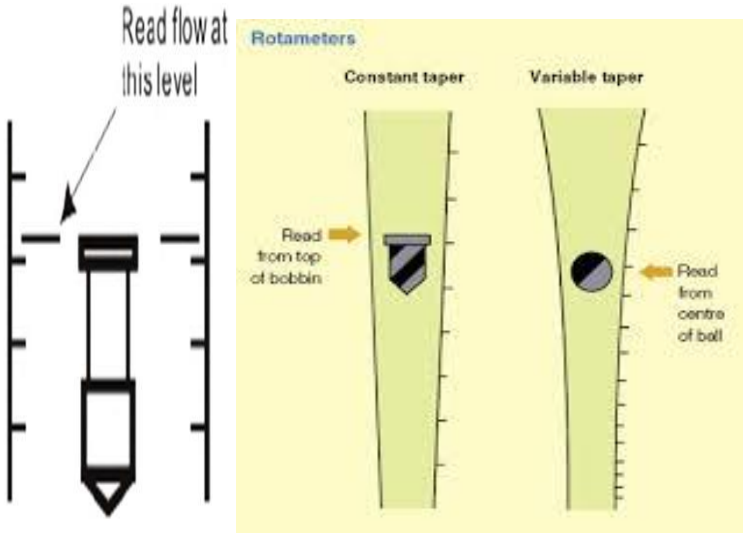


Figure 4.13: Flow meter reading level

Learning activity 4.3:
Duration: 20min
Group Discussion
1. Why it is not recommended to use Pressure Regulator with Flow Meter on anesthesia machine?

2. What did you face regarding gases supply system on anesthesia machine?
Is there any solution you did for the problems?

4.5.1.1 Oxygen supply safety system:

1. **Visual and audible alarm for cylinder or pipeline pressure**

Less than 20-25 PSI or manufacturer's specification

O_2 pressure failure alarm

2. **Oxygen failure protection device * N2O gas cut-off ***

Proportionally restricts flow of gases other than O_2in the event of partial loss O_2pressure or complete loss O_2 pressure.

3. **Proportioning System for Anti-Hypoxia**

Use "bicycle chain" to prevent hypoxic mixture. Use Mechanical link type, Proportional control type to prevent hypoxia mixture.

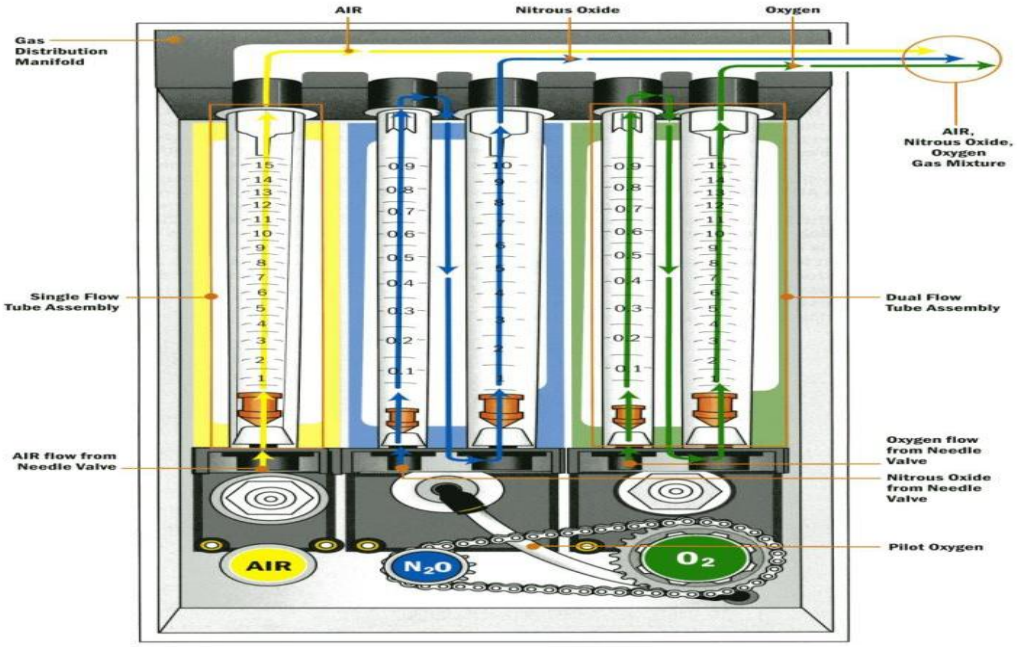


Figure 4.14: Anti-hypoxia system

4. **Flow meter safety device(fail safe system)**

N_2O and O_2 flow controls are interlocked so that the proportion of O_2 to N_2O can never fall below a minimum value (nominal 0.25) to produce a hypoxic breathing mixture

Figure 4.15: Oxygen Failure Protection Device (OFPD)

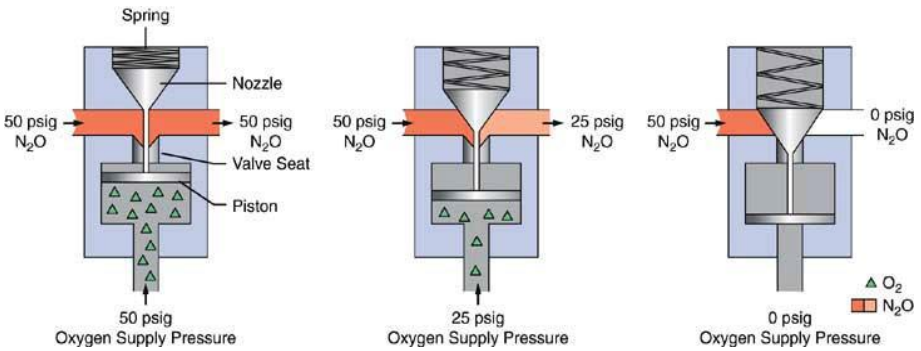


Figure 4.16: Pneumatic diagram for anesthesia machine

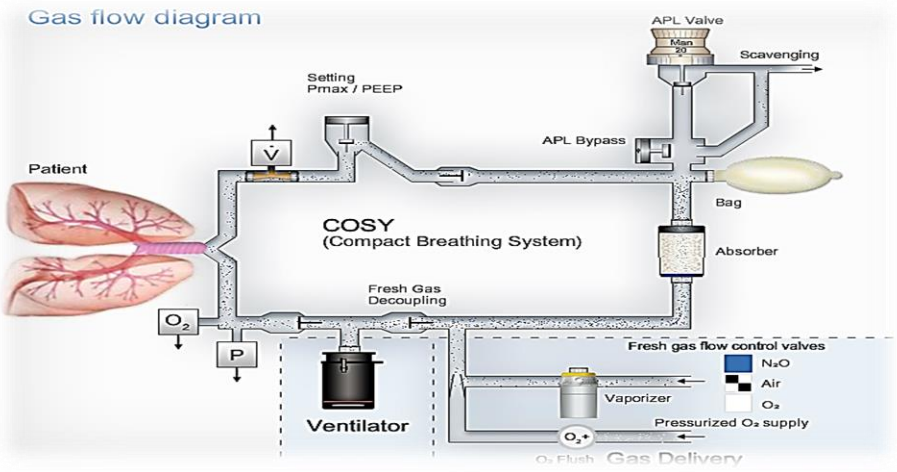


Figure 4.17: Gas flow system circuit

4.6 Anesthesia Machine systemic circuit

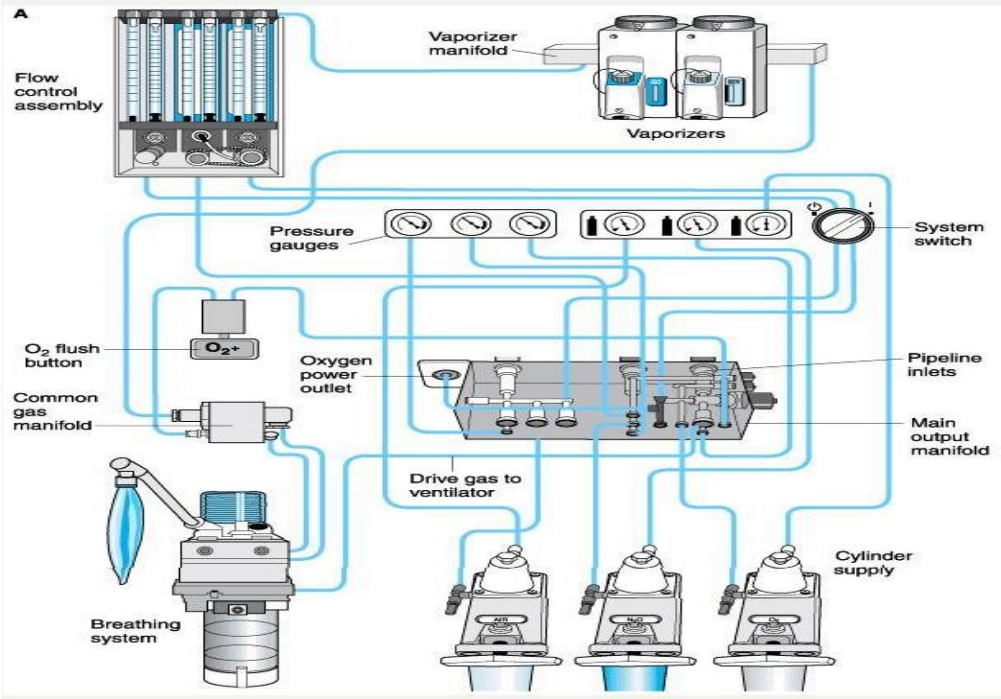


Figure 4.18: Anesthesia Machine systemic circuit

Anesthesia Machine configuration Diagram:

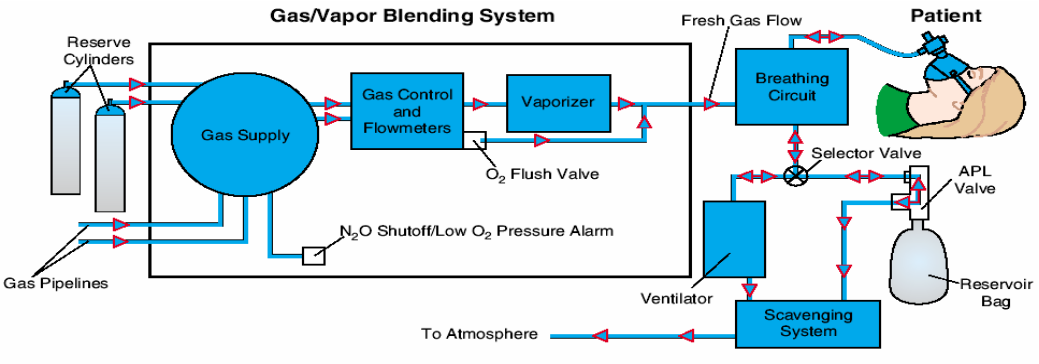


Figure 4.19: Anesthesia machine configuration diagram 1

Learning activities 4.4:

Duration: 15 min

Presentation in a group of 5 participants

- List main components of anesthesia machine
- In your group discuss on the following diagram to identify each components location and discuss how the gasess flow .

It is very important to know how the direction of gas flow. during maintenance you can easly identify where the the problem is .

- If the oxygen flush is not functional what kind of problem will happen during operation? And where is oxygen flush is located in the diagram below?

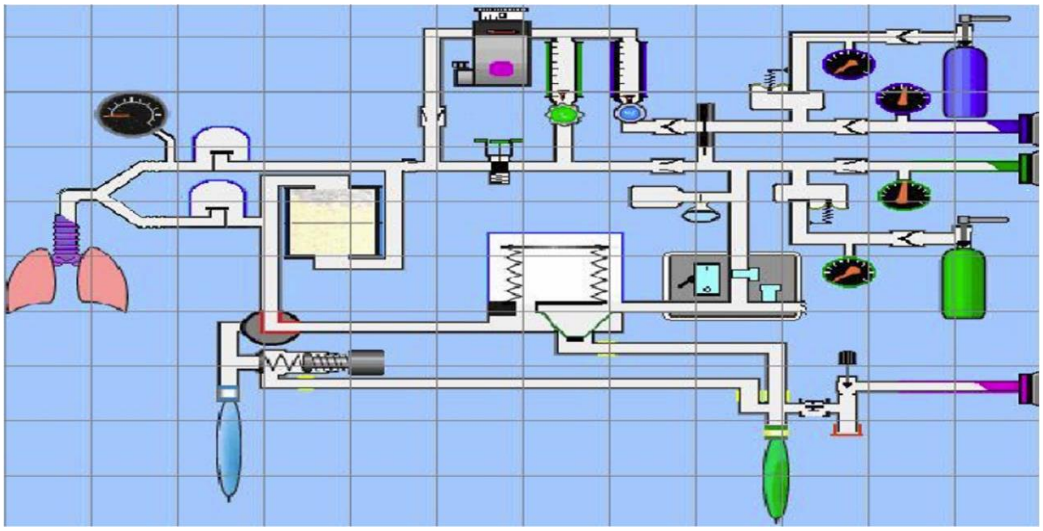


Figure 4.20: Anesthesia Machine configuration Diagram 2

4.7 Basic components of anesthesia machine and their function:

1. Reservoir bag

- Supplying intake air to the patient for storing the role
- Provide artificial respiration using hand tools during manual ventilation
- Determine the patient's condition during spontaneous breathing

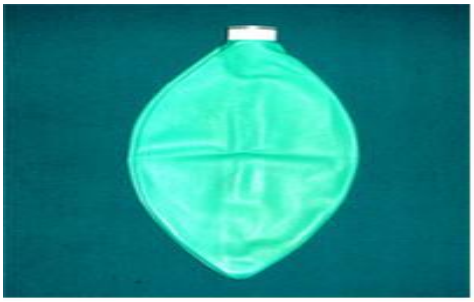


Figure 4.21: Reservoir bag

2. Oxygen flush valve

- Used to bypass gas directly from pipeline or cylinder pressure regulator to common gas outlet
- Re-pressurize the system
- Deliver 35 – 70 l/min(litter per minutes)
- Do not use it when the patient is intubated can cause barotrauma

3. Oxygen sensor

An O_2 monitor located on the inspiratory side of the breathing circuit analyzes gas sampled from the Y-piece of the patient's breathing circuit and displays O_2concentration in volume percent.O_2 monitors sound an alarm if the O_2concentration falls below the preset limit.

4. Vaporizer

A. Working principle of vaporizers

Flow from the flow meters enters the inlet of the vaporizer .The function of the concentration control valve is to regulate the amount of flow through the bypass and vaporizing chambers

Splitting Ratio = flow though vaporizing chamber/flow through bypass chamber

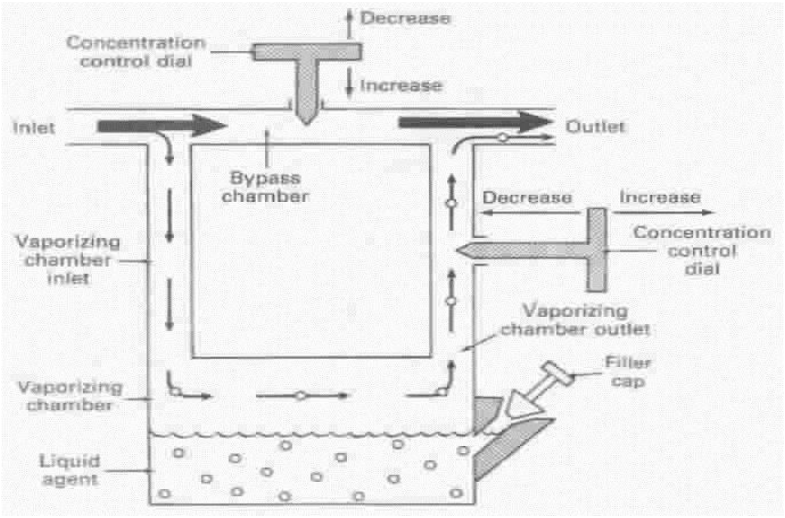


Figure 4.22: Working principle of vaporizer

B. Vaporizer protection system

The vaporizer protection system: Allows only one vaporizer use on at a time.

The “SELECTATEC” vaporizer manifold system: Pins extend from used vaporizer to shut off and prevent the use of others.

Figure 4.23: Selectatec vaporizer

The vaporizer exclusion system (Cage type**):** Uses cams, pins, and levers on back of machine allowing only one vaporizer on at a time.

Figure 4.24: Cage type vaporizer

C. Vaporizer mounts

4 or 2 mount system, Cage-mount or SELECTATEC type.

Figure 4.25: Single vaporizer mounted (left) and two vaporizer mounted (right)

D. Factors that influence vaporizer output

a. Flow Rate: The output of the vaporizer is generally *less* than the dial setting at very low (< 200 ml/min) or very high (> 15 L/min) flows.

b. Temperature: Automatic temperature compensating mechanisms in bypass chambers maintain a constant vaporizer output with varying temperatures.

c. Back Pressure: Intermittent back pressure (e.g. positive pressure ventilation causes a *higher* vaporizer output than the dial setting.

d. Atmospheric Pressure: Changes in atmospheric pressure affect variable bypass vaporizer output as measured by volume % concentration, but not (or very little) as measured by partial pressure (lowering atmospheric pressure increases volume % concentration and vice versa).

e. Carrier Gas: Vaporizers are calibrated for 100% oxygen. Carrier gases other than this result in decreased vaporizer output.

f. Low Atmospheric Pressure – High Altitude

Decreased barometric pressure will affect a concentration calibrated vaporizer by altering the splitting ratio .The high-resistance pathway through the vaporizing chamber offers less resistance under hypobaric conditions, increasing vaporizer output.

g. High Atmospheric Pressures – Hyperbaric Chamber

When atmospheric pressure is increased, changes in the density of gases cause more resistance to flow through the vaporizing chamber and a decrease in vaporizer output.

E. Safety Features Vaporizer

a. Agent specific keyed filling devices - prevents filling with wrong agent. Overfilling is minimized because filler port is located at the maximum safe liquid level.

b. Interlock system– prevents simultaneous use of two vaporizers thereby preventing administration of more than one inhaled agent at the same time.

Do not use O2 flush valve for this purpose as it bypasses the vaporizer leaks.

- A loose filler cap is the most common source of leaks
- Leaks can also occur at the O-ring junction between the vaporizer and its manifold Leaks can cause awareness
- Vaporizer must be in the “on” position to detect a leak
- Positive and negative pressure leak tests can be used to detect vaporizer leaks

5. Canister(CO_2Absorber)

Canister is used to remove carbon dioxide from the cycle system.

Three types

- ❖ Single canister system
- ❖ Dual canister system
- ❖ Disposable system

Figure 4.26: Single canister system

Figure 4.27: Dual canister system

a. CO2 absorber system – Gas flow direction

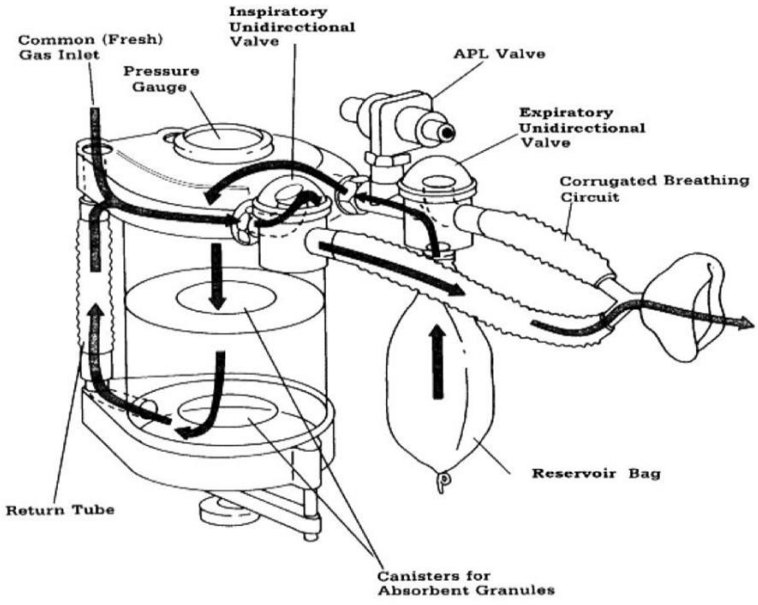


Figure 4.28: CO2 Absorber System – Gas flow direction

b. CO2 absorber system indicators

pH sensitive and colorless when soda lime is fresh but become colored when pH decreases ethyl violet most frequently use indicator.

- ❖ changes to purple as absorption proceeds
- ❖ may be deactivated by fluorescent lighting

6. Adjustable pressure limit (APL) valve

- To limit the maximum pressure during manual ventilation.(It controls the circuit pressure and volume)
- APL valve allows excess gas to escape when a preset pressure is exceeded. Manual exhaust to Scavenger system
- the excess gas during spontaneous breathing, Manual exhaust to Scavenger system

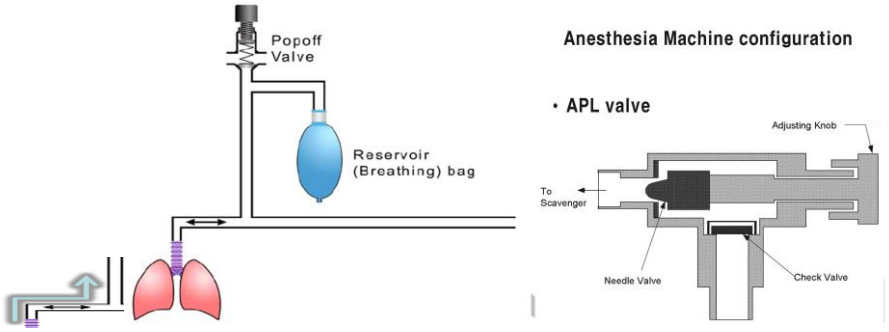


Figure 4.29: Adjustable pressure limit (APL) valve

A **"POP-Off valve"** close to the bag lets **the excess gas, likely contain CO2, escape**. Observe that the system depends in the fresh gas flow to wash away previously exhales gases and prevent re-breathing. The exhaled gas is delivered into a reservoir bag. During expiration the fresh gas pushes the patient's CO2-containinggas toward and into the breathing bag.

7. Unidirectional valves

When the patient inhales, the expiratory valve closes and the patient inhales from the bag and the continuously flowing oxygen. When the fresh gas flow matches the patient's minute volume, no fresh gas is spilled. If the fresh gas exceeds the patient's minute volume, the excess gas escapes during exhalation. If the fresh gas flow were to exceed the patient's peak inspiratory flow rate, fresh gas would escape even during inspiration as well as expiration.

Learning activity 4.5:

Duration: 10min

Material: Figure 1.30

Individual participation

1. Ask the participant to relate the following parts with the diagram bellow and to tell you their function

- Inspiratory valve
- Expiratory valve
- POP-Off valve (APL)
- Bag(Manual) / Ventilator selector
- Patient manometer(it indicate that inspire pressure)

Figure 4.30: Inspiratory/Expiratory valve

8. Oxygen flush valve

- Bypass valve directly from pipeline or cylinder pressure regulator to common gas outlet.
- Used to re-pressurize system
- Do not use while patient is intubated - can cause barotraumas
- Delivers 35-70L/min

9. Monitoring and display

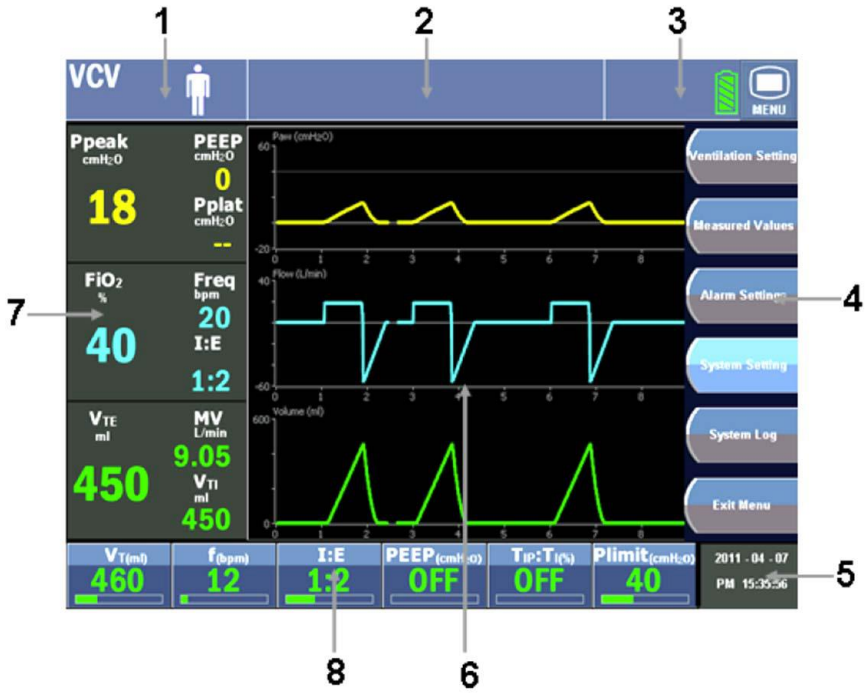


Figure 4.31: Monitoring and display

1. Mode information display area: (1) Display the current ventilation mode (2) Display the current patient category

2. Alarm information display area: Display the current alarm information

3. Status information display area: Display the battery power status**,** the tool menu button, the alarm silence icon

4. Function keys area: (1) Ventilation Setting (2) Measured Values (3) Alarm Settings (4) System Settings (5) System Log (6) Exit Menu

5. System time display area: Display the current date and time

6. Waveform display area: According to different configuration of models and different settings by users, it will display the waveform.

7. Measured parameter area: Display the current measuring parameter of the patient.

8. Ventilation modes setting area: Users can set the relative ventilation parameter of the current ventilation mode in the main menu directly; the gray touch key means the parameter has nothing to do with the current ventilation mode and cannot be adjusted.

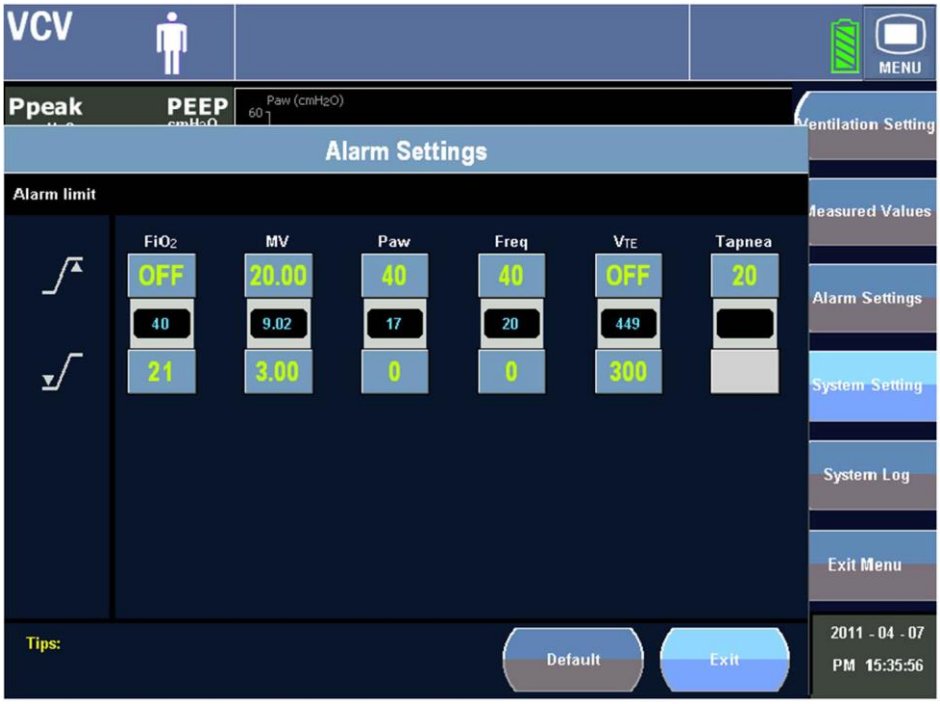


Figure 4.32: Alarm Display

Monitoring:

1. Inspiratory/Expiratory Tidal volume, Minute volume
2. PIP, Mean, Plateau pressure
3. Breath rate
4. I: E ratio
5. O2 %
6. Compliance, Resistance

10. Scavenging system

A. Purpose of the scavenging system

- Removes anesthetic gas outside the operating room
- Excessive negative pressure anesthetic gas removal system causes a negative pressure in the patient breathing circuit
- If the path is blocked exhaust gas pressure in excess of the breathing circuit causing lung damage
- To remove breathing circuit and ventilator gases from the anesthesia machine.

Scavenging Systems Components:

- Gas collection assembly, (tubes connected to APL and vent relief valve)

- Transfer tubing
- Scavenging interface
- Gas disposal tubing (carries gas from interface to disposal assembly)
- Gas disposal assembly (active or passive - active most common, uses the hospital suction system)

B. Scavenger interface:

- The scavenger interface is the most important component. It protects the breathing circuit from excess positive or negative pressure.
- Positive-pressure relief is mandatory to vent excess gas in case of occlusion downstream from the interface, irrespective of the type of disposal system used. If active disposal system used, must have negative pressure relief as well. Reservoir highly desirable with active systems.
- Negative pressure relief is necessary to protect the breathing circuit or ventilator from excessive sub atmospheric pressure, if the disposal system is active (vacuum suction)
- Excess (or waste) gas from the breathing circuit is vented through the APL valve when the selector switch is on “bag”
- Waste gas is vented from the ventilator bellows when the selector switch is on “ventilator”
- Gas is vented to the atmosphere through the positive pressure relief valve if the system pressure exceeds +5 cm H2O (centimeter of water).
- Leakage of waste gases into the atmosphere occurs only if the reservoir bag becomes fully inflated and the pressure increases sufficiently to open the positive-pressure relief valve
- The vacuum control valve should be adjusted so that the reservoir bag is properly inflated and not over distended or completely deflated

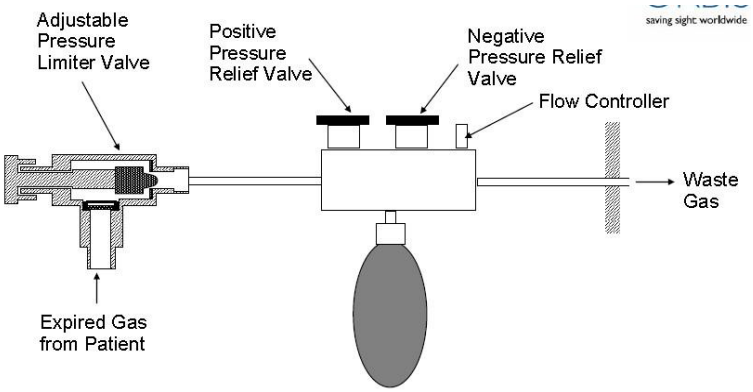


Figure 4.33: Scavenging Systems Guidelines

A. Types of scavenging systems

- Active
- Passive
- open

a. Active scavenging system

This system has suction attached to carry gases away to vacuum pipeline. The scavenger interface controls the flow of suction and maintains the balance with the quantity of exhaust gas. If do not use a scavenger interface, it should be either adjust the flow of suction from the gas evacuation system so it does not draw up the gas intended for the patient, or it should be increase the suction flow.

- Connects to hospital suction system
- Positive and negative pressure relief valves prevent fluctuation to the patient
- A 3 liter reservoir bag is present (holds excess gas until it can be removed)
- The positive relief valve opens at 5cm H20 (with exhalation by the patient or ventilator)
- Closed interface communicates with atmosphere only through valves. Should adjust vacuum so that reservoir bag neither flat not over-distended.

Figure 4.34: Active scavenging system

b. Passive scavenging system

- Interfaces with hospital ventilation duct
- Relies on the buildup of gases in the bag to passively empty into the hospital ventilation system
- May see both active and passive systems in the same institution
- No suction. Just a hose going out a window. Large bore hose is required.

Figure 4.35: Passive scavenging system

c. Open scavenging system

Open scavenging system a form of interface in an ACTIVE scavenging system. It has a canister hanging on the side of the machine with a ball floating inside. It should be view with suction unit attached and plugged into the wall. It allows negative pressure open and positive pressure relief. It is open to the atmosphere and does not have valves.

Figure 4.36: Open scavenging system

- Open interface has no valves, and is open to atmosphere (allows both negative and positive pressure relief). Should be used only with active systems. Remember that hissing from an open interface is normal (there is no audible indication of waste gas leaks).

- Scavenging system (interface) is either open or closed
- Open interface relies on relief ports for +ve or –ve pressure relief – *(should be used only with active disposal systems)*
- Closed interface relies on relief valves – *(can be used with both active and passive disposal systems)*
- Gas disposal can be active or passive
- Active disposal relies on suction
- Passive disposal relies on waste gas pressure (no suction) to push gas out

11. Bellow assembly

A. Ascending bellows chamber system

Moves the bellows to down direction when activate. Ascending bellows will collapse with a disconnect or gas leak.

Figure 4.37: Ascending bellows

B. Descending bellows chamber system

Move the bellows to up direction when activate descending bellows will go up during inspiration and fall during expiration. These bellows will continue to appear to be working on disconnect and will draw in room air.

Figure 4.38: Descending bellows

4.8 Understanding anesthesia ventilation

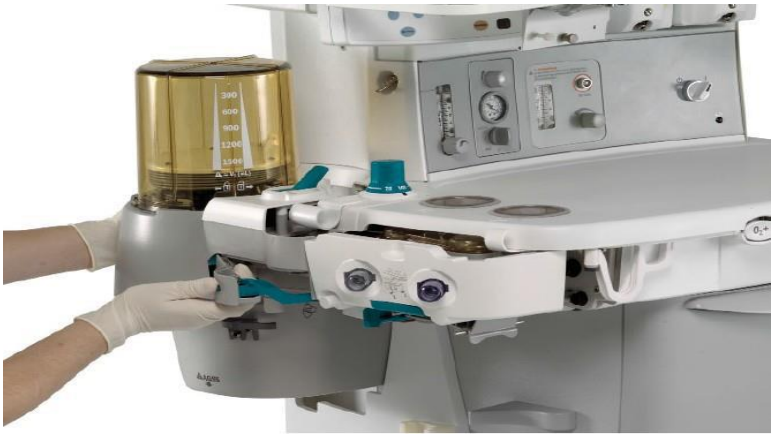


Figure 4.39: Ventilation system

- ✓ Patient under General Anesthesia may require mechanical ventilation
- ✓ A ventilator is used to control the breathing pattern for the patient
- ✓ Ventilators allow the Anesthesia Provider to control respirations "hands free"

4.8.1 Basic terms in ventilator

1. Control/ breath type : Pressure control, Volume control
2. Ventilation mode : CMV, ACMV, SIMV, Spontaneous/CPAP
3. Control parameter, basic:
    - Breath rate (BPM) / RR(Respiration rate) /Peak flow (LPM)
    - Tidal volume (mL)
    - Airway pressure (CmH2O)
    - Time(Inspiratory/Expiratory time) (second)

4.8.2 Ventilation control type (Breath Type)

1. VC Volume Control, volume targeted and pressure variable

- Volume Control mandatory breaths is delivered primarily according to the user-selected
- Tidal Volume and Flow/Inspiratory Time(or Insp. Pause time) setting and is secondarily affected by Respiratory Rate, PEEP/CPAP, Pause, Sigh, and F-end (Flow end) pattern settings.

2. PC - Pressure Control, pressure limited and volume variable

- Pressure Control mandatory breath is delivered primarily according to the user-selected

- Pressure Limit and Inspiratory Time settings and is secondarily affected by Respiratory Rate, PEEP/CPAP.

1. Pressure Support:

- For patient spontaneous efforts that trigger the ventilator, the ventilator delivers breaths with a constant pressure in the breathing circuit at a pressure equal to PEEP/CPAP + Pressure Support, until the end of patient inspiration.
- The breaths are delivered according to the user-selected settings for Pressure Support and PEEP/CPAP

Normal pressure wave:

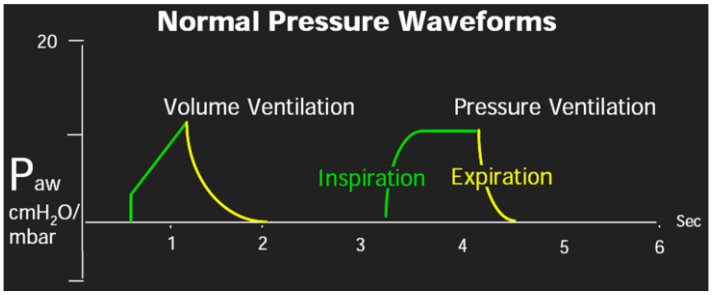


Figure 4.40: Normal pressure wave form

4.8.3 Ventilation (Breath) modes

1. CMV: Controlled mandatory ventilation

- All breaths delivered to the patient are mandatory breaths
- The user may choose to Pressure Control, Volume Control the mandatory breaths.
- The Respiratory Rate setting determines the minimum number of time-triggered mandatory breaths delivered each minute.
- The patient is guaranteed to receive this number of mandatory breaths per minute determined by the respiratory rate.
- Without allowances for spontaneous breathing.
- Most of anesthesia ventilator use this CMV mode

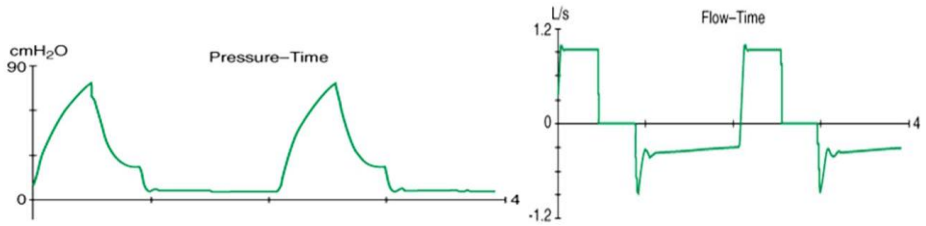


Figure 4.41: Controlled mandatory ventilation pressure time and flow time wave

2. ACV (ACMV): Assist Control:

- The breaths may be time (ventilator-triggered) or patient-triggered.
- Determined by the trigger (sensitivity) level and respiratory rate.
- Assisted breaths are delivered in response to each patient inspiratory effort.
- The Respiratory Rate setting determines the minimum number of time-triggered or patient triggered mandatory breaths delivered each minute.
- The Trigger setting determines the airway pressure or airway flow threshold that the patient's effort must reach in order to trigger these and additional mandatory breaths.
- If the patient doesn't breathe or if the patient's efforts don't cause airway pressure or airway flow to reach the Trigger sensitivity, the Ventilator delivers the number of time-triggered breaths each minute selected via the Respiratory Rate setting

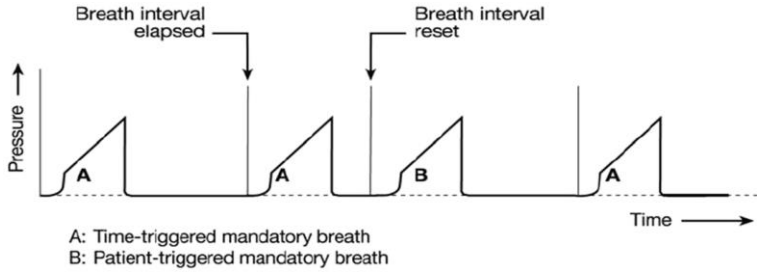


Figure 4.42: Assist Control mandatory ventilation

3. SIMV: Spontaneous intermittent mandatory ventilation

- ✓ Mandatory and spontaneous breaths may be delivered to the patient.
- ✓ The user may choose to Pressure Control, Volume Control the mandatory breaths.
- ✓ The breaths may be time (ventilator-triggered) or patient-triggered.
- ✓ In VC or PC, the user may choose to pressure support the spontaneous breaths.
- ✓ The Respiratory Rate setting determines the total number of mandatory breaths delivered each minute.
- ✓ The Trigger setting determines the airway pressure or airway flow sensitivity that the patient's effort must reach in order to trigger mandatory breaths and also to trigger spontaneous breaths in between mandatory breaths.
- ✓ If there are **no patient** breathing efforts or if patient efforts fail to cause enough airway pressure or airway flow **change to meet the set Trigger** sensitivity, the patient receives the number of time triggered breaths each minute selected via the Respiratory Rate setting

1. **Spontaneous:**

- All breaths delivered to the patient are spontaneous breaths.
- When Volume Control or Pressure Control breath types are selected, the user may choose to add Pressure Support to assist spontaneous efforts.
- The Trigger setting determines the airway pressure or airway flow sensitivity that the patient's effort must reach in order to trigger spontaneous breathing assistance from the ventilator.
- If there are **No patient efforts** or if the patient efforts fail to cause enough airway pressure or airway flow change to meet the **Set Trigger sensitivity**, no spontaneous breathing assistance is provided.

4.8.4 Ventilator monitoring

1. Monitoring parameter:

- Airway pressure (Ppeak, Ppause, Pmean, PEEPH, PEEPL)
- Expiratory flow, Tidal volume /Minute volume
- I:E time, Inspiratory time, expiration rate, pause time ,rise time
- Respiratory rate, Spontaneous rate, Total rate

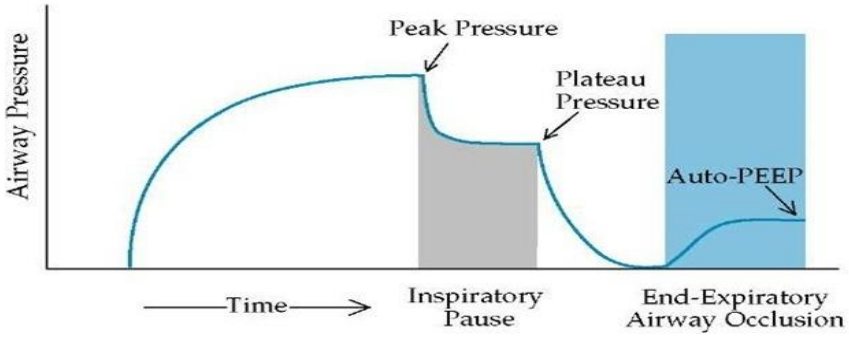


Figure 4.43: Airway pressure wave form

2. Cycling mechanism:

The ventilator switches from inspiration to expiration can be by:

a. Time cycled: Pressure controlled ventilation

b. Volume cycled: Volume controlled ventilation .The ventilator cycles to expiration once a set tidal volume has been delivered.

c. Flow cycled: Pressure support .Response to each patient aspiratory effort. (Reaches the trigger level; pressure or flow)

3. Breaths may be triggered by:

- **A patient** taking their own breath
- **A ventilator** operator pressing a manual breath button or by the ventilator based on the set breathe rate and mode of ventilation.

4. Bellows Classification:

Determined by direction of bellows movement during the expiratory phase

- Ascending (standing) bellows – ascend during expiratory phase
- Descending (hanging) bellows – descend during expiratory phase

Learning activity 4.6:

Duration: 15min

Discussion in pair

1. What will happen if there is leak between bellow housing and bellow itself?
2. Which one is safer Ascending or Descending bellow? Why?
3. Discuss on diagram below how the gases are flowing during inspiration and expiration and? What type of bellow it is?

Answers:

Ascending bellows is safer because it does not refill if a total disconnection occurs Descending bellows continues its upward and downward movement during a disconnection because room air is entrained by gravity into the breathing system at site of disconnection

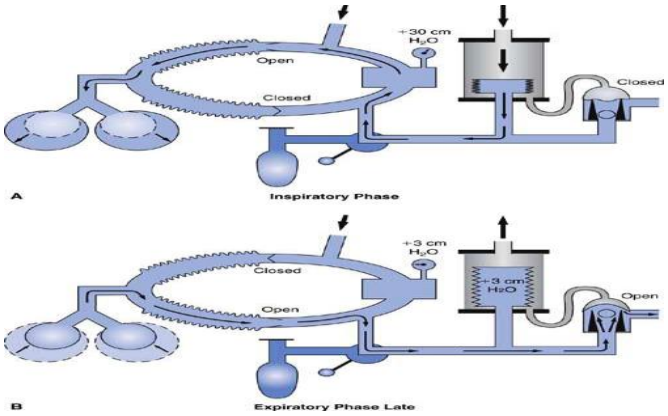


Figure 4.44: Direction of bellows movement during inspiratory and expiratory phase

5. Type of breathing circuit

a. Rebreathing circuits

Here the same gases are re-used, and CO_2 is removed by passage of the gas through soda lime.

A circle rebreathing circuit is composed of:

- Carbon dioxide absorbing canister
- Y-piece
- Inhalation and exhalation breathing tubes
- Inhalation and exhalation unidirectional (one way) valves
- Fresh gas inlet
- Pressure manometer
- pop-off valve
- A reservoir bag

b. Non-rebreathing circuits

With these, the patient breathes in from the reservoir and out to atmosphere. The gases are not re-used. Satisfactory elimination of CO2 is dependent on adequate gas flow, and on minimal dead space in the circuit.

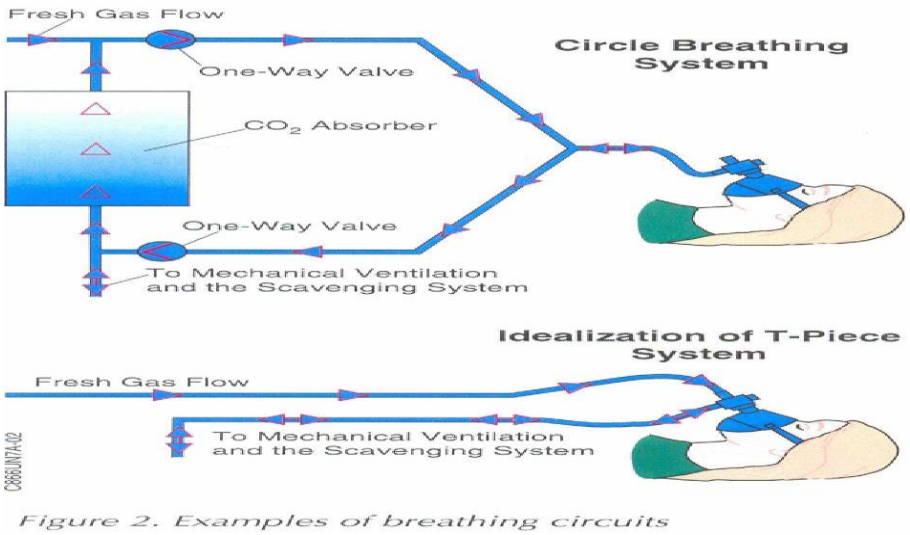


Figure 4.45: Breathing circuit

- During inspiration expiratory valve is closed, the fresh gas flow through the respiratory cycle (to the lung).
- During expiration inspiratory valve is closed, the exhaust gas flows from the lung to the machine.
- The gas flowing into the system during expiration will be forced to flow in the direction of the Co_2 absorber only to be inspired during the next cycle
  - ✓ Ventilator controls on the front of the Anesthesia Machine to:
  - ✓ Select the volume, rate and limit the pressure of the gas to be delivered to the patient airway
  - ✓ Control components that allow inhalation or exhalation and to respond to high pressure in the patient airway
  - ✓ Display information about percentage of oxygen in the gas supplied to the pt, and the volume of gas exhaled from the patient
  - ✓ Select alarm limits for oxygen percentage, airway pressure and exhaled volume
  - ✓ Display and sound alarms when alarm limits are exceeded

The control module includes:

- ✓ User controls and a display panel
- ✓ A microprocessor and electronic circuits
- ✓ Pressure regulators and transducers
- ✓ Electronically controlled pneumatic valves that open and close to allow inhalation and exhalation
- ✓ Tidal volume (ml per breath)

- ✓ Rate in completed cycles (breaths per minute)
- ✓ Flow (controls the flow rate of drive gas (l/min)
- ✓ Pressure limit
- ✓ Inspiratory pause
- ✓ Mechanical Vent (on-off button)
- ✓ I:E ratios
- ✓ Tidal Volume (ml/kg), depending on age, etc.Most providers adjust depend

Learning activity 4.7:

Duration: 20min

Material: Anesthesia machine, Figure 4.46

First individual then group discussion, last presentation

See figure 1.5 Assume oxygen source (O_2) has enough amounts for a patient. The drive gas is not good. Does patient get breath during mechanical (automatic) ventilation? Why? When we suppose to close APL valve?

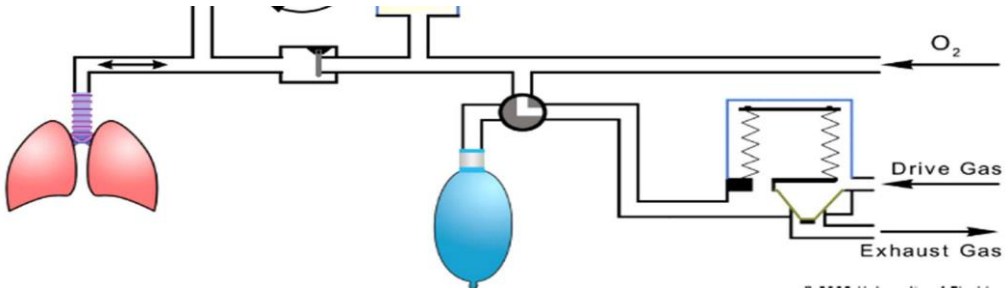


Figure 4.46: Automatic and manual ventilation system

4.9 Assemble and disassemble basic components for maintenance

Before any maintenance or troubleshooting process it is important to know how to assemble and disassemble the parts then you can troubleshoot where ever component you want to repair.

Learning activities 4.8:

Duration: 2hrs

Material: anesthesia machine, maintenance tools. Gloves .service manual

Demonstration: checklists

Demonstrate how to disassemble and assemble: Breathing system, Canister, Bellows, APL valve, vaporizer

Group practice: within two groups

4.9.1 Assemble and disassemble – Breathing system

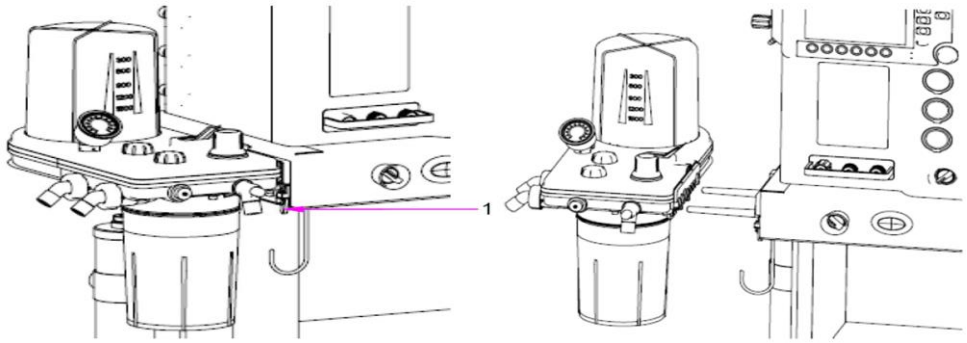


Figure 4.47: Locking / Unlocking lever of breathing system

4.9.2 Assemble and Disassemble - Canister

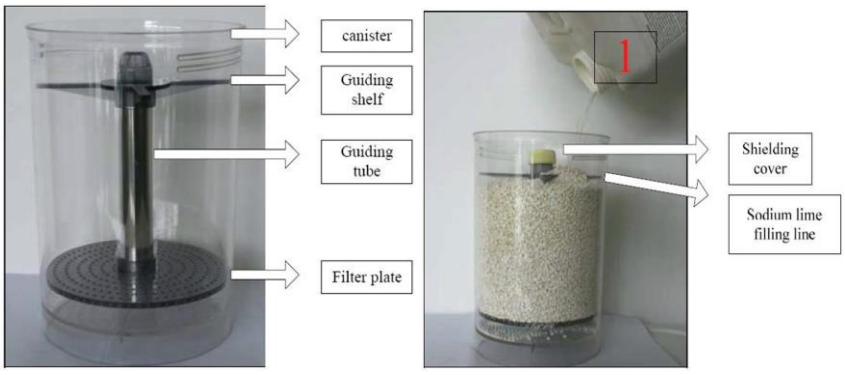


Figure 4.48: Assemble and Disassemble - Canister

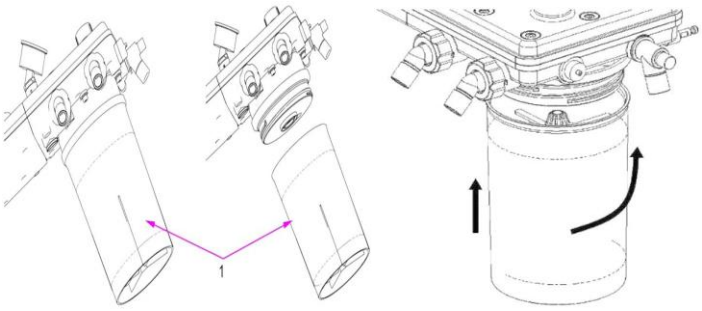


Figure 4.49: Assemble /Disassemble, lock/ unlock of Canister

4.9.3 Assemble and Disassemble – Housing and Bellows

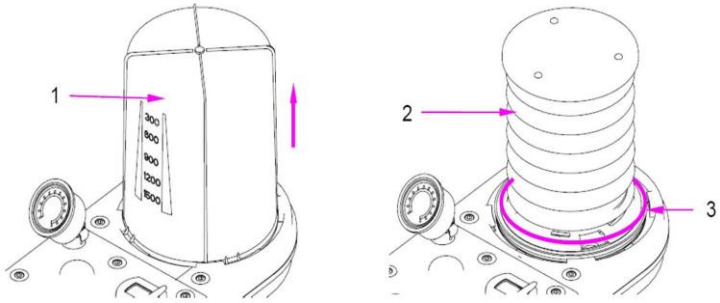


Figure 4.50: Assemble and Disassemble – Housing and Bellows

1. Bellows housing (chamber)
2. Bellows
3. Connection base for bellows and housing

4.9.4 Assemble and Disassemble – Spill valve

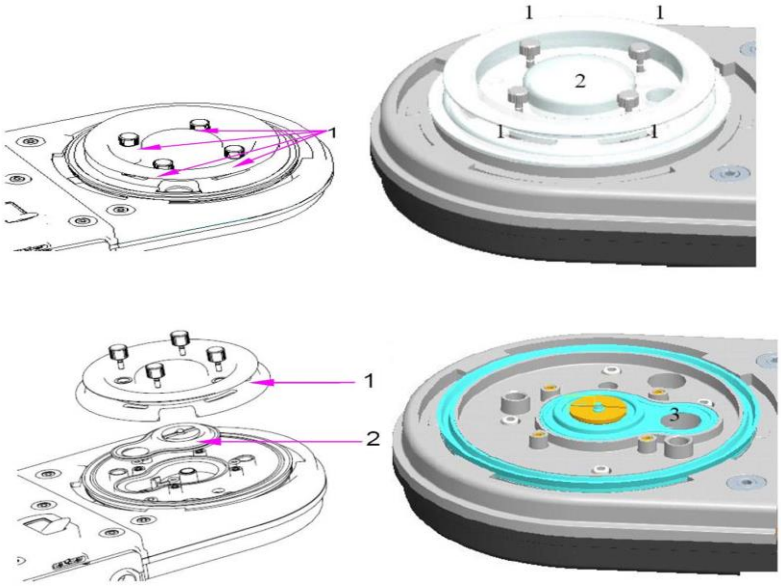


Figure 4.51: Assemble and disassemble – Spill valve

1. Housing with fixing screw for spill valve
2. Base for spill valve
3. Spill valve

4.9.5 Assemble and Disassemble – APL valve

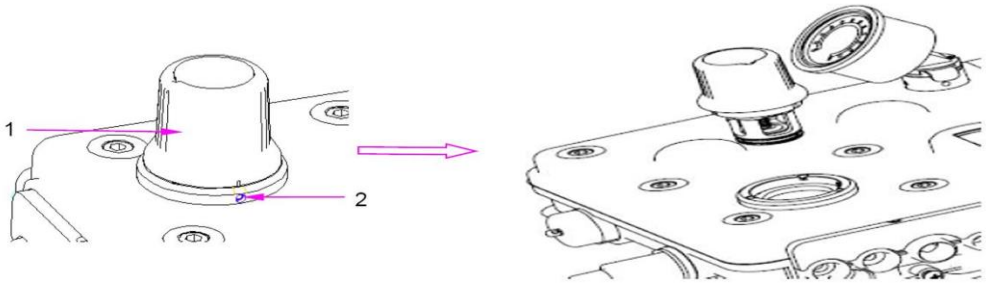


Figure 4.52: Assemble and Disassemble – APL valve

1. APL (POP-Off) valve knob 2. Fixing screw

4.9.6 Assemble and Disassemble – O2 Sensor

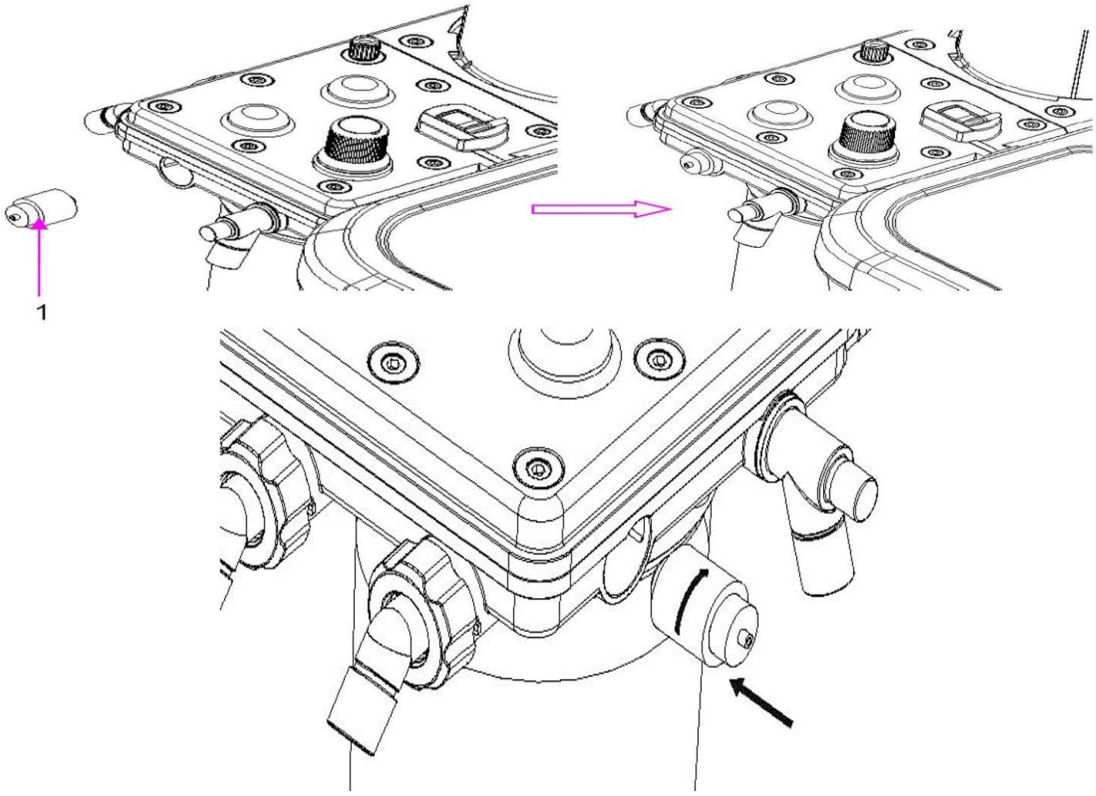


Figure 4.53: Assemble and Disassemble – O2 Sensor

4.10 Common anesthesia problems

- Leakage at different places:

4.10.1 The main causes of leakage:

1. Breathing hose (circle) damage and Tube crack and hose over stretch
2. O_2 sensor is incorrectly combined or not combined
3. Sample line for the measurement of gas unbinds.
4. Water trap the unbind
5. Breathing bag / diaphragm defects
6. Vaporizer combines an inaccurate anddamage of internal Gasket
7. Flow sensor connection is incorrect
8. The incorrect connection through Soda lime
9. Breathing system incorrect connection
10. Absence of Periodic inspection and Spare replacement

- Gas supply shortage
- Flow meter problem
- Improper Fixing of tubes and hose
- Reservoir bag leakage
- Problem at Auto/Mechanical ventilation knob(Switch)
- Electric Power Fluctuation
- Bellows system Problem
- APL Valve
- Oxygen Regulator
- Patient monitoring Probe loos and crack

4.11 Preventive Maintenance

The purpose of performing preventive maintenance on a periodic basis is to prevents possible malfunction or breakdown and to assure optimum performance of the equipment at all times. All anesthesia machine manufacturers offer service contracts which cover preventive maintenance and emergency repairs. Current recommendations are that every anesthesia machine should be serviced every 3 to 4 months. Documentation of the service performed on each anesthesia machine, including tests performed and parts used, should be kept on file in the department. In addition to the preventive maintenance records, the department may find it desirable to keep track

of modification and complaints associated with use of the machine. Anesthesia Preventive maintenance must be followed by cleaning and thorough operational checks by anesthesia support personnel and anesthesiologist before each use. it is recommended to use a short daily anesthesia machine checklist that may be incorporated into the patient's anesthetic record.

4.11.1 Basic Preventive Maintenance for anesthesia machine:

Completely clean anesthesia Machine Parts and Accessories Most of the time Check each Part for Preventing Leakage Periodically i.e.

- Hose connection
- Breathing circuit connection
- Oxygen regulator
- O2 absorber connection
- Reservoir Bag
- Sterilize equipment accessories that can undergo sterilization
- Properly handle each hose and tubing system. (carless handling of hose and Tube may lead to Leakage)
- Properly Fix The Vaporizer
- Prevent any leak from scavenging Tube.
- Make sure there is Proper Power supply
- Make the power supply off at the end of daily task
- Check each power cord; Power stabilizer; gas supply continuously
- Make sure to have reserved oxygen supply
- Take care for push button
- Take care for Auto/manual switch
- Cover Anesthesia Machine by dust Protective Cover at the end of Daily Task.

4.11.2 Preventive maintenance for Patient Monitoring integrated with Anesthesia Machine:

- Properly handle each Probe such as ECG probe; SPO2 Probe; PB probe; Co2 concentration (Capnography); Temperature sensor etc…
- Carless handling of the above components may lead to crack; Physical Damage; probe bending which leads to false reading implies false diagnosis and Treatments

- CO2 absorbent canister should be replaced if two-thirds of the color changes. The color change indicates that the absorbent cannot absorb more CO2 (typically absorbing color changes from white to violet).

Check at least the Following basics for Anesthesia Machine before using:

- Everywhere check The Presence of Any leak
- Check Breathing circuit and Vaporizer
- ventilation system check
- High and low Pressure system check including Pressure control system
- Scavenging system check
- Manual and automatic ventilation system
- Patient Monitoring functionality check.
- Final Position check

4.11.3 How to Perform a Leak Test?

A leak test is the basic troubleshooting technique for diagnosing anesthesia systems. Each time you use your anesthesia system, it is recommend checking for pressure leaks in the machine and ensuring that waste-gas evacuation system is working properly.

How to perform a basic 10-second leak test:

Before each use, "leak check" the machine, and also ensure that the waste gases have a patent way through your evacuation system

1. Connect a rebreathing circuit and bag to machine and Close pop-off valve and cover theY-piece with your palm or thumb.
2. Push oxygen flush or turn on oxygen until the bag is distended.
3. Turn the oxygen off and watch the manometer or the bag if your machine does not have a manometer. If the manometer reading drops rapidly, or the bag deflates rapidly, or if you hear a hissing sound, you have a leak.
4. Check hoses, bag, vaporizer inlet and outlet,any screw down fittings, and the seals at the top and bottom of your soda sorb container for leaks. When the pressure remains fairly constant with the oxygen turned off, your machine can be considered leak free on the low pressure side.
5. Reopen the pop-off to your usual setting.
6. Squeeze the bag (with your thumb still over the Y-piece) to ensure the gases have a patent way out through your scavenging system.

Learning activity 4.9:

Duration: 10min

Video lecture then practice

Use test leak video. How to Leak Test an Anesthesia Machine.mp4 then do leak checking test practically

I. Leak Test High Pressure System (Oxygen tank to back of O2 flow meter)

A. Turn off O2 flow control.

B. Turn on O2 tank.

C. Watch tank pressure gauge needle stabilize and note PSI.

D. Turn off O2 tank.

E. Watch pressure gauge needle. If needle drops, you have a leak. The bigger the leak, the faster the needle drops.

1. If needle drops 50 PSI in one minute, look for leaks.
    a. Windex can be used on fittings. If Windex bubbles, you have a leak. Tighten fitting.
2. If needle does not drop 50 PSI in one minute, proceed with further testing as follows:

II. Leak Test Low Pressure (O2 flow meter to common outlet)

A. Turn on O2 tank.

B. Put thumb over common outlet.

C. Turn on O2 Flow meter to one liter per minute flow (with vaporizer off).

1. Watch float in flow tube.
    a. If no leak, ball will drop slightly and pressure will be build-up on thumb.
2. If float does not drop and pressure does not build-up on thumb, check:
    a. All tubing for cracks and proper connections.
    b. Inlet and outlet adapters to ensure they are properly positioned into vaporizer.

D. Turn on O2 Flow meter to one liter per minute flow (with vaporizer on).

1. Watch float in flow tube.
    a. If no leak, ball will drop slightly and pressure will be build-up on thumb.
2. If float does not drop and pressure does not build-up on thumb, check:

a. Fill cap of vaporizer to ensure it is tightly sealed.
b. Stop is positioned properly in pin-indexed vaporizer

Learning activity 4.10:

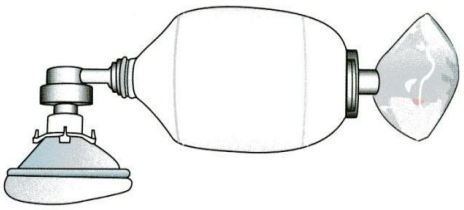
Duration: 4hrs

Material: backup ventilation equipment, pressure gauge, reservoir bag

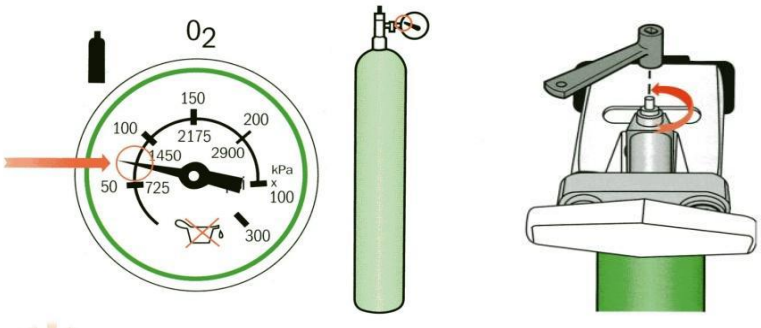
Group practice: do the following steps

4.11.4 Recommendations for preventive maintenance before operation

Step 1: Verify backup ventilation equipment is available and functioning e.g. properly functioning manual resuscitator



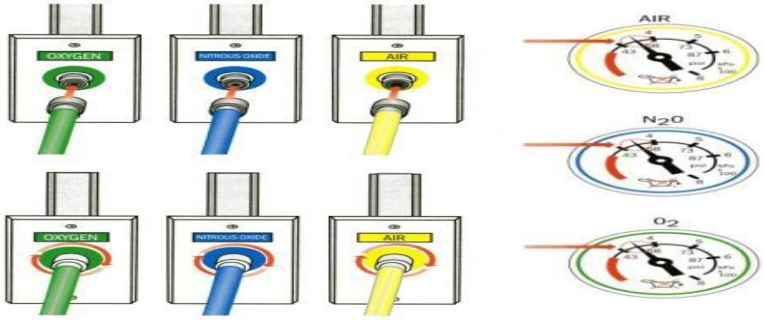
Step 2: Check the oxygen cylinder supply



Open oxygen cylinder and verify that it is at least half full (about 1000 psi). Close cylinder manufacturer recommends that cylinders remain closed so that they do not inadvertently get drained.

Step 3: Check central pipeline supplies

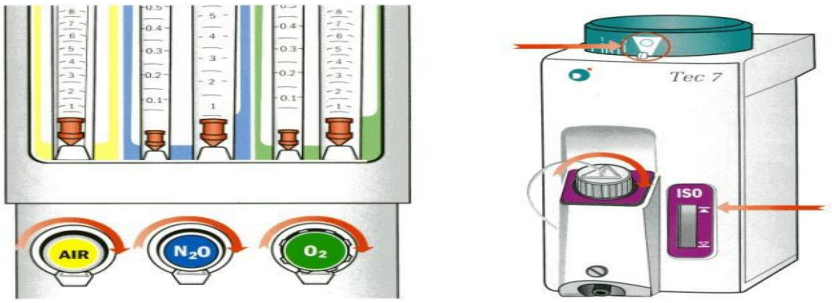
Check that pipeline hoses are connected and pipeline gauges read about 50 psi



Step 4: Check initial status of low pressure system

a. Close flow control valves and turn vaporizer off

b. Check fill level and tighten vaporizers' filler caps



Step 5: Perform leak check of machine low pressure system

a. Verify that the machine master switch and flow control valves are OFF

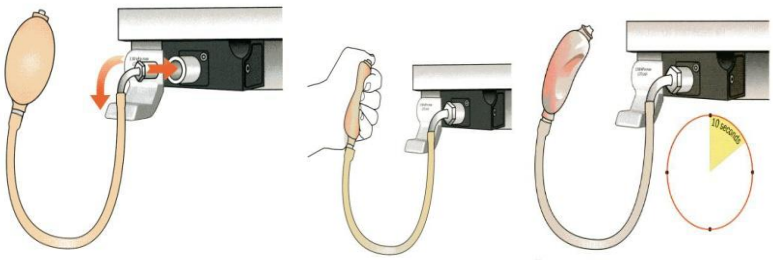
b. Attach "suction bulb" to common (fresh gas) outlet

c. Squeeze bulb repeatedly until fully collapsed

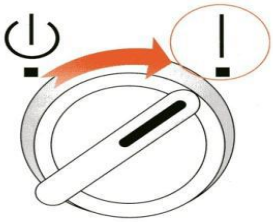
d. Verify bulb stays fully collapsed for at least 10 seconds

e. Open one vaporizer at a time and repeat steps ***c*** and ***d*** above

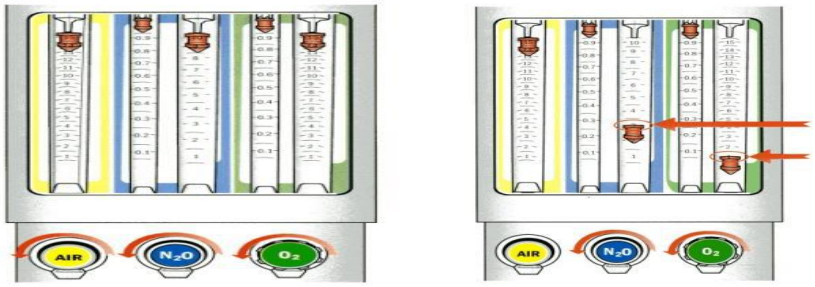
f. Remove suction bulb, and reconnect fresh gas hose



Step 6: Turn on machine master switch and all necessary electrical equipment



Step 7: Test flow meters



a. Adjust flow of all gases through their full range, checking for smooth operation of floats and undamaged flow tubes

b. Attempt to create a hypoxic O_2/N_2O mixture and verify correct changes in flow and/or alarm

Step 8: Adjust and check scavenging system

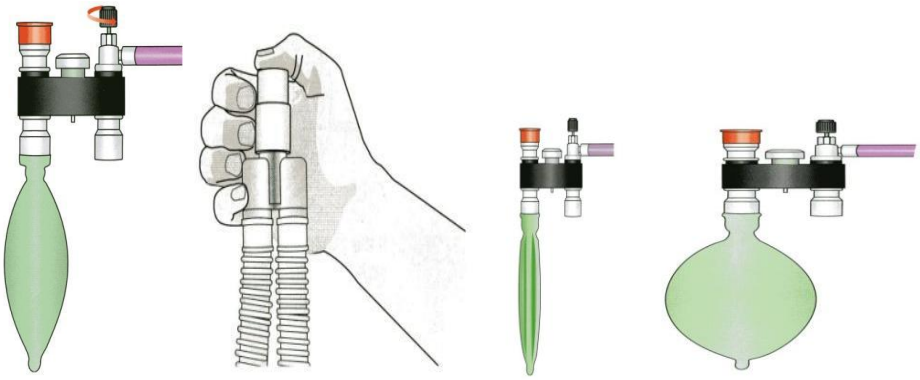
a. Ensure proper connections between scavenging system and both APL (pop-off) valve and ventilator relief valve

b. Adjust waste gas vacuum (if possible)

c. Fully open APL valve and occlude Y-piece

d. With minimum O_2 flow, allow scavenger reservoir bag to collapse completely and verify that absorber pressure gauge reads about zero

e. With O_2 flush activated, allow the scavenger reservoir bag to distend fully, then verify that absorber gauge reads < 10 cmH_2O



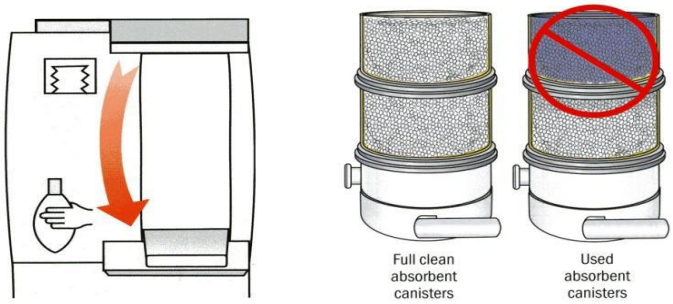
Step 9: Check initial status of breathing system:

a. Set selector switch to “bag” mode

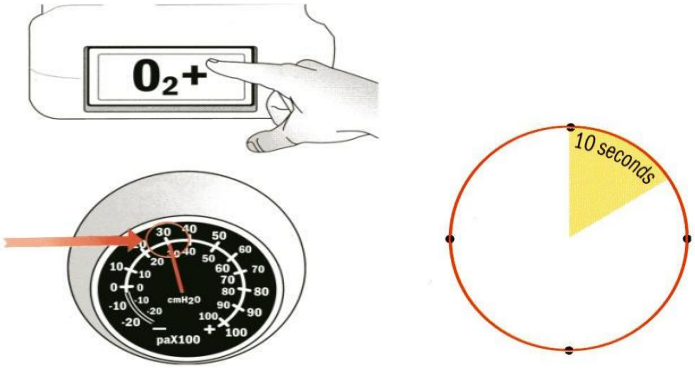
b. Check that breathing circuit is complete, undamaged and unobstructed

c. Verify that CO_2 absorbent is adequate

d. Install breathing circuit accessory equipment (e.g. humidifier, PEEP valve) to be used during the case



Step 10: Perform leak check of the breathing system:



Step 11: Test ventilation systems and unidirectional valves:

a. Place a second breathing bag on Y-piece

b. Set appropriate ventilator parameters for next patient

c. Switch to automatic ventilation (ventilator) mode

d. Fill bellows and breathing bag with O_2 flush and then turn ventilator ON

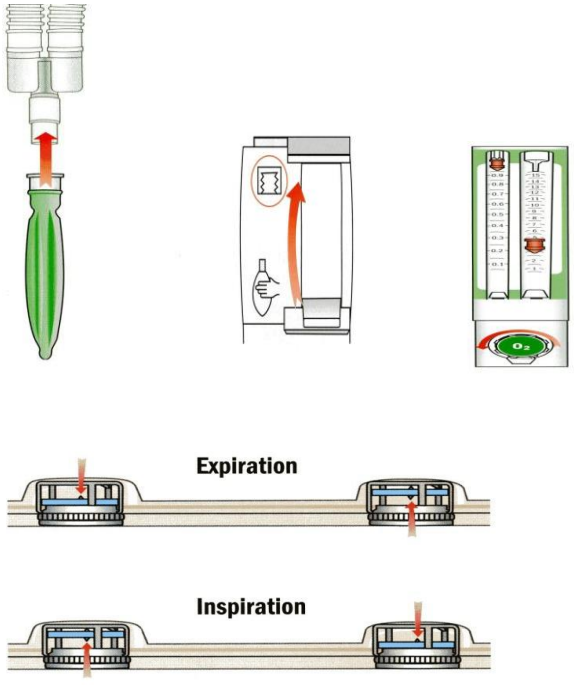
e. Set O_2 flow to minimum, other gas flows to zero

f. Verify that during inspiration bellows delivers appropriate tidal volume and that during expiration bellows fill completely

g. Set fresh gas flow to about 5L/min

h. Verify that the ventilator bellows and simulated lungs fill **and empty** appropriately without sustained pressure at end expiration

i. Check for proper action of unidirectional valves



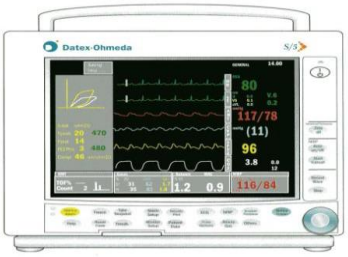
j. Exercise breathing circuit accessories to ensure proper function

k. Turn ventilator OFF and switch to manual ventilation (Bag/APL) mode

l. Ventilate manually and assure inflation and deflation of artificial lungs and appropriate feel of system resistance and compliance

m. Remove second breathing bag from Y-piece

Step 12: Check, calibrate and/or set alarm limits of all monitors:



- Oxygen Analyzer
- Capnometer
- Pressure Monitor with high and low airway alarms
- Pulse Oximeter
- Respiratory Volume Monitor (Spiro meter)

Step 13: Check final status of machine

a. Vaporizers off

b. APL valve open

c. Selector switch to "bag"

d. All flow meters to zero

e. Patients suction level adequate

f. Breathing system ready to use

4.12 Troubleshooting and Maintenance of Anesthesia Machine

Perform appropriate troubleshooting procedure:

- ❖ Check each Tube step by step to locate exact place of leakage
- ❖ Check the Presence of Proper gas supply by regulator or other means and take any necessary action if there is problem.
- ❖ Check Vaporizer Gasket when halothane (Anesthetic gas leak occurs)
- ❖ Check Proper bellow Assembly
- ❖ Check Reservoir bag
- ❖ Check each power supply
- ❖ Check Fuse if the machine cannot run due to power at the Presence of Electric Power
- ❖ If fuse is fine and still the machine cannot run , it is necessary to contact Trained Service Engineer

- ❖ Check each push button
- ❖ Check Monitoring Screen and when Problem occurs contact Trained service Engineer
- ❖ check the Proper fixing of gas hose
- ❖ Check Gas regulator
- ❖ Use mechanical ventilation system to detect leak easily
- ❖ Check APL Valve
- ❖ Check any physical damage in patient Monitoring Probes
- ❖ For any internal Leakage and related Problem; contact Trained service Engineer

Learning activity 4.11:
Duration: 4hrs

Material: Anesthesia machine, training manual, service manual, Gloves, maintenance tools Leak tester, Windex, Teflon, Hose, pressure regulator,

Group Practice:

- Try to troubleshoot the following problems in a group
- When one group troubleshoots the other group must observe what the others are doing!!
- After each trouble shooting observe that how the participants are doing their tasks and how there are handling the machine.

1. The oxygen doesn't seem to be flowing or cannot turn oxygen off on anesthesia machine."

2. "Unable to keep a patient down. The vaporizer setting to 5% and the patient still begins to wake up."

Problem 1:

If you are unable to find a leak and your patients continue to be light, there may be issues with your vaporizer or scavenger system.

Solution:

- If you find a crack in CO_2 absorbing canister or the black tubing, change canister or the black tubing
- If the leak is coming from the dome O-ring area, check to see whether the O-rings are seated incorrectly or cracked.

- Unscrew dome counterclockwise and slip O-ring off dome. Inspect for cracks.
- If you don't see any cracks, place O-ring on top of dome and slide down evenly until it "snaps" into place.
- Screw dome back into place clockwise until tight. Perform leak test again.
- If the leak is coming from the inlet and outlet vaporizer adaptors, they may not be seated properly.
- If the leak is coming from around the base of the Pop-Off Valve, remove the valve, wrap Teflon tape on the threads, and reinstall.
- If the leak is coming from around the rebreathing liter bag, a common problem, check to see whether the bag is cracked or has holes, if so, remove and replace.
- If the leak is coming from the rebreathing hoses, check for cracks and if needed, replace.
- Retest to ensure no leaks persist.

Problem 2:

"I am unable to keep a patient down. I set the vaporizer setting to 5% and my patient still begins to wake up."

Troubleshoot by:

- Performing a leak test. If you find no leaks, check your evacuation system. If there is an imbalance between the positive and negative pressures in your anesthesia system, the anesthetic agent may be effectively removed from your system due to the vacuum effect of the evacuation device.
- Check the vaporizer. It may not be outputting the percentage indicated. When vaporizers fail, they usually fail on the low side and rarely on the high side. But before sending the vaporizer in for service, please check:
- Is the vaporizer is full of anesthetic?
- Are the manifold inlet and outlet adapters pressed snugly onto vaporizer manifold?
- Is the vaporizer's drain tightened down?
- Is the vaporizer fill cap tightened down?

Solution:

- If your leak test shows bubbling, check for leak sources as above. If you find the evacuation system is a problem, you may need a waste-gas interface device to balance the

pressures, ensuring the anesthetic agent is delivered to the patient and not sucked out by the evacuation system.

Problem 3:

"There is a leak somewhere between oxygen tank and the flow meter on the anesthesia system, the high-pressure side of the anesthesia system."

Troubleshoot by: spraying **Windex** on the fittings where you hear the sound. If you have a leak, it will bubble. Here's how:

- Turn flow meter off.
- Turn oxygen tank on so you can watch the pressure regulator rise.
- Turn oxygen tank off.
- The pressure regulator should hold steady. If the pressure begins to fall, you have a leak.

Solution:

- Check the oxygen hose nut. If it is not fully tightened, use appropriate tools to fully tighten.
- **Check the oxygen flow meter flow control assembly** to ensure it is not stuck in an open position. If the ball floats and will not fall to zero, the meter is stuck. Under normal circumstances, this requires replacement of the flow control assembly.

Problem 4:

"The oxygen doesn't seem to be flowing or I cannot turn my oxygen off on my anesthesia machine."

Troubleshoot by:

- Checking to make sure the oxygen tank is on pushing on the oxygen flush to ensure oxygen is flowing to the machine
- Turning mechanical stop flow control and see if ball moves up and down the flow meter. See if ball hovers above zero in the flow meter. If not,

Solution:

- If the oxygen flush and oxygen flow meter are not working and the oxygen tank has been turned on and does have oxygen in it, the regulator or the oxygen tank may need to be replaced.
- **If the ball hovers above zero and does not come to rest at the bottom** of the flow tube, you will need to replace the mechanical stop flow control assembly.

Problem 5:

"My oxygen system is not working correctly."

Troubleshoot by checking:

- The oxygen quick disconnects
- The oxygen check valves in dual gas supply
- The oxygen flush
- For an oxygen leak from regulator
- For improper or insufficient oxygen flush
- For improper or insufficient metabolic oxygen delivered to patient

Solution:

- If no problem is apparent in any of the above, yet you are getting either pressure that is too high or too low, you may need to replace the regulator. The oxygen regulator is a medical grade, preset, non-adjustable regulator designed to reduce oxygen tank pressure from approximately 2100 psi (when full) to approximately 50 psi. If pressure is either too high or too low, your regulator may have failed.

Problem 6:

"The needle on my monometer gauge is not at zero."

Solution:

- The re-zero screw is located at the 12 o'clock position (top, dead-center) under the crystal manometer cover.
- Remove cover by turning counterclockwise. Adjust screw mechanism with small screwdriver until needle is zeroed. Replace manometer cover.
- If manometer will not re-zero, or if needle will not indicate proper pressure, manometer should be replaced.

Problem 7:

"Low/High FiO2 concentration"

Solutions:

- Check Air & Oxygen Supply if sufficient
- Look for possible leaks
- Perform two-point O_2 sensor calibration
- Replace O_2 cell with new one

- Acceptable variance – (+/- 5% concentration)

Problem 8:

"High/Low Tidal Volume as per the preset values"

Solutions:

- Check medical gas if sufficient
- Look for possible leaks
- Clean the flow valves (Ins. & Exp. Valves)
- Perform flow sensor calibration
- Replace flow sensors

Learning activity 4.12:

Duration: 2hrs

Material: Operation room close,

Site visit:

Visit Operation room to see the setup of operation room and if you observe any inconvenient discuss in a group.

Discuss in your group what you observe from your visit?

4.13 Calibration

4.13.1 Vaporizer calibration

Vaporizers should be drained of the liquid agent periodically to rid it of any contaminants that may be present. This drained liquid should be properly labeled and discarded. Halothane contains 0.01 percent thymol which is used to improve the stability of halothane. Thymol tends to accumulate in the vaporizer with time because its vapor pressure is much lower than that of halothane. High concentration of thymol may affect some of the internal components of the vaporizer thereby altering its accuracy. The increased thymol concentration may be noticed because it gives a brown tint to the liquid in the vaporizer.

4.13.2 Calibrate O2 Monitor

a. Ensure monitor reads 21% in room air (remove O2 cell and let it hang in room air to calibrate)

b. Verify low O2 alarm is enabled and functioning

c. Re-install sensor in circuit and flush breathing system with O2

d. Verify that monitor now reads greater than 90%

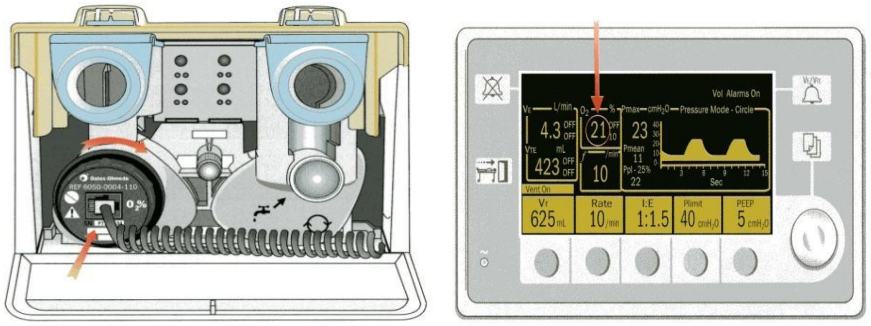


Figure 4.54: Calibrate O2 Monitor

4.14 Safety, proper handling and professional ethics for anesthesia machine:

Table 4.2: Safety precaution

Safety to the Machine	Safety to The Patient	Safety to user
➢ Put in the proper Position ➢ Clean it daily ➢ Protect from dust and Moisture ➢ Power off the Machine at the end of daily Task ➢ Protect from high Pressure ➢ Protect from Mechanical Damage ➢ Don't put any extra equipment's over it. ➢ Check and clean the internal components annually by Trained Service Engineer ➢ Replace consumables and easily damageable Parts by Trained Service Engineer	➢ Make sure that the scavenging system is outside the operation room. ➢ make sure there is no any leak from the vaporizer ➢ Make sure there is no leak in breathing circuit ➢ Do not move the machine at the time of operation ➢ Make sure the functionality of Patient monitoring continuously ➢ Supply sufficient gas to the machine	➢ Make sure that the scavenging system is outside the operation room. ➢ make sure there is no any leak from the vaporizer ➢ Protect yourself from Electrical shock i.e make sure every power cord is safe. ➢ Be care full from mechanical damage Biohazards damage, Chemical damage …

4.15 Maintenance guide

Table 4.3: Maintenance guide

Failure	Possible cause	Remedy
O2 supply pressure is low	1. The oxygen supply pressure is less than normal pressure. 2. The pipeline falls off. 3. HI pressure sensor board failed or sealing ring is broken. 4. System control board failed. 5. Gas circuit module has leakage.	1. Adjust the oxygen supply pressure to the appropriate range. 2. Check the connection of the pipeline and re-connect. 3. Replace the hi-pressure sensor board or sealing ring. 4. Replace the system control board. 5. Check the leakage of the gas circuit module.
N_2O supply pressure is low	1. The N2O supply pressure is less than normal pressure 2. The pipeline falls off. 3. HI-pressure sensor board failed or sealing ring is broken. 4. System control board failed. 5. Gas circuit module has leakage.	1. Adjust the N2O supply pressure to the appropriate range. 2. Check the connection of the pipeline and re-connect. 3. Replace the hi-pressure sensor board or sealing ring. 4. Replace the system control board. 5. Check the leakage of the gas circuit module.
Flow meter can not open and close the gas flow	The input gas pressure is abnormal or there is no gas input. The flow meter is damaged.	Check the tubes of the gas input end. Replace the flow meter.
Breathing circuit is not installed	1. The circuit is not installed or is not installed in place. 2. The switch in transfer block failed. 3. The wire from the switch to gas circuit control board failed or connection failure. 4. Gas circuit control board failed.	1. Reinstall the circuit assembly and make sure it is installed in place. 2. Replace the switch 3. Check and replace the connection wire 4. Replace the gas circuit control board.
The pressure or tidal volume does not reached to set value	1. Breathing circuit leakage 2. Patient manometer broken 3. Flow sensors are damaged 4. Pressure/Flow sensor board failed	1. Reinstall the patient breathing circuit or check In/Ex valve. 2. Replace the manometer 3. Check and replace the sensors 4. Replace the sensor board

4.15.1 Maintenance guide for alarm messages

Table 4.4: Maintenance guide for alarm messages

Alarm Information	Reason and Solution
High tidal volume	➢ The expiratory tidal volume exceeds the upper limit of the alarm settings. ➢ Decrease the set tidal volume or increase the alarm upper limit
Low tidal volume	➢ The expiratory tidal volume is less than the lower limit of the alarm settings. ➢ Increase the set tidal volume or decrease the alarm lower limit
High minute ventilation	➢ The minute ventilation volume exceeds the upper limit of the alarm settings. ➢ Decrease the set tidal volume or the respiratory frequency or increase the alarm upper limit.
Low minute ventilation	➢ The minute ventilation volume is less than the lower limit of the alarm settings. ➢ Increase the set tidal volume or the respiratory frequency or decrease the alarm lower limit
High breathing frequency	➢ The ventilation frequency exceeds the upper limit of the alarm settings. ➢ Decrease the set respiratory frequency or increase the alarm upper limit.
Low breathing frequency	➢ The ventilation frequency is less than the lower limit of the alarm settings. ➢ Decrease the set respiratory frequency or decrease the alarm lower limit.
High inspiratory oxygen concentration	➢ The FiO2 exceeds the upper limit of the alarm settings. ➢ Decrease the oxygen volume of the fresh gas or increase the alarm upper limit.
Low inspiratory oxygen concentration	➢ This less than the lower limit of the alarm settings. ➢ Increase the oxygen volume of the fresh gas or decrease the alarm lower limit.
High airway pressure	➢ The airway peek pressure exceeds the upper limit of the alarm settings. ➢ Check if the ventilation pipeline bent or plugged up, if the pipeline if the pipeline connection is normal, ➢ The inspiratory pressure or the tidal volume should be decreased or increase the alarm upper limit.
Low airway pressure	➢ The airway pressure (pressure waveform data) is less than the lower limit of the alarm settings. ➢ Check if the ventilation pipeline leak or fall off, if the pipeline connection is normal, the inspiratory

	➢ Pressure or the tidal volume should be increase or decrease the alarm lower limit.
continuous high airway pressure	➢ The patient absorber airway pressure has been above the continuous airway pressure alarm limit for ➢ more than 15 seconds. ➢ Check if the pipeline bent, plugged up or disconnected.
Negative pressure alarm	➢ Lower than the atmospheric pressure 10cmH2O. ➢ Check if the patient is breathing spontaneously. Increase the fresh gas flow. ➢ Observe whether there is high speed flow passing through the residual gas purging system. If there is, ➢ Check the negative pressure releasing valve on the receiver.
Suffocation	➢ The two trigger conditions are met at the same time: ➢ The airway pressure has been lower than) PEEP+3）cmH2O for more than 20 seconds. ➢ The expiratory tidal volume has been less than 10mL for more than 20 seconds. ➢ Increase the settings of the tidal volume and respiratory frequency or begin manual ventilation.
Low O2 supply	➢ The oxygen source pressure is low. ➢ Should use or replace the backup cylinder immediately.
Low battery power	➢ The battery power is low. ➢ The system is operable; please connect it to the AC power at once. ➢ If the power supply is cutoff, please use manual ventilation to support the patient breath. ➢ If the battery cannot be charged fully within 24 hours.

4.16 Summary

Chapter summary:

An anesthesia machine is a medical device designed to provide

- Accurate and continuous supply of medical gases mixed with an accurate concentration of anesthetic vapor to a patient.
- Deliver levels of oxygen necessary to sustain life.
- Provide basic patient monitoring
- Safely remove waste and excess gas from the patient.
- Create artificial breathing environment for patient
- It ensures that the patient does not feel pain and minimizes patient discomfort

There are at least four types of anesthesia which are used in medical operating departments of health facilities

- General anesthesia
- Local anesthesia
- Saddle anesthesia
- Spinal anesthesia

Troubleshooting process of solving a problem or determining a problem to an issue it involves the process of elimination, where a technician will follow a set of steps to determine the problem or resolve the problem.

Chapter 5
Autoclave

Duration: 12hrs

Chapter description

This chapter is designed to develop the necessary knowledge, skills and attitude of the learners to the standard required in operating room equipment maintenance for biomedical engineers and technicians. It covers basic working principles, purposes, and main components, troubleshooting techniques and safety procedures for Autoclaves.

Chapter objective

By the end of this session, the participants will be able to maintain autoclaves.

Enabling objective

5. Explain the purpose and clinical application of autoclaves
6. Describe the working principle of autoclaves
7. Identify the basic components of autoclaves and describe their functions
8. Perform appropriate troubleshooting procedure
9. Perform preventive and corrective maintenance

Chapter Outline:

5.1 Introduction

Learning activity 5.1:

Duration: 10min

What is the definition of autoclave?

Autoclaves a pressurized device designed to heat aqueous solutions above their boiling point at normal atmospheric pressure to achieve sterilization. Maintaining autoclaves in proper working order improves productivity, reduces contamination and as well as downtime of the device, extends the life of the autoclave, and helps to ensure overall safety in the workplace. basic programs for autoclaves are sterilizing temperature, sterilizing time and drying time those can be automatically set up by Microprocessor. The most common method of sterilization in health care is by pressurized, high temperature steam. This is the preferred method of sterilization used by health care professionals' world**w**ide, including the World Health Organization, because it is a rapid, simple and effective process. As it does not use any chemical, it is safer and more environmentally friendly. It is also more cost effective than other methods. If air is present in the sterilizing chamber, a satisfactory temperature will not be achieved and pockets of air may prevent penetration of the load of articles by the steam. The air must therefore be removed

5.1.1 General introduction of microbes, Bacterium, Spores

Microbes

A microbe is defined as a general term for a microscopic creature which consists of a protozoan of the animal kingdom and some parts of fungi and bacterial of the thallaspore plant (sometimes the virus is included).

Classification and Reproduction of Bacterium

Bacterium is unicellular and reproduces by unicellular division. Bacterium can be divided into three basic types in its configurations; bulboid bacterium, bacillus bacterium and spiral bacterium. And it can be further classified as negative or positive by Gram Stating. As bacterium reproduces by cell division it may be called schizomycete.

Division

Figure 5.1: Cell Division of Bacterium

Generation

Bacterium divides itself on a continuous periodical basis. This cycle of division is called Generation. The necessary time from the first division to the second is called "Average Generation Time".

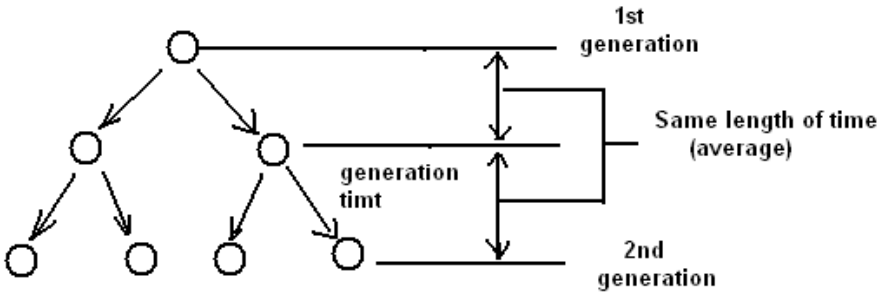


Figure 5.2: Generation of Bacterium

The approximate average generation time for coli bacillus is 20 minutes, hay bacillus is 30 minutes, and staphylococcus is 30 to 40 minutes and tubercle bacillus is 18 to 24 hours.

Spores

Certain types of bacterium, mainly Gram-Positive bacillus, from a ball- shaped configuration with a coat when it is placed in an improper atmosphere. The bacterium spore is a dormant type and has the strongest heat resistance of all creatures existing on earth.

Definition of Extinction and Extinction of Bacterium

When a bacterium no longer reproduces under the optimum conditions (nutrients, temperature, pH), we define it as extinct. When a bacterium changes irreversibly, we call that change "**extinction**'. That is why it is important to use an Autoclave which is strong heated container used for chemical reactions or serialization processes using high pressures and temperatures. Autoclaving changes the biological character of the wastes or microorganisms to reduce or eliminate its potential for causing disease and the purpose of an autoclave in the operation room or laboratory is to sterilized contaminated material.

5.2 Purpose and clinical application of autoclave:

Sterilization autoclaves are widely used in microbiology, medicine, podiatry, tattooing, body piercing, veterinary medicine, mycology, funeral homes, dentistry, and prosthetics fabrication. A medical autoclave is a device that uses steam to sterilize equipment and other objects. This means that all bacteria, viruses, fungi, and spores are inactivated.

Figure 5.3: Use of autoclave in medicine

In dentistry, autoclaves provide sterilization of dental instruments. Instruments can be kept, once sterilized using a vacuum autoclave for up to 12 months using sealed pouches. Autoclaving is often used to sterilize medical waste prior to disposal in the standard municipal solid waste stream. This application has become more common as an alternative to incineration due to environmental and health concerns raised because of the combustion by-products emitted by incinerators.

5.3 Principle of Sterilization and Disinfections

Bacterium is a unicellular creature and the main ingredient of its cytoplasm is **protein**. If an Irreversible change takes place inside a bacterium, whether by heat or chemical, its function will be halted and it will perish. If we boil and egg or add acid to milk, they will harden. We call this change **"coagulation of Protein".** If we expose bacteria to heat for sterilization or disinfections, they will be destroyed because the protein which is the main ingredient of the cytoplasm becomes coagulated and loses its mobility. In other words, wet heat sterilization and disinfections, which are the most popular sterilization methods today, utilize coagulation of protein. A wet heat method is therefore more effective in sterilization than a dry heat method.

Sterilization

Sterilization is a process whereby all micro-organisms, including heat-resistant bacteria spores, are removed or destroyed. Sterilization is recommended for all items penetrating the skin or which will be in contact with broken skin and mucous membranes or entering otherwise sterile body areas. This includes equipment such as surgical instruments, implants, dressings, gowns, catheters, wound irrigation fluids, syringes, needles and other items which may pierce the skin or be in contact with open wounds.

Sterilization cycle

When the correct temperature in relation to the pressure used has been reached, the sterilization cycle is commenced. Sterilization can have two or more cycles.

a. First cycle

It is an initial vacuum, which is created and held for about 5 minute, followed by the admittance of steam to the chamber. When the selected temperature/pressure has been reached in the chamber, a second vacuum is created.

b. Second Cycle

Here is the steam is admitted to the chamber again and raised to select temperature /pressure. the temperature and time at which all parts of the load must be held and it is advisable to increase composite holding times and temperatures allow this margin of safety.

c. Final cycle

The steam is released from the chamber, and the materials, are dried in a vacuum for 40 minutes to an hour.

Temperature/time and pressure/time diagram sterilization cycle.

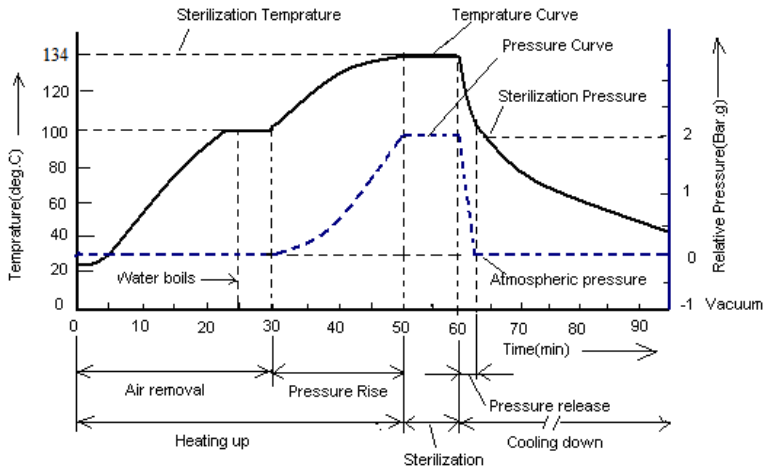


Figure 5.4: Temperature/time and pressure/time diagram of a typical sterilization cycle of n autoclave

Sterilization is done here at 134○C for a period of 10 minutes.

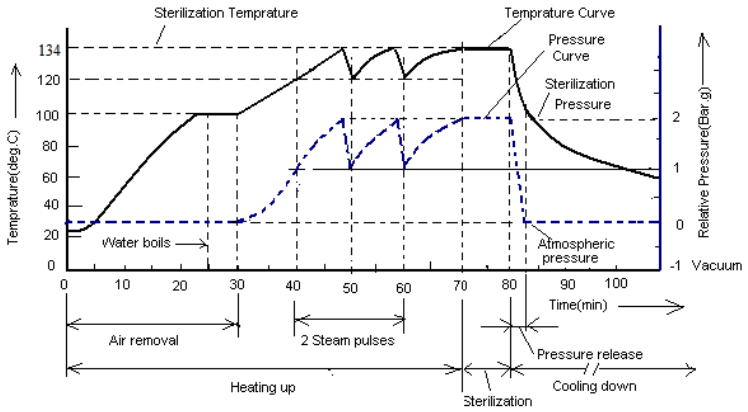


Figure 5.5: Temperature/time and pressure/time diagram of a typical sterilization cycle of an autoclave

Sterilization is done here at 134○C for a period of 10 minutes.

Disinfection|: The process of removing or destroying microorganisms to a level which is safe for some purpose but not for all is called disinfections. With this method heat resistant spores will not be destroyed. Disinfections such as phenol, cresol, detergent, etc. are well known.

Classification of sterilization and disinfections methods

1. Physical Methods {time, pressure, Temperature)

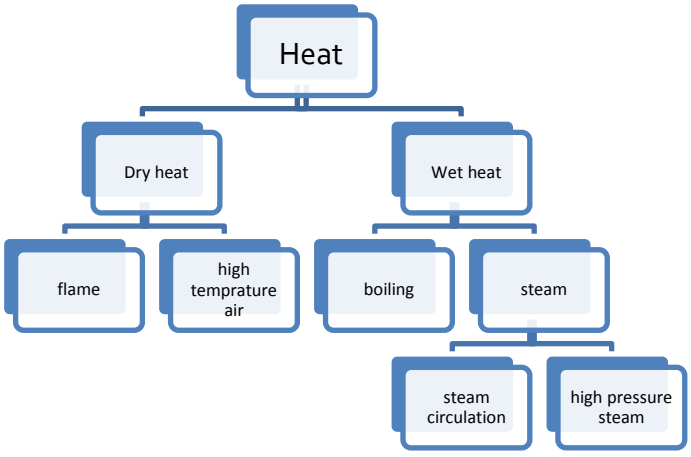


Figure 5.6: Physical Classification Method

2. Chemical Methods

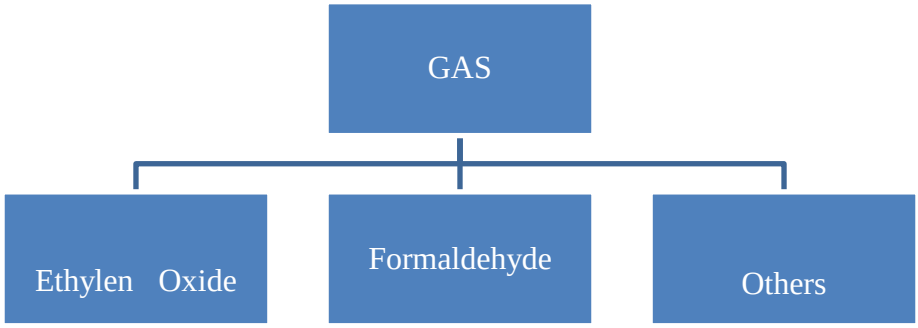


Figure 5.7: Chemical classification method

5.4 Working principle and purpose of autoclave

Autoclaves work by taking advantage of the thermodynamic properties of water which can be considered as the branch of science concerned with the relations between heat and other forms of energy involved in physical and chemical processes. Autoclaves use high pressure steam and boiling water mixed with chemicals to achieve sterilization or the killing of microorganisms. When heat is used as a sterilizing agent, the vibratory motion of every molecule of a microorganism is increased to levels that induce the cleavage (sharp division) of intermolecular hydrogen bonds between proteins and the result would be the death of organisms caused by an accumulation of irreversible damage to all metabolic functions of the organs. A type of autoclaves uses gravity displacement to circulate high pressure steam through autoclaving material.

Learning activity 5.2:

Duration: 2min

Video lecture

1. Working principle of autoclave video for autoclave\Horizontal autoclave-sterilizer AH-1200T (operating principle animation).mp4

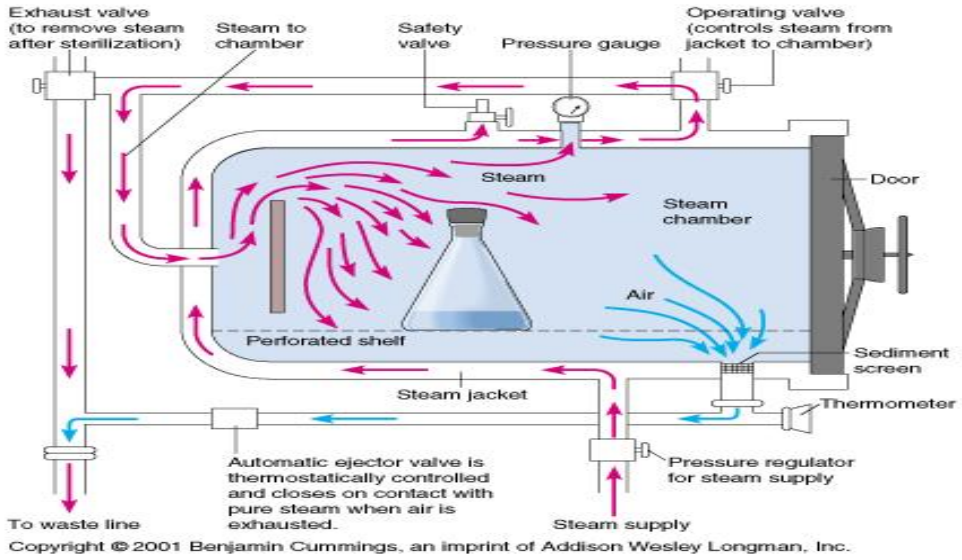


Figure 5.8: Gravity displacement autoclaving process

1. Operation of autoclave

Why is an autoclave such an effective sterilizer? An autoclave is a large pressure cooker; it operates by using steam under pressure as the sterilizing agent. High pressures enable steam to reach high temperatures, thus increasing its heat content and killing power. Most of the heating power of steam comes from its latent heat of vaporization. This is the amount of heat required to convert boiling water to steam. This amount of heat is large compared to that required to make water hot. For example, it takes 80 calories to make 1 liter of water boil, but 540 calories to convert that boiling water to steam. Therefore, steam at 100¼ C has almost seven times more heat than boiling water. Steam is able to penetrate objects with cooler temperatures because once the steam contacts a cooler surface; it immediately condenses to water, producing a concomitant

1,870 fold decrease in steam volume. This creates negative pressure at the point of condensation and draws more steam to the area. A condensation continues so long as the temperature of the condensing surface is less than that of steam; once temperatures equilibrate, a saturated steam environment is formed. Achieving high and even moisture content in the steam-air environment is important for effective autoclaving.

The ability of air to carry heat is directly related to the amount of moisture present in the air. The more moisture present, the more heat can be carried, so steam is one of the most effective carriers of heat. Steam therefore also results in the efficient killing of cells, and the coagulation of proteins.

Death rate is directly proportional to the concentration of microorganisms at any given time. The time required to kill a known population of microorganisms in a specific suspension at a particular temperature is referred to as thermal death time (TDT). All autoclaves operate on a time/temperature relationship; increasing the temperature decreases TDT, and lowering the temperature increases TDT.

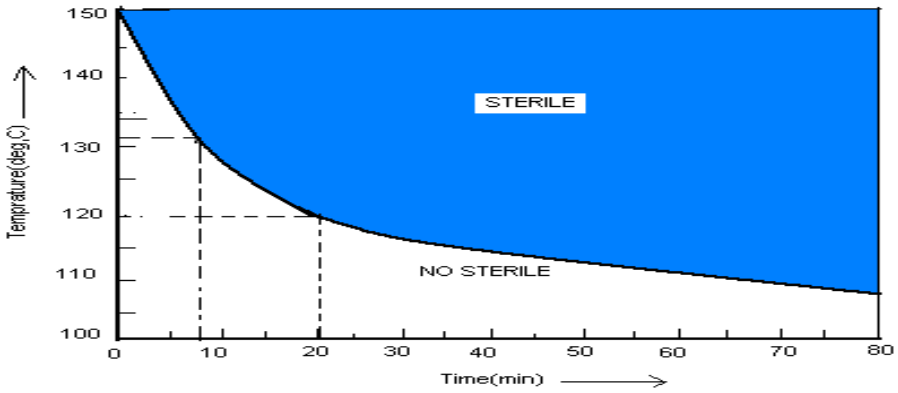


Figure 5.9: Thermal death curve for steam

Learning Activity 5.3:

Duration: 10 min

Group discussion:

Which one is preferable more and why?

- Processes conducted at high temperatures for short time or lower temperatures for longer times.

Basically, steam enters the chamber jacket, passes through an operating valve and enters the rear of the chamber behind a baffle plate. It flows forward and down through the chamber and the load, exiting at the front bottom. A pressure regulator maintains jacket and chamber pressure at a minimum of 15 psi, the pressure required for steam to reach 121¼C (250¼F). Over pressure protection is provided by a safety valve. The conditions inside are thermostatically controlled so that heat (more steam) is applied until 121C is achieved, at which time the timer starts, and the temperature is maintained for the selected time.

How to achieve perfect sterilization every time is obviously an important issue. Improperly autoclaved materials results in contamination, lost time, and wastes money. There is no simple formula for how long a certain item needs to be autoclaved to achieve sterility. Consideration must be given to the type of primary container (the beaker or flask or packet containing the item to be sterilized), the volume of liquid, amount of solid material, and the secondary container (such as a tray containing the primary container).

Operation cycles during autoclaving

i. Preparation cycle

- Turn the cycle select lever to the position of vacuum
- Put the water in the boiler till 80% level with opening the water supply valve
- Close the water supply valve after finishing it
- Put the cycle select lever to complete door closing handle
- Put sterilizing materials into chamber
- Turn the door handle after turning the door lever till downward position
- Turn the switch of safety breaker ON
- Select the switch of sterilizing pressure. High ($2kg/cm^2$ = 132ºC) or Low ($1kg/cm^2$ =121ºC) even if it depend on our autoclave specification
- Turn the power switch ON. Lightened power pilot lamp, heater pilot lamp and heating element is started
- Raised up the jacket pressure gauge in 20-30 minutes at high ($2kg/cm^2$ = 132ºC) or Low ($1kg/cm^2$ = 121ºC)

ii. Vacuum cycle

- Shift the cycle select lever to vacuum position
- Switch the vacuum switch in the ON after confirming of jacket pressure raised up on the jacket pressure gauge
- Exhaust the air of the chamber enough till chamber pressure on the chamber pressure gauge is decreased to -200 to -400cmHg

iii. Sterilizing cycle

- Switch the vacuum switch OFF
- Shift the cycle select lever to sterilizing position after confirming of chamber pressure gauge
- Chamber pressure is raised up till the setting pressure point on the chamber pressure gauge reaches
- Temperature of thermometer is raised up till the setting temperature after reached the setting pressure point.
- Make sterilization for a certain time after reached the setting temperature high ($2kg/cm^2$ = 132ºC) or Low ($1kg/cm^2$ = 121ºC)

iv. Exhaust cycle

- Shift the cycle select lever to exhaust position
- Make sure that the chamber pressure on the chamber pressure gauge is exhausted to around $0kg/cm^2$

v. Drying cycle

- Shift the cycle lever to dry position and switch the drying switch ON after chamber
- Pressure on the chamber pressure gauge is decreased to around $0kg/cm^2$
- Vacuum dry is made keeping the negative pressure around -50 to -100 cm Hg on the chamber pressure gauge
- Switch the drying switch OFF and shift the cycle select lever to completion position after drying enough

vi. Complete cycle

Take the sterilized materials out with opening the door after confirmation of chamber pressure, $0kg/cm^2$ on the chamber pressure gauge In case of repeat use for the unit, confirm the water level of boiler and make an operation. From preparation cycle turn the power switch OFF and put the

cycle select lever to the position of Vacuum Open the exhaust valve slightly to make exhaust and drainage. Put the cycle select lever to the position of complete. Turn the switch of safety breaker OFF after confirmation of jacket pressure, 0kg/cm² on the jacket pressure gauge.

Steam vapor condenser

The temperature of steam vapor, exhaust and drainage (high temp.) are decreased to 40ºC to 60ºC with the help of steam vapor condenser

This steam vapor condenser is operated automatically by thermal regulator as long asthe safety breaker is not switched off

Operation of Air removal process

It is very important to ensure that all of the trapped air is removed from the autoclave before activation, as trapped air is a very poor medium for achieving sterility. Steam at 134 °C can achieve in three minutes the same sterility that hot air at 160 °C can take two hours to achieve. Methods of air removal include:

a. Downward displacement (or **gravity-type**): As steam enters the chamber, it fills the upper areas first as it is less dense than air. This process compresses the air to the bottom, forcing it out through a drain which often contains a temperature sensor. Only when air evacuation is complete does the discharge stop. Flow is usually controlled by a steam trap or a solenoid valve, but bleed holes are sometimes used, often in conjunction with a solenoid valve. As the steam and air mix, it is also possible to force out the mixture from locations in the chamber other than the bottom.

b. Steam pulsing: air dilution by using a series of steam pulses, in which the chamber is alternately pressurized and then depressurized to near atmospheric pressure.

c. **Vacuum pumps**: a vacuum pump sucks air or air/steam mixtures from the chamber.

d. Super-atmospheric cycles: achieved with a vacuum pump. It starts with a vacuum followed by a steam pulse followed by a vacuum followed by a steam pulse. The number of pulses depends on the particular autoclave and cycle chosen.

e. Sub-atmospheric cycles: similar to the super-atmospheric cycles, but chamber pressure never exceeds atmospheric pressure until they pressurize up to the sterilizing temperature.

Learning activity 5.4:

Duration: 4 min

Lecture with video

1. Autoclave sterilization cycles AUTOCLAVES DE ESTERILIZACIÓN 02.mp4

5.5 Types of Autoclaves

There are four types of autoclaves:-

- **Positive Pressure Displacement**

  This type is the improvement of downward displacement type. The steam is created within a second in separate unit (steam generator). The steam is released to the sterilization chamber to start the sterilization progress.

- **Negative Pressure Displacement**

  This type is one of the most recommended types of autoclave sterilizer. It is very accurate and it can achieve high sterility assurance level. The disappointing fact is that sometimes the system is too large and too expensive.

- **Downward Displacement**

  This unit is also called as the gravity displacement autoclave. This unit heats water that becomes steam. The steam then forces the air in the chamber to go through the drain hole. The drain hole is closed once the temperature is sufficient for the serialization process to begin.

- **Triple Vacuum Displacement**

  This type is similar to the negative pressure displacement type. This unit is named "triple vacuum" because there are three process of removing the air and the steam's pulse. This unit is perfect to sterile any kind of instruments.

Based on devices don't use a vacuum for removing the air from the chamber, and feature with a special vacuum pump

Type "N" or type "B", you can find type "N" or type "B". Type "N" does not use vacuum to remove air from the chamber. Contrary, type "B" uses vacuum pump in operation. Type N

devices are suitable for solid unwrapped instruments, whereas type B ones are used for hollow and wrapped instruments.

Wet and Hot Air Sterilizer

Hot air sterilizer:

It is used to sterilize instruments or materials with heated and forced Air.

How it works: The materials to be sterilized are loaded in the chamber and the door is locked properly. The thermal regulator is adjusted to the required working (sterilizing) temperature. (Different materials need different sterilizing temperatures and time up to 200ºC and 2 hours). Then put ON the power supply. This time the heating elements and the fan motor start working. The heated air will be forced to circulate inside the chamber resulting in the materials being heated equally (uniformly). The temperature rises till it reaches the set temperature and cut OFF the power to the heater, but the fan motor remains functional till the end of the program. After the heaters goes OFF sterilization time starts to count, the temperature will reduce to a certain value then the heater goes ON again and temperature rises to the set value and again goes OFF. The temperature will remain stable within a certain tolerance till the set time elapses, and after the sterilization time ends the unit will shut OFF. Then by opening the door the sterilized materials can be taken out.

NOTE: - When opening the door care must be taken from getting burns from the heated air i.e. unlock and slightly open the door and wait for some time then open totally and take of the materials out.

Steam (Wet) autoclave (steam under pressure)

Steam sterilization is the most inexpensive and effective method of sterilization. Steam under pressure permits permeation of moist heat to porous substances by condensation and results in destruction of all microbial life. This is the usual method of sterilizing surgical instruments, dressing, drapes, swabs, laps sponges and culture media**.**

5.6 Basic components of autoclave and their function

Figure 5.10: components of steam autoclave

I. Heating elements

Heating system: Steam generator is used to boil water to 100ºC and above to get steam 134ºC which suitable to kill all kind of germs and viruses for high temperature steam autoclave .For the gas sterilization, the steam generator is used to create the gas vapor at a range between 52ºC to 78ºC by mixing the sterilization solution like formaldehyde and distilled water, by abruptly pouring the mixture to the high heated plates. The heating element can be:

- Internal heating system
- External heating system

Heating Element Circuit In portable autoclaves line switch, line-on-indicator, thermostat switch, heater-on- indicator, and double heating elements are used.

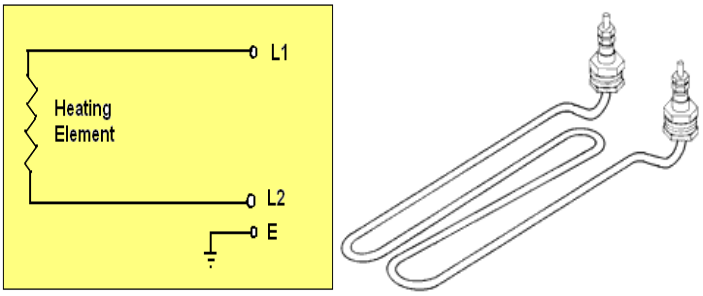


Figure 5.11: Heating element direct supply Circuit

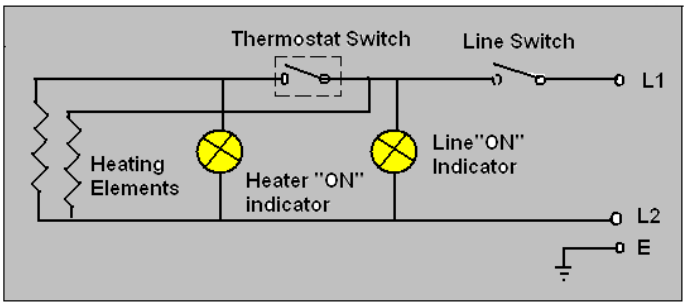


Figure 5.12: Double heating element with thermostat switch

Types of heating elements

Air Heating Elements

Air heaters can be used for almost any air-moving application. These types are commonly used for convection or with fans & blowers for heating cabinets and other spaces. Many sizes are available to match industry standard components. This group includes both the original patented Zigzag style heater and self-regulating PTC heaters.

Contact Heating Elements

Contact heaters are used in direct contact with the part to be heated. The possible uses include heaters that are inserted into a blind hole, mounted to a surface, clamped in place or even embedded in a casting.

Flanged Immersion Heating Elements

Immersion heaters are usually used to heat liquids in a tank. This is most effective method to heat a container of fluid. This group includes many OEM replacements for industry standard water boilers, steam generators, autoclaves and sterilizers.

II. **Temperature controllers:**

Thermometer indicates the chamber temperature

III. **Pressure controller**

Located on the upper part of the control unit, and will control and maintain the pressure in the Chamber and jacket within the range

- **Chamber pressure gauge:** It indicates the positive chamber pressure
- **Jacket pressure gauge:** Indicates the jacket pressure in kg/cm

IV. Valves

Vacuum solenoid valve

During this time the chamber temperature raised quickly

Water supply valve

Closes the valve after confirming that the water level is reached

Drain Valve (water drain valve)

It drains the water from the boiler

Drying Valve (Dry air Valve)

This valve opens when drying cycle starts

The hot air entering through the valve can be adjusted

Safety Valve

Ensures safety and installed at the water storage tank and directly connected to the chamber with piping. In case the inside pressure of the chamber goes up more than desired values, the safety valve is to be open to discharge the steam into the tank.

Electromagnetic Exhaust Valve

When sterilization process is completed, electromagnetic exhaust valve is to open to return the steam and hot water in the chamber to the water storage tank. The drain filter installed in the chamber is to prevent dirt flowing into the electromagnetic valve. If the electromagnetic valve is closed, steam in the chamber shall remain inside even sterilization process is completed and drying cannot properly be performed.

V. Switches

Drying Timer and Main Switch

Function as the drying timer and main switch. When sterilization is performed, the knob is to be set to "sterilization" position. If drying is performed, desired drying time is to be set with the knob

Limit Switch

Located at the back of door cover and shall be ready to function when door is closed correctly with "click" sound. Power is not ON, when the door not closed properly

Door Switch

Door switch is to be used when the drying is required to be completed in a short time. With completion of sterilization process, steam shall be automatically exhausted and pressure gauge is to indicate "0". After confirming that the pressure gauge is showing "0", the switch is to be set to the "drying" position. The door handle is to be loosened a little by turning to counterclockwise, to let the remaining steam gush out of the door. By removing the remaining steam from the chamber, efficiency of the drying shall be improve

Vacuum Switch (per/vacuum switch)

When you turn ON it in vacuum cycle, the vacuum pump is operated with opening vacuum switch

Drying Switch (Dry/vacuum switch)

When you turn ON the switch in the dry cycle, vacuum pump is operated with opening drying solenoid valve to put the air for dry in to chamber.

VI. Chamber

Sterilization chamber

Single wall chamber-Has direct heating system

Double wall chamber has indirect heating system

The inside view of autoclave chamber consists of

1. Sterilizer container
2. Basket
3. Basket support
4. Dressing drum
5. Heating elements

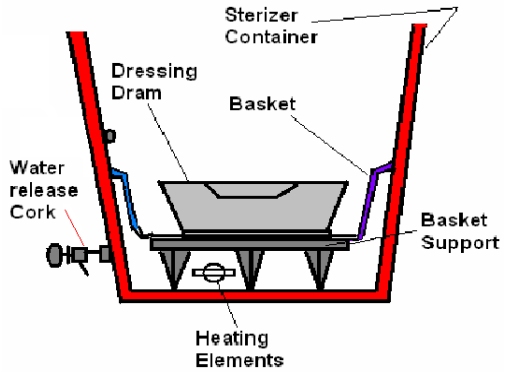


Figure 5.13: inside view of autoclave chamber

VII. Water storage tank

Made of stainless steel and has a capacity of water containing depend on each models follow instructional manual to fill it. Adding water through it will depend on quality of water and conditions of the operations.

VIII. Steam Trap

It is fitted directly at the back of the chamber and functions as air discharge unit. When the chamber is filled with steam generated, the air inside the chamber is squeezed out through the steam trap. When the temperature in the chamber goes up to 100ºC water in the chamber is mostly changed to steam. The heat form the chamber is conducted to the steam trap and its air discharge valve is to be closed. The inside of the chamber shall be of saturated condition with Steam.

IX. Vacuum pumps

A vacuum pump sucks air or air/steam mixtures from the chamber.

1. Internal/inbuilt vacuum system

2. External vacuum system

Pre-Cycle Vacuum: Improved air removal as repeated vacuum pulses draw trapped air out from difficult loads to be replaced by steam.

Post-Cycle Vacuum: Available on some autoclaves. Repeated post sterilizing vacuum cycles can be used to rapidly cool the load contents, improving cycle times.

X. **Timers**

Sterilization Timer

Analog or automatic type sterilization timer is located at the control panel in front and uses to set the sterilization time. Once the timer is set, the pointer will remain as positioned even the sterilization cycle is processed. If the operation is being performed under the same conditions, no setting of timer is required for the subsequent or following operations.

Dry timer: used to set dry time based on the operation performed

XI. **Air Compressor**

Compressed air required for door seals and control valves on some autoclaves and for air ballasting systems. On many autoclaves an air compressor may already be built in.

5.7 Maintenance procedure of Autoclave

5.7.1 Preventive Maintenance of steam autoclave main components

Valves

There are two primary types of automatic valves used: Valves for steam and valves for other applications like air, water and exhaust. Typically the steam valves will wear quicker than other valves. Steam to jacket valves see the most use as most jackets remain at temperature while awaiting the next sterilization load. Thus the jacket valve is consistently pulsing while maintaining the appropriate temperature/pressure in the jacket. Manual valves like ball valves and needle valves will typically last the life of the stream autoclave.

Heating Coils

Steam autoclave life is highly dependent on incoming water quality and maintenance particularly water hardness, frequency of blow-downs (draining the generator of water and flushing out deposits). With proper boiler maintenance and attention to water quality, heating coils should last five to ten years on average, although decreasing efficiency and performance may be experienced. Depending on water quality, and the number of cycles run, it is recommended to blow down the generator daily or weekly.

Contactors

Contactors are basically high amperage electrical relays and are used on sterilizers equipped with electric steam generators and liquid ring pumps. Switching a high voltage connection on and off is a very demanding function and causes significant wear on the contactors. It is vital to ensure that all high voltage wires are periodically tightened as thermal cycling can cause them to loosen over time. Contactors should be regularly inspected and replaced when there are signs of pitting, heat damage, or excessive arcing on the points. The life of the contactors will depend greatly on the amount of use the sterilizer sees.

Steam Traps

Steam traps are heavily dependent on the quality of the steam delivery system and absence of debris. For facility-supplied steam, a steam trap inspection program should extend beyond the sterilizer to include all of the traps back to the boiler. Although various types of traps can be used in a steam delivery system/steam autoclave, they all perform the same function–removing condensate while allowing the passage of dry steam.

Safety Valves

Safety valves are calibrated and set to be equal to or less than the maximum allowable working pressure (MAWP) of the chamber and/or jacket, depending on sterilizer manufacturer. The MAWP will be shown on the stamped vessel plate visibly located somewhere on the vessel exterior. This is the final fail-safe device for the pressure vessel should all electronic controls fail. Therefore, it is imperative that the safety valve is inspected, tested and verified to be in proper working condition based on the recommendation of the sterilizer and/or valve manufacturer as well as local inspection and insurance agencies. It is common practice to inspect and test safety valves on a regular basis.

Controls

The controls should last the lifetime of the device assuming they are protected from excessive heat, humidity, and electrical noise/surges/spikes. Although devices vary, in most cases the backup battery should be replaced every 3-5 years to avoid loss of memory or programs. The electrical connections should be covered or within an enclosure to avoid direct contact with water, steam (when the door is opened, for instance), or vapor from the drain or other devices in the same area. Items like control screens may be located above the chamber door provided they are adequately protected from heat and excessive moisture. In rare cases where software updates are

required, modern controls can typically be updated via laptop software, USB port, or remotely via an internet/Ethernet connection.

Vacuum pump

Vacuum pumps should last the lifetime of the steam autoclave. Hard water can cause a build up to occur within the pump decreasing efficiency and placing greater strain on the motor and impeller. It is possible for the impeller to become nicked by debris that passes through the strainer and the impeller can become imbalanced. Monitor solid goods such as animal bedding that can be drawn through the drain by ensuring that the chamber drain strainer is clean and in good condition. Occasionally, pump bearings will wear depending on usage. If pump maintenance is needed, trained service technicians can often easily clean the pump head and replace worn components.

5.7.2 Regular Preventive maintenance before operation

- Check periodically that the electrical wiring is as per prescribed rules and the instrument for any current leakage
- Examine the cable for any damage and replace if it is damaged.
- Check periodically kettle connectors, power plugs, heating elements for any breakage or fault. Replace if defective
- Examine heating element and inside of the instrument body for any unwanted deposits and clean them
- Examine rubber packing on the lid and replace if defective
- Examine hinges for their proper working and lubricate them periodically
- Examine periodically supports, tray and handles for any defective and replace/repair if defective
- Check periodically leakage of water through heating element system for flow outside the body and arrange proper packing

Daily:

Before using the autoclave:

- Fill with distilled or dematerialized water. Clean rain water can be used in emergencies. Do not use water which has a high mineral or salt content as this will corrode the sterilizer and instruments.
- Check that the machine is not damage and does not have any leaks.
- Check that the electricity supply/gas ring/kerosene burner is ready for use

- Check that the chamber is clean after previous use.
- Make sure that you follow the correct instructions for each type of load (non-porous load, porous load or fluids)
- When running the autoclave, check that the appropriate temperature and pressure are reached by checking the gauges (if your autoclave is equipped with a thermometer and pressure gauge)
- Keep the autoclave clean; prevent damage due to cleaning. Do not use abrasive powders, metal cleaners or bleaches as they will damage the surface

Weekly:

- Check that the door opens and shuts easily. Lubricate the hinges if necessary as described in the manufacturer's handbook.
- Test the performance of the autoclave with its load by using indicator strips.
- Check the lid/door gasket for any deterioration or damage.
- Check that all valves turn easily and are not leaking.

Every three months:

- When the autoclave is under pressure: check that the safety valve opens and blows off Steam when activating the test lever.
- The autoclave technician should carry out a complete examination of the autoclave. User entries in the logbook over the previous three months can be used as a reference for possible necessary repairs.

Daily preventive maintenance, inspection for high pressure steam sterilizer

1. If rust, dust and others are found in the chamber, remove them immediately. As the rust by salt water spreads rapidly, takes sufficient care to it.

2. Clean sometimes the exhaust outlet strainer in the chamber. Stuffing with dust deteriorates drying and retards rise of sterilization temperature.

3. Clean or exchange the air filter periodically Stuffing with dust deteriorates drying and retards returning of the inner pressure to the normal pressure.

4. Conduct the air leak test. Conduct it periodically about once per week and inform a person in charge if there is anything unusual.

5. Clean the strainer sometimes

When newly building a hospital or repairing piping, clean the steam supply strainer until dust, scale and other cannot be found in it.

Other strainers should be cleaned once or twice per year.

6. Inspect the steam trap

7. Test the function of safety valves.

8. Check Cycle-indicating lamp includes

5.7.3 Corrective maintenance

Before and after any maintenance it is important to know how to assemble and disassemble each component step by step;

Dismantling and Assembly for maintenance

Before dismantling, if the autoclave is under pressure, always open the steam release cock and wait until pressure has come to zero

Drain out water from the instrument completely by opening the drain plug once in a fortnight to remove sediments

During dismantling check rubber gasket. Rubber gasket should normally check periodically.

The instrument should be at normal temperature and pressure when the lid holding nuts are moved anticlockwise

The autoclave can be dismantled for cleaning, servicing and repair

1. Replacing door gasket

The silicone rubber gasket is the most excellent material as a gasket for high pressure steam sterilizer. However, it is very weak to shock. Sufficient care is necessary for handling (exchanging) it.

- Before removing the old gasket, check the width, thickness and length of a new one. If the gasket is a little shorter, it will not cause any inconvenience.
- Remove the old gasket. In this instance, clean dust, fouls and others in the groove, Check also damage of the groove.
- Place the new gasket in to the groove and flatten the surface by patting it lightly. If the gasket projects from the groove, push asbestos yarn supplementary to the side of the gasket to fix it. If the gasket remarkably sinks, spread the yarn under it. When pushing the gasket into the groove, don't use a tool with an acute angled tip such as a screw driver. Take care so that the gasket is not damaged.

- Lock the door once lightly. If the (entry) of the radial locking arm is insufficient, repeat the procedure described in item 3.
- After confirming the (entry) other radical locking are. Introduce steam and check the state of locking. In this case, do not lock excessively.
- Make operation several times for confirmation. Any leak is often caused by pushing the gasket partially too much. Pick up such portion to flatten it.
- Check generally each part of the door.

The hardness of gasket

The replaced gasket is sometimes broken by locking the door too strongly when the new

Gasket has any unevenness. Never fail to flatten it before operation.

The gasket should be exchanged in one to three years generally through its life varies with the conditions of use.

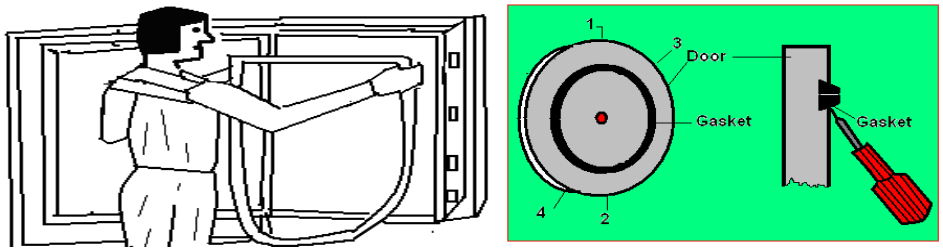


Figure 5.14: Repair gasket

Insert a tip of flat screw driver in to a gap between the gasket and the body then twist the gasket to take it out and Fix a new gasket in to order of 1 to 4 and press down the whole part

5.7.4 Corrective maintenance guide

Table 5.1: Possible frailer in manually or automatically operated autoclave and their remedy

No	Symptom	Cause	Remedy
1	Water is not flowing in to steam generator	a- water supply valve not opened b- pipe line after supply valve blocked by sedimentation c- Feed pump not functional	a- open the water supply valve b- remove steam generator and clean the entire vessel c- Check for pump motor, electric supply like fuse, contactor, over load relay etc. and repair or change defective parts.
2	Jacket pressure does not increase to	a- Heating element not functional b- Main steam supply valve not open c- Low pressure in central source d- Incorrectly adjusted pressure	a- Check for heating element, water level sensor or contactor. Change for defective parts b- open main steam supply valve

	the stetted level or does not increase at all	governor to the required level. e- Steam supply strainer closed f- The setting pressure of the reducing valve is too low g- Trap valve (condensing pot) not closing	c- secure the required pressure from the central source d- Adjust if not replace pressure governor e- Remove the cap of strainer and clean the inside net f- Turn the adjustment handle to the right to raise the pressure (turning to the left lowers the pressure) g- Check for gap generated with dirt's between the valve and valve seat. Clean or if below perforated change the trap.
3	Steam keeps blowing through Safety	a- Excessive pressure in central source b- cock valve closed or clogged at the reducing valve balancing pipe c- Dirty valve seat d- Lame valve spring	a- Stop immediately the operation. Set pressure governor to the required level. b- Keep reducing valve cock fully open or clean if clogged /closed/ c- Blow the valve through, should thus not help dismount the valve and clean the seat. d- Replace it.
4	Steam enter into chamber during the preparation step	Sterilization valve leaks due to dirt or foreign matter engagements	Stop the operation or put off the heating element wait for jacket pressure reaching "0" dismount the Valve, clean the valve and valve seat assemble and start the unit. If is the same, change the sterilization valve.
5	No vacuum in the chamber Vacuum pump not working Vacuum pump ok	faulty motor, cut off circuit breaker, faulty contactor a- clogged out let hole in the sterilizer b- Vacuum pump rotation reversed c- No water or main water supply valve closed d- Water supply solenoid valve not Opening.	Detect the frailer and replace defective parts. a- clean out piping line, including valves b- correct the direction by changing the connection of 2 lines among 3 c- Stop the operation fill water comes or open the main water supply valve. d- check for the power supply for the solenoid or if defective replace it,
6	Sterilization pressure (chamber pressure) not reaches the specified pressure level.	a- Is the main steam pressure all right? b- Is the sterilization valve fully open? c- Is the sterilization solenoid valve open? d- Is the exhaust valve not closing? e- Is the steam trap (condensing pot) out of order?	a- check and adjust the pressure governor (pressure switch) to the setting pressure. b- Check for the valves and maintain c- Check the power supply for the valve or if valve defective replace it. d- Dismount the valve, inspect or clean valve and valve seat, if valve is defective change it. e- Inspect, clean or replace.

7	Steam leakage around the door seal at a closed door(during sterilization cycle)	a- Is the door handle not tightened sufficiently? b- Is the door gasket aged or is there dirt or scare?	a- make the retightening work a little more. b- If the damage or ageing is clear, replace the door gasket.
8	The sterilization timer after being started once, is reset halfway	Is the main steam pressure lowered than the sated pressure during sterilization operation	Refer to the main steam pressure gauge and confirm the desired pressure level, When the temperature is lower than the set temperature, the sterilization temperature controller will reset Instantaneously or after 2 minutes after the set temperature is achieved again. Sometimes if temperature decreases even at the last second of the sterilization time, it will start to count from"0" or repeat the sterilization cycle.
9	No drying operation is made at all	Is the vacuum pump functioning?	Refer to #5 of troubles at vacuum step
10	Drying condition is poor(article is wet)	Are articles to be sterilized loaded too much?	Make sure that the articles to be sterilized are loaded with as much allowance as possible.
11	The door cannot be opened after the sterilization cycle is completed.	a- Does the sterilization compound pressure gauge show "0"? b- Does the air inlet solenoid valve functions properly? c- Air filter may be clogged	a- wait until the sterilization compound pressure gauge shows "0" * Be sure to keep the switch at ON position(don't put OFF) b- Check for supply to the solenoid valve, if valve is defective replace c- Clean the air filter or replace filter.
12	The autoclave does not heat up	a-electrical problem b- Fuel problem if heated by fuel or gas.	a- check the power supply, fuse and other electrical parts b- Check the fuel supply; check that the burner or stove is clean, that is positioned correctly under the autoclave and that it is not in a strong draught.

Learning activity 5.5:

Duration: 5 min

Let the trainees to answer the following question

1. How Steam& Water Quality damage or affect performance of autoclave?

Answers:

Steam and water quality contribute the most notable impacts. Ensuring that the equipment is fed saturated steam with acceptable dryness and particulate levels is vital. Particulates can damage valves and cause steam traps to fail prematurely. Water quality is also critical. Hard water in the form of calcium carbonate can cause scaling of heating elements, plumbing components, and sterilizer surfaces. Scale buildup will decrease the efficiency of the heating elements significantly—causing components to work harder and reducing life expectancy. Chlorides in the water source can be particularly damaging even to high quality stainless steel and can lead to corrosion, pitting, and other damage of the metal.

5.8 Troubleshooting and repairing for autoclave

Troubleshooting is a process of solving or determining a problem to an issue. It involves the process of elimination, where a technician will follow a set of steps to determine the problem or resolve the problem.

Learning activity: 5.6:

Duration: 30min

Materials: working tools, PPE, service manual, multi meter (analog and digital multi meter)

- ✓ What do you do when the boiler is not heating up what will be the cause?
- ✓ Measure and read the resistance value of the thermal fuse and how interpret the reading (when you are using analog and digital multi meter)?

Generally caused by no power to the boiler .In most cases, the Thermal Fuse has blown. The thermal fuse is located under the boiler. The fuse is contained inside the wire insulation, so it

looks like a wire…and not a normal fuse. Simply test it for continuity. To check the thermal fuse for continuity, disconnect the fuse assembly from the main PC board by removing the wire. Then measure the resistance of the thermal fuse assembly. An "open" reading signifies the fuse is bad and must be replaced. Be sure to reconnect the wire on the main PC board pin. If the Thermal Fuse is good, then you will need to proceed with the next steps.

Answers:

If using an analog meter and the needle doesn't move (stays to the left - the reading is infinity), this means Thermal Fuse is bad and replacement is required. If it approaches zero, Thermal Fuse is good and is not the source of the problem you are experiencing on a digital meter, if the reading is "1", Thermal Fuse is bad and replacement is required. If the reading approaches zero, Thermal fuse is good and not the source of your problem.

Figure 5.15: Thermal fuse

Important note: To avoid damaging the new thermal fuse assembly tries to identify the cause of the failure. There are a number of causes for thermal fuse failure. This could be caused by a weak water pump, steam leaks, faulty thermocouple, and or malfunctioning steam generator (also known as the boiler) (which may require cleaning or calibration).

5.8.1 Troubleshooting autoclave components

Staining:

You need to only used distilled water inside your autoclave. Tap water includes minerals and additives that could literally be baked onto your instruments by the hot steam. Clean the steam line filter according to the manufacturer's directions and wipe out the inside from the autoclave following each and every use to stop build-up. You need to also separate various metals having a tray liner and thoroughly clean all instruments ahead of loading them in to the autoclave.

Temperature problems:

If the temperature does not rise, or it rises then drops during the cycle, the drain line or strainer are probably plugged. The drain line permits air to escape as the pressure inside the chamber increases. In the event the air can't escape, cooler pockets of air form inside the steam which prevents it from reaching the optimum temperature.

Pressure problems:

If the pressure doesn't rise or it fluctuates, again, check the drain line or strainer. If they're clogged it is going to avert the release of air from the chamber and which will trigger the pressure to drop or fluctuate.

Damp equipment:

Excessive moisture in your equipment in the finish in the cycle normally indicates all you have to do is enhance the dry time. It really is also essential to create confident you happen to be not over-loading your autoclave. Follow the manufacturer's guidelines for load limits.

Cracks in chamber:

You ought to never use unauthorized chemical compounds within your autoclave. Uses distilled deionized water only or adhere to the manufacturer's instructions. By no means are use bleach or other harsh chemical substances or you able to damage the interior.

Steam escapes:

Steam escaping from around the door throughout the cycle indicates a worn gasket which it is possible to easily replace oneself.

Water in chamber:

Water within the chamber in the finish of the cycle normally signals a blocked or clogged drain. If clearing the drain doesn't care for the issue it may be that you just want a new valve for the drain line. This can be a thing that is easily handled correct there within your workplace and you can do it oneself with just several basic steps.

Low heat

Possible causes for this message are:

- No power to the Heating Elements
- Bad Heating Elements
- Very low line voltage delaying heat up

- Safety Thermostat is opening prematurely, turning off the Heating Elements (This only applies to units with Microprocessors dated earlier than T93N5 or T93N6)
- A clogged Air Jet
- An Air Outlet Valve is stuck closed

Low temperature

Possible causes for this message are:

- Insufficient water in the Chamber (see Low Water message)
- The sterilization phase of the cycle has been set for too long a period of time, allowing the Chamber water to boil away, and the Chamber to run dry
- The Safety Thermostat is opening prematurely, turning off the Heating Elements (this only applies to units with Microprocessors dated earlier than T93N5 or T93N6)
- A bad Temperature Sensor

Low pressure

Possible causes for this message are:

- Insufficient water in the Chamber (see Low Water message)
- The Heating Elements not cycling on and off properly
- Problem with the Solid State Relay
- Problem with the control circuit
- Bad Heating Elements -- not producing enough wattage
- The Safety Thermostat is opening prematurely, turning off the Heating Elements -- this only applies to units with Microprocessors dated earlier than T93N5 or T93N6
- A bad Pressure Transducer

Fuses

Fuses are an important facet to troubleshooting autoclave problems like in any other electrical device, to protect electronics from being damaged by things like electrical shorts.

Learning activity 5.7:

Duration: 20min

Group discussion:

Share ideas in a group for the following case

1. You have got a call from CSR department for autoclave maintenance and you replaced fuse with you have got locally but they are blown out shortly after installing them. This leads you to believe something is causing them to blow….like an electrical short somewhere within the autoclave. While an electrical short is possible, what do you think in most cases the new ones are blowing?

They will have markings like: 2A 250V.This means the fuse is rated at 2 Amps and up to 250 Volts. So, do you think, all 2 amps, 250v fuses are the same….right?

Wrong! What is missing is the fuses reaction time – that is, what happens (how long) before the fuse blows? All fuses in your autoclave will have one or two letters in front of the amperage rating. These letters are extremely important and tell you what their reaction time is. Not matching the fuses with the proper reaction time is where everyone goes wrong. It is always good to look at the fuses location on the circuit board to make sure you get the right fuse. Let's take a look at what the readings on fuse might look like as showing a rating of **F 2A 250V.** Since we already know what the 2A, 2 50V means, the letter F should be our focus. So what are these letters and what do they mean? The first letter(s) (TT, T, M, F, and FF) tell you what type of fuse it is and what you should be looking for

FF = Fast Fast. Very Quick Acting. (also known as Anti Surge)

F = Fast. Quick Acting (also known as Anti Surge). Typically open in less than 20 ms at ten times the rated current

M = Medium. "Normal" or Very Short Delay (Typically open between 50 and 90 msat ten times the rated current)

T = Time. Time Delay or Slow Blow Typically opens between 100 and 300 ms at ten times the rated current

TT = Time. Long Time Delay or Very Slow Blow.

Figure 5.16: Fuse position on board

Air Compressor

The Air Compressor was making loud noise. The instruments were coming out wet both of these items together tell us there is definitely a problem with his Compressor. The biological filter is on the autoclave to remove any remaining living organisms from the air before sending it on into the cassette keeping the sterilized instruments sterile so it is recommended to change or cleans it.

Learning activity 5.8:

Material: multi meter, heater, working tools

Duration: 20min

Individual response and practice

1. The users told you that to complete all sterilization cycle it took too long, what will you do to solve this? How do you test the heating element?
2. How to test autoclave heating elements**?**

Heating Elements

The fact that a heating element shows continuity does not tell you whether the heating element is good, only that there are no breaks in the wiring.

This test consists of measuring the amount of resistance in the element. To do this, first, turn the autoclave off and unplug it from the wall

WARNING: CURRENT MUST NOT BE PRESENT WHEN MEASURING RESISTANCE.

Next, determine what the resistance value is because the resistance value determines heating capacity of the heater. If you need, or want, to calculate them on your own you can use formulas below.

Set your volt/ohm meter on 200 ohms. The ohms range is located within the Omega (Ω). Place a probe from the volt/ohm meter on each wire where it connects to the Write the readings for the heating element to be good, it must fall within a range of (+) or (-) 10%. For example, if the heating element you are testing has a resistance value of 9 ohms, the range is 8.1 to 9.9.

Electrical Formulas Needed For Testing the Heating Elements

Figure 5.17: Heating Elements

Symbols:

V=Volts

A= Amps (Current)

W=Watts

R = Resistance (measured in OHMS)

To find the number of Volts, the formula is:

V = (A) x (R)

(Volts is equal to the number of Amps multiplied by the number of Resistance (ohms)

Example: A Heating Element Pulling 13.333 Amps with a Resistance Level of 9.000 OHMS

V=(13.333) x (9.000) = 120 Volts (rounded Off). So the heating element is for a 120 Volt unit

To find the number of Amps, the formula is:

A = (W) / (V)

(Amps is equal to Watts divided by Volts)

Example: A 1600 Watt, 120 Volt Heating Element

A = (1600) / (120) = 13.333 Amps. So the heating element is Pulling 13.333 Amps

To find the Resistance, the formula is

R = (V) / (A)

(Resistance is equal to the number of Volts divided by the number of Amps)

Example: A 120 Volt Heating Element is Pulling 13.333 Amps

R = (120) / (13.333) R = 9 Ohms (Resistance is measured in OHMS) So the heating element has a resistance value of 9.000 OHMS

To find the number of Watts, the formula is

W = (V) x (A)

(Watts is equal to the Number of Volts multiplied by the number of Amps)

Example: A 120 volt heating element is Pulling 13.333 amps

W = (120) x (13.333) W = 1600 Watts (Rounded Off)

Pressure Leak

A pressure leak is any leak of steam, air or water within the autoclave. Here are the four most common causes Pressure Leak:

1. A faulty Door or Dam Gasket

If you can see steam coming out anywhere around the door, the door or dam gasket is the cause and they both should be replaced

2. A faulty Air Valve

A properly functioning Air Valve removes air from the chamber. When it senses air, it opens and allows air from the chamber to pass through to the Water Reservoir When it senses steam, it closes and seals the chamber. When the Air Valve is defective on the Autoclave, it either will not close, or will not open, or opens to soon.

Figure 5.18: Air Valve

3. A faulty Vent Valve

The Vent Valve is designed to open at the end of the cycle, allowing the steam to enter the condensation coil inside the Water Reservoir Once the steam travels through the coil, it is cooled down enough to return the from a gaseous state, back into the liquid state (water)

4. A faulty Fill Valve

The fill valve opens at the beginning of the cycle and shuts off and seals when water touches the Water Level Sensor located inside, finding a leaking valve will require a little more investigation, but is not difficult.

How to Find the Faulty Valve on Your Autoclave?

The first thing you will need to do is remove the side where you put the water in. Once the panel is removed, you will see the reservoirs, the Inside the reservoir, you will see the condensation coil. There is a hook on the end of the reservoir that sticks out above the water line. The end of that hook is one of the places you are going to be watching (a dental mirror can come in handy First, look for bubbling coming from the bottom of the reservoir. If you see bubbles, then the fill valve is defective and needs to be replaced. If you do not see bubbles, then start watching the end of the hook on the coil.

Table 5.2: Trouble shooting guide for autoclaves

DEFECTS	CAUSES	ACTION
Pressure rises above the marked Line	Bore in pressure regulating valve may be dirty	It has to be cleaned
Steam cannot be clearly heard escaping from the valve	There is not enough water in the sterilizer	Check water level and in case of shortage, put water up to level
Steam is constantly escaping from the side of handle by lid release knob	Lid release valve is dirty or defective	Press the lid release knob several times, in order to clean the escaping release valve by the escaping steam. If steam is still escaping from the side of the handle, remove the lid release valve from inside the lid and replace it by a new one
Steam or water comes out from underneath the lid	The gasket is either dirty or not correctly placed or defective	Replace it by dry clean gasket and place it correctly
Instrument not working	a) Main power supply not available b) Power supply wall plug socket defective c) Power supply cable assembly defective d) Kettle connector defective e) Heating Element defective	a) Check the input power source, b) Check, repair or replace c) Check, repair or replace d) Check, repair or replace e) Check, if defective replace with element of proper rating
Instrument body giving shock	Defective power cable	Test, make proper connections,

	connections, heating element insulating packing worn out, insulated legs worn out	replace packing and insulated legs
Steam or water leaking from	Packing has became defective	Repair or replace
Power lamp does not light	a) No power supply from wall outlet socket b) Power cord may not properly be plugged in	a) Check power supply b) Check power cord connection
	c) Door is not closed insufficiently d) Door switch may be "drying" position	c) Close the door tightly until "click" sound d) Set the switch "sterilization" position
	e) Power lamp may be defective f) Circuit breaker may be off position	e) Replace the lamp f) Press the red button on the breaker
No water supply to sterilizer	a) No water or insufficient water in water storage tank b) Water supply valve may be defective	a) Fill the tank with sufficient water b) Replace the valve
Heater does not function Properly	a) Wire breaking or disconnection of heater b) Wire breaking or disconnection of relay coil	a) Replace the heater b) Replace the coil
Pressure does not rise even after 30 min	a)Thermostat may not be properly adjusted or defective b) Steam Trap may be defective (pressure in chamber shall be exhausted)	a) Re- adjust the thermostat or replace it b) Replace the valve or its element cap
	c) Electromagnetic valve may not	c) Clean the valve

	function properly (Water in chamber shall be drained out)	
Even though pressure reaches to designated level sterilization cycle does not start (timer lamp does not light)	a) Insufficient supply of water into chamber b) Malfunctioning of thermostat c) Failure in adjustment of pressure controller	a) Supply water to required water level b).Adjust the thermostat c) re- adjust the pressure controller
Pressure continues to rise even sterilization cycle started	a) Failure in adjustment of pressure controller (Bellow) a) Pressure controller may be defective c) Safety valve may be defective	a) Re- adjust the controller b) Replace the controller c) Adjust the safety valve or replace it
Inner pressure does not come to "0"even sterilization time is over	a) Sterilization timer may be defective b) Drain filter may be locked c) Electromagnetic valve may not function properly	a) Replace the timer b) Clean the filter c) Clean the valve or replace it
Drying timer does not function (timer knob does not return automatically to the position)	a) Timer knob may be stuck to the panel b) Timer may be defective	a) Adjust the knob (loosing screw) b) Replace the timer
Sterilized objects found Burns	a) Drying time might have been longer b) Sterilizing objects might have been placed directly on hurdled rest c) Failure in thermostat adjustment	a) Adjust the drying time b) Place the objects always in dressing drum or tray c) Readjust the thermostat

Pressure rises during drying cycle	a) Electromagnetic valve may be defective	a) Replace the valve
Leakage of the steam from the door	a) Gasket for the door may be defective b) Teflon washer for lock bolt may be defective	a) Replace the gasket b) Replace the Teflon washer
Buzzer does not sound	a) Coil for buzzer may be defective b) Contact point of drying timer may be defective	a) Replace the buzzer b) Replace the timer
Buzzer sound during drying cycle	buzzer of electromagnetic valve may be defective	Dismantle the valve and clean
Power is not cut off even after drying cycle is over	Contac point of drying timer may be defective	Replace the timer
Incomplete drying	Adjustment of thermostat may not be satisfactory	Re-adjust the thermostat

5.9 Performance testing

Performance testing is the testing, which is performed, to ascertain how the components of a system are performing, given a particular situation. Resource usage, scalability and reliability of the product are also validated under this testing. so it establish the benchmark behavior of the system.

How to Test the performance of autoclaves?

Sterilization test must periodically be performed by using living bacteria to conform the function.

Do not relay completely upon chemical indictors. Sterilization of goods is a process in which the sterilizer, the sterilization process and the load all influence the result. The performance of an autoclave for each different type of load must be tested by using the appropriate process.

Table 5.3: Performance Testing

Performance tests	**How to use**	**Remarks**
Sterilization tape	The tape is used as adhesive tape for packaging, or can be stuck on the load as a "was sterilized" indicator.	A line of heat/moisture sensitive ink on the indicator tape has been color when the tape has been exposed to a steam sterilization processor. It cannot be used as a real performance indicator as it does not indicate whether all Sterilization conditions were met. When ordering, specify that the tape is to be used for a steam sterilization process.
Maximum Thermometer	Can be put in the most critical location of the load.	The thermometer indicates the maximum temperature which was reached during a process. It does not indicate for how long the temperature was reached and whether it was actually steam which reached this temperature.
Chemical indicators	Indicators can be put in critical location of the load such as the center of a textile pack or inside hollow instruments.	The indicator is usually a small strip of paper or cardboard which has a spot or area with a special ink, which can change color. Various types are available. Some types verify the presence of steam at a special temperature for a minimum period of time. Usually the indicators are designed for fast cycle vacuum sterilization. These are not suitable for the basic non-vacuum sterilizers. When ordering, mention the type of sterilizer and the time/temperature for which you want to use the indicators. 
Sterilizer control tubes	Can be put in critical locations of the load or inside the fluid in a test bottle.	The glass tube verifies that it was exposed to temperature for a minimum period of time by changing color. it does not distinguish between air and steam. Sterilizer control tubes are commonly used for testing performance of sterilization of fluids. Test tubes are available for various sterilization times and temperatures.
Bowie and Disk Test	The test pack should be in the center of the chamber.	Standardized steam penetration test for autoclaves with a vacuum system. It is used to verify the presence of steam at a specified temperature for a minimum time. It consists of a standard size pack of

		folder cotton sheets: approx.22cm (high). A chemical indicator paper is placed in the middle of the sheets, which are put inside the sterilizer and a normal sterilization cycle is run. The indicator sheet will indicate the presence of any air inside the pack by a non-even color change. Mini-bowie and dick test packs are now available which are much smaller than the standard packs. Their main advantage is that they are easy to prepare sheets and fold your own full-size pack.
Biological indicators	Can be put in the most Critical location of the load. 	They are a direct method of checking the performance of a sterilizer as they show the distraction of microbiological life. They do not provide an instant result: they must be incubated or processed to determine pass or fail'. Their reliability depends on strict quality control during manufacture and decreases during storage. This method is not recommended.

Learning activity 5.9:

Duration: 15min

Group discussion

1. How altitude Influence the cycle for sterilization? And which parameters can be adjusted?

Answer:

Pressure decreases as altitude increases. The temperature at which water boils also decreases with the altitude. You must therefore make adjustment in the cycle for sterilization for the altitude at which you are working. Either have to increase the relative sterilization pressure in order to get the temperature of steam, or extend the sterilization time. Increase the relative operating pressure by the amount of pressure reduction caused by the altitude.

Table 5.4: Sterilization Temperature of Different Objects.

Sterilizing temperature		
121 to 123^{0}C	132^{0}C	**Objects to be sterilized**
15 min.	3min	Bottle.....turned upside down an unwrapped Surgical instruments.....only steel instruments, independently of size. Injector.....up wrapped.
15 min.	7min	Surgical instruments.... made of steel and other material Surgical instruments....only steel instruments in the tray.
30 min.	10min	Clothing....wrapped in paper or muslin (calico) Clothing....in cast Injector.....wrapped separately in muslin or paper.
20min	10min	Surgical instruments...wrapped doubly in muslin (calico) Suture.....smaller amount, unwrapped
20min	5min	Rubber gloves....wrapped in muslin or paper

5.10 Calibration, setting and adjustment of autoclave

The calibration must be carried out by professionals. Incorrect use of this function can damage the sterilization process or workers health. It's necessary to have suitable certified equipment to run this operation (for example, thermometer well, sample manometer, etc.). The function of calibration operates on temperature and pressure analogue values, which are detected by the system. Service technicians are trained on the intricacies of calibrating temperature, part thermocouples, vacuum transducers, pressure transducers, and more.

Safety valves are calibrated and set to be equal to or less than the maximum allowable working pressure (MAWP) of the chamber and/or jacket, depending on sterilizer manufacturer. Adjustment of Safety Valve The safety valve is the most critical part of the Autoclave to maintain safely.

In order to keep the fixed pressure spring in the housing has precisely been adjusted by Spring Nut and Lock Nut (engraved as needed pressure on the surface of the housing)

Hence, DO NOT TOUCH Spring Nut and Lock Nut!

After years of operation of autoclave, silicon gasket may cause wear (and tear), which may require the replacement.

In case of replacement of the safety valve, it should be replaced completely by new.

Date and time setting

Set the "sterilization Timer and dry timer" to desired sterilization time.

Circuit Breaker Reset:

When a breaker faces an abnormal voltage, the red button installed on the rear will trip out. After checking and remedying the cause, push the red button down. Then the breaker will be reset

5.11 Safety precaution and proper handling for Autoclave

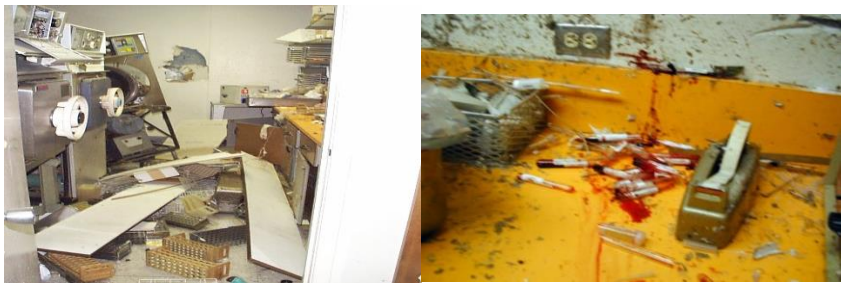


Figure 5.19:: Autoclave explosion

Learning Activity 5.10:

Duration: 1hr

Group discussion and sharing idea among the group, site visit

1. Did you face any problem regarding to safety of autoclave? Discuss in a group and tell for others groups
2. Assume there are autoclave room, clean area and inspection/packaging area where should the autoclave installed? (Answer: The autoclave should be installed between the inspection/packaging area and the clean area)
3 .How explosion of autoclave will be occurred Fig.5.19?
4. Visit central sterilization room.

5.11.1 Safety Guidelines when using autoclaves

1. All personnel using autoclaves should be adequately trained by an experienced user. During operation, Standard Operating Procedures should be used and posted near the autoclave and followed.

2. The maximum operating temperature and pressure of the autoclave should never be exceeded. Refer to the manual for the autoclave, includes operating instructions.

3. Use only type 1 borosilicate glass bottles. Do not use ordinary glass bottles or any container not designated for autoclave use.

4. Do not use plastic containers that will melt or distort during autoclaving. Use autoclavable containers.

5. Place items to be autoclaved in a stainless steel tray or autoclave able container to retain any accidental melting of any containers or overflow from heated liquids.

6. Autoclavable plastic bags containing waste should be placed in secondary containers to retain it far away or other liquid waste that may accidentally leak through the bags.

7. Electric autoclaves should have a proper earth connection.

8. All testing should be done after disconnecting the power supply cable and the instrument from the power supply.

9. For performance test, after repairs, always be sure that sufficient quantity of water is poured in to the instrument such that the heater element is well immersed, or else the heater element will burn-out immediately.

When you are using a paraffin- heated autoclave:

1. Immediately wipe up any accidentally spilled fuel with a rag to avoid a fire hazard

2. Make sure there is sufficient ventilation.

3. Do always make sure there is sufficient water inside the chamber. Heating up without enough water can damage the autoclave beyond repair and may cause great danger to the operator.

4. Do check for steam leakages around the lid, valves and piping.

5. Do make for sure that the clamps/fastening bolts of the lid can be secured tightly.

6. Do make sure that personnel operating the equipment are well trained and understand their duties properly.

7. Do keep unauthorized people away from the sterilization department.

8. Do take great care when opening the lid, as the load may still be very hot, even after a period of cooling down.

9. Do not interrupt the sterilization cycle unless there is an emergency. Of a cycle is Interrupted, the whole cycle has to be started again from the beginning.

10. Do not leave the autoclave unattended when in use.

When sterilizing fluids:

1. Do not open the air-removal/pressure-release valve at the end of the sterilization time. Let the autoclave cool down by itself.
2. Before opening the lid, do make sure that the temperature inside the fluid has reduce to 80ºC.
3. If you cannot measure the temperature inside the fluid: let the autoclave cool down overnight.
4. Never touch drainage tap or outlet valve while heating under pressure.
5. Never touch the safety valve while heating under pressure.
6. Never heat too quickly to bring up the pressure, once the outlet valve has been closed.
7. Never leave the autoclave unattended while the pressure is rising.
8. Never leave the autoclave to cool too long. If it is left for several hours without the Outflow valve being opened, a vacuum forms and the sterilized material may break.
9. Never open the lid when there is steam; otherwise it will come on the face of the operator and may cause injuries.
10. Never put loose cloth packages in the chamber, always use dressing drums.
11. Avoid using hard water.
12. Never put cold water in to a hot autoclave otherwise casting shall crack,
13. All testing should be done after disconnecting the power supply and the instrument from the power supply.
14. For performance test, after repairs, always be sure that sufficient quantity of water is Poured in to the instrument such that the heater element is well immersed, or else the Heater element will burn-out immediately.

5.11.2 Personal protective equipment's during operation and maintenance of autoclave

PPE is defined in the Personal Protective Equipment at Work Regulations as: 'All equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work which protects them against one or more risks to their health and safety'.

- Eye Protection
- Lab Coat,
- Buttoned
- Closed-toed Shoes
- Heat-resistant Gloves

5.11.3 Loading the Autoclave

- Load materials to allow efficient steam penetration
- Autoclave clean items and waste separately
- Do not allow material to be autoclaved to touch the sides or top of the chamber

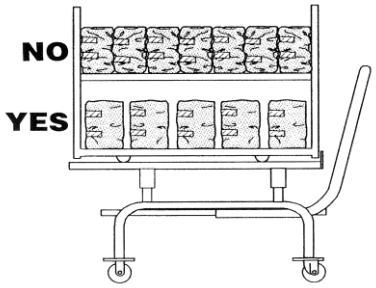


Figure 5.20: Loading and Un-loading of the Autoclave

- Put on Personal Protective Equipment
- Allow the autoclave to completely finish cycle
- Pressure gauge must read zero
- Verify cycle conditions were met
- Open door slightly to allow steam to escape
- Allow contents to cool before removal
- Carefully remove items
- Be especially careful with fluids and plastic bins

5.12 Summary

Summary of the chapter

- Autoclaves are widely used in operating departments of health facilities. Medical autoclave is a device that uses steam to sterilize equipment and other objects.
- There are four types of sterilizations using steam sterilizers positive pressure displacement, negative pressure displacement, downward displacement, and triple vacuum displacement.
- Majorly we can mention the following components for autoclaves heating elements, temperature controllers, pressure controllers, valves, chamber, water storage tank, steam trap, vacuum pumps, timers, air compressors.
- There are many procedures we should follow whenever we operate and maintain an autoclave
- Troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device.
- One should follow different steps to perform both preventive and corrective maintenance on autoclave machines which is one of operation medical equipment.

Chapter 6
Patient Monitoring System

Duration: 12hrs

Chapter Description

This chapter is designed to develop the necessary knowledge, skills and attitude of the learners to the standard required in operating room equipment maintenance for biomedical engineers and technicians. It covers basic working principles, purposes, and main components, troubleshooting techniques and safety procedures for patient monitoring system.

Chapter objective:

By the end of this session, the participants will be able to know how to handle, install, and maintain patient monitoring system.

Enabling objectives:

By the end of this chapter the participants will be able to:

- Describe the clinical uses and importance of patient monitoring system
- Describe the working principle and main parts of patient monitoring system
- Demonstrate and apply safety maintenance procedure of patient monitoring system
- Demonstrate basic preventive and corrective maintenance procedure of patient monitoring system

Chapter Outlines:

1.1.Introduction
1.2.Purpose and clinical application of patient monitoring system.
1.3.Working principle of patient monitoring system.
1.4.Basic Parts /Components and Functions of patient monitoring system.
1.5.Safe handling procedures of patient monitoring system
1.6.Troubleshooting techniques and repair of patient monitoring system.
1.7.Maintenance Procedure for patient monitoring system.
1.8.Summary

6.1 Introduction

Patient Monitoring devices are used to monitor patient's physiological parameters such as Electrocardiogram (ECG), respiration rate (RESP), blood oxygen and carbon dioxide saturation level (SPO2 and CO_2), non-invasive and invasive blood pressure (NIBP and IBP), and temperature (TEMP) continuously in a dynamic and long-time range. It is used in various hospital rooms such as Operation Room, Coronary Care Unit, Intensive Care Unit, and Neonatal Intensive Care Unit to provide additional information to medical and nursing staff about the physiological condition of the patient. This chapter discusses about the purposes/clinical applications, working principles, basic components, and the safe handling, troubleshooting, and maintenance procedures/techniques of a general patient monitoring device.

6.2 Purpose and clinical application of patient monitor

Learning activity 6.1:

Time: 5min

Explain the purpose and clinical applications of a patient monitoring device.

Patient monitoring can be defined as "Repeated or continuous observations or measurements of the patient, his or her physiological function, and the function of life support equipment, for the purpose of guiding management decisions, including when to make therapeutic interventions, and assessment of those interventions. Monitoring is an integral part of the care process together with the administration of therapy. The primary aim of monitoring is to ensure that appropriate care or therapy can be given prior to the onset of complications. Monitoring is therefore a tool that provides early indication of changing patient status, and allows for early intervention, but is also a means by which the effect of interventions and therapies may be recorded, evaluated and controlled.

Generally patient monitoring system is a system for the acquisition of patient parameters, which are processed and presented in an instantly-recognizable form on a variety of displays, these parameters include the continuous noninvasive monitoring of the electrocardiogram, respirations, arterial oxygen saturation level (SPO_2), arterial CO_2 level, blood pressure (NIBP) and temperature. Insertion of specialized catheters enables continuous invasive monitoring of arterial blood pressure (IBP), central venous pressure, pulmonary arterial pressure, right and left atrial pressure, intracranial pressure, and intermittent calculations of stroke volume, systemic and

pulmonary vascular resistance, and cardiac output. Arrhythmia detection algorithms are the first advances to take advantage of improved computer power and use real-time R wave and ventricular arrhythmia detection algorithms to identify and detect cardiac ventricular arrhythmias with a sufficient sensitivity and specificity.

6.3 Working principle

Generally the functions of patient monitoring systems are detecting/sensing, transducing, processing, recording and displaying of the various physiological parameters of the patient (see figure 6.1 which indicate the system block diagram of patient monitoring system). The Detection/sensing of physiological parameters are accomplished by measuring the change in physiological signals that emanate from the patient through the use of some biosignals sensing elements/biosensors.

The working principles of those sensors are by detecting the change in:

- **Bioelectrical signal** of the body through measuring the potential difference between electrodes which can be used for further extraction of information about the electrical activity of the heart/ECG
- **Biomechanical signal** of the chest by measuring the impedance between two electrodes which can be further processed to extract information about the respiration rate/RESP.
- **Bo optical signal** of the blood by sending a light wave at two different band width/ frequencies and measuring the reflected light wave through optical sensors to extract information about the blood oxygen and carbon dioxide concentration (SP02, CO2) level and pulse rate.
- **Bio autistic signal** of the blood by measuring/estimating the systolic and diastolic pressures within the blood vessels by measuring the change of the pressure within blood pressure cuff along with the volume of the arteries and calculating the average. This helps to extract information about the patient blood pressure and blood flow rate.
- **Patient temperature** using temperature sensors to detect temperature.

In general, a transducer is defined as a device capable of converting one form of energy or signal to another. In patient monitoring system, each transducer is used to produce an electric signal that is an analog of the phenomenon being measured. In most systems the transducing and sensing elements are integrated together as a transducer/sensor component. The sensing element just detects a change in the physiological parameter of the patient and the transducing element

converts it to an equivalent electrical signal. In patient monitoring system independent set of transducer/sensor elements are used for measuring each individual physiological parameters of the patient such as temperature, pressure, flow, $SPO_{2,}$ RESP, or any of the other variables that can be found in the body, but its output is always an electric signal.

The part of the patient monitoring system that amplifies, filter, modifies, or in any other way changes the electrical output of the transducer is called signal-processing (or signal-conditioning) equipment. Signal-conditioning equipment is also used to combine or relate the outputs of two or more transducers. Thus, for each item of signal-processing equipment, both the input and the output are electric signals, although the output signal is often greatly modified with respect to the input. In essence, then, the purpose of the signal-processing equipment is to process the signals from the transducers in order to satisfy the functions of the system and to prepare signals suitable for operating the display or recording equipment that follows. To be meaningful, the electrical output of the signal-processing equipment must be converted into a form that can be perceived by one of man's senses and that can convey the information obtained by the measurement in a meaningful way. The input to the display device is the modified electric signal from the signal processing equipment. Its output is some form of visual, audible, or possibly tactile information. In the patient monitoring system, the display equipment includes a recorder that produces a permanent record of the data. It is often necessary, or at least desirable, to record the measured information for possible later use or to transmit it from one location to another, whether across the hall of the hospital or halfway around the world.

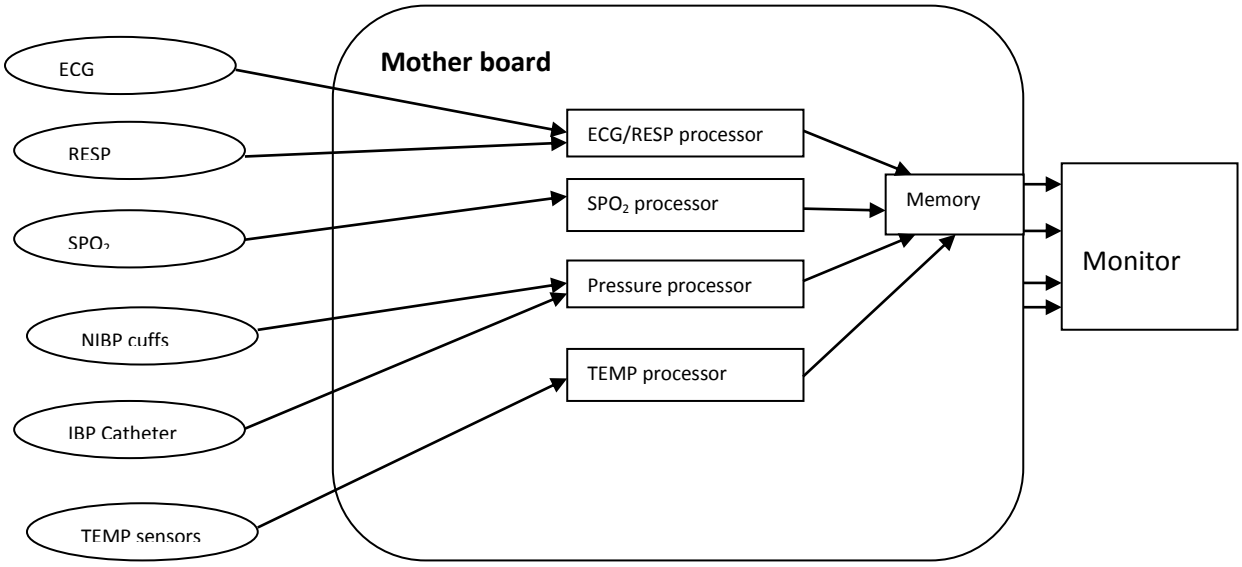


Figure 6.1: System block diagram of patient monitoring system

Learning activity 6.2:

Time 5min

Discuss the detection mechanism of the following physiological parameters:

6.4 Basic components of a patient monitoring device

Leering activity 6.3:

Time 5min

List out basic parts of P.M.S?

The major components of a patient monitoring system are:

- Power unit
- ECG measuring electrodes
- Respiration rate measuring electrodes
- ECG/RESP processing module
- SPO_2 measuring transducer
- SPO_2 processing module
- Temperature probe
- Temperature module
- NIBP/IBP measuring transducers
- NIBP/IBP processing module
- Monitor
- Alarm system

6.4.1 Power unit

This unit of the patient monitoring system supplies the required electrical power to all components of the system. Its input is an AC power from external socket outlet. Most of the time built-in rechargeable and maintenance-free batteries are found inside the power unit of patient monitoring systems to enables continuous working when AC power is off.

The most common elements of the power unit are fuse, transformer and rectifier. The fuse prevents the flow of over current to the system than the rating of the system by damaging itself.

The transformer steps up or down the input voltage to the rating voltage of the system depending on the power rating of the system and the external input socket outlet. The rectifier unit converts the output AC power from the transformer to a rectified DC output.

6.4.2 ECG measuring electrodes

Before the mechanical contraction, the heart will first produce electric polarization and biological ionic current, which will be conducted to body surface through tissue and humors. This current will present difference in potential in different locations of the body, forming potential difference. ECG, also known as body surface ECG or regular ECG, is obtained by recording this changing potential difference to form a dynamic curve. In ECG measurement a lead is defined as the potential difference between two electrodes. Based on this the ECG measuring electrodes can be arranged in three lead ECG system, seven lead ECG system, or twelve lead ECG system.

6.4.3 Respiration rate measuring electrodes

This electrodes measures respiration rate (RESP) with the method of impedance. When a patient exhales and inhales, changes will take place in the size and shape of the thoracic cavity, causing consequent changes in the impedance between the two electrodes installed at the patient's chest. Based on the cycle of impedance changes, the respiration rate can be calculated. The measuring range of respiration rate depends on the manufacturer's specification.

6.4.4 ECG/RESP processing module

The ECG/RESP processing module is found inside the mother board of the patient monitoring system. It is a microcontroller with a very high speed Digital signal processing (DSP) IC chip which is programmed to perform a specific application.

The ECG/RESP processing module

- Accepts analog signal from ECG/RESP measuring electrodes,
- Converts the analog signal to digital signal,
- Process the digital signal
- Extract meaning full information about :
    - The change in the body surface potentials caused by the heart of the patient
    - The cardio electric activities
- Calculates the heart rate and respiration rate through the multiple electrodes connected to various cables
- Record the cardio electric waveforms and heart rates in bits/min.

- Send the cardio electric waveforms and heart rate variability to the monitor to be displayed
- It also display graphic user interface on the monitor for ECG lead selection so that users can select 3 lead, 7 lead, or 12 lead ECG waveform to be displayed on the monitor.

6.4.5 SPO_2 measuring transducer

The measurement of degree of blood oxygen saturation and carbon dioxide level (also known as pulse oxygen saturation, usually shortened as SPO_2, and carbon dioxide level, CO_2) adopts the principles of light spectra and volume tracing. The LED emits lights with two specific bandwidths, which are selectively absorbed by hemoferrum and desoxyhemoglobin. The optical receptor measures the changes in the light intensity after the light passes the capillary network and estimates the ratio of and the total hemoglobin. The measurement range of SPO2 is 0~100%. The percentage oxygen saturation level is calculated based on the following formula.

Degree of pulse oxygen saturation %= (hemoferrum + desoxyhemoglobin)*100 /hemoferrum

6.4.6 SPO_2 processing module

The SPO_2 processing module is found inside the mother board of the patient monitoring system. It is a microcontroller with a very high speed Digital signal processing (DSP) IC chip which is programmed to perform a specific application.

This module:

- Accepts analog signal from SPO_2 measuring transducer,
- Converts the analog signal to digital signal,
- Process the digital signal
    - Use various filters and signal correlation techniques to extract useful information from the SPo2 pulse waveform signals.
- Record the extracted blood oxygen saturation and carbon dioxide level
- Display the result on the monitor

6.4.7 Temperature probes

This probe is a sensor that detects the temperature of the patient's body by using thermistor, a resistor whose resistance value varies with temperature. The temperature range in which the sensors can detects generally varies from device to device.

6.4.8 Temperature module

This module is a Digital signal processing (DSP) IC chip which is found inside the mother board of the patient monitoring device.

This module:

- Accepts analog signal from the temperature sensors,
- Converts the analog signal to digital signal,
- Record and display the temperature in ^{0}C.
- In some devices it may have two or more channels and can measure temperature of two or more different positions

6.4.9 NIBP and IBP measuring transducers

The non-invasive blood pressure transducers/sensors detect a chance in pressure within the blood pressure cuff along with the volume of the artery while the invasive blood pressure transducers/sensors directly detects the BP of artery or veins through the insertion of specialized catheters

6.4.10 NIBP/IBP processing module

The NIBP and IBP processing module is found inside the mother board of the patient monitoring system. It is a microcontroller with a very high speed Digital signal processing (DSP) IC chip which is programmed to perform a specific application. The NIBP and IBP processing module automatically conducts measurement of NIBP and IBP by applying a set of information extraction algorithms and input signal acquisition techniques.

The detection of NIBP is based on measurement of NIBP with the method of shockwave. The method of shockwave indirectly estimates the systolic and diastolic pressures within the blood vessels by measuring the change of the pressure within blood pressure cuff along with the volume of the arteries and calculates the average pressure.

Most of the time a measurement time of BP on a calm patient is less than 40s, and when each measurement ends, the cuff automatically deflates to zero.

This processing module applies to any standards of the cuffs for neonate, child and adult (including the cuffs used for arms and legs). The module measures the blood pressure during the time of deflation. It automatically conducts the second and third inflation measurements in case during the first inflation it is unable to measure the value of BP, and gives out the information for measurement failures.

Most of the time the maximum cuff pressure allowed by adult mode is 315mmHg 10mmHg, and the maximum cuff pressure allowed by child mode is 255mmHg 10mmHg, and the maximum cuff pressure allowed by neonate mode is 170mmHg 10mmHg. The longest cuff pressure maintaining duration is 90 seconds, and when the time is exceeded, the air will be deflated automatically. It also has a GUI interface to enable users to insert the above parameters.

The method of IBP measurement is direct measuring the BP of artery or veins on the pressure sensor mainly through liquid coupling so as to obtain the pressure curve of the continuous BP. Most of the time the IBP parameters of the module has a GUI to select Arterial Pressure (ART), Pulmonary Artery pressure (PA), Left Atrium Pressure (LAP), Right Atrium Pressure (RAP), Central Venous Pressure (CVP), Intracranial Pressure (ICP).

6.4.11 Monitor

The monitor applies high-lightness multicolor LCD or LED screen, which can show all the parameters, waveforms, data, system time, and information of the patients and other prompt information.

Most of the time the whole main screen can be divided into following regions:

- Patients Information and alarm prompt information region (**upmost left**)
- User operation menu region (**bottommost right**)
- Waveform display region (**left**)
- Parameters display region (**right**)

For example, a configuration of a sample standard screen/monitor of a patient monitoring system is shown in figure 6.2.

Alarm system

When alarm occurs, the monitor may raise the user's attention in two ways, which are audio prompt, visual prompt and description. Visual prompt is given by screen of the monitor while audio prompt is given by speaker in the device. In most patient monitoring systems alarms can be categorized as:

- Physiological alarms
- Technical alarms or
- General alarms

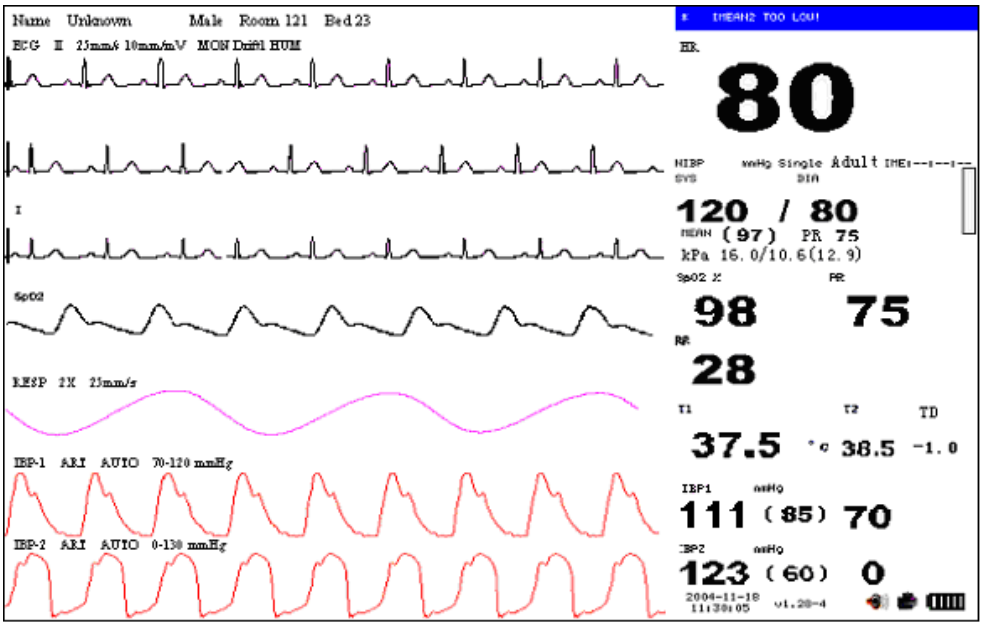


Figure 6.2: Sample standard monitor/screen of a patient monitoring system [1]

Physiological alarms refer to those alarms triggered by patient's physiological situation which could be considered dangerous to his or her life, such as SpO2 exceeding alarm limit (parameter alarms).

Technical alarms refer to system failure, which can make certain monitoring process technically impossible or make monitoring result unbelievable.

General alarm belongs to those situations that cannot be categorized into these two cases but still need to pay some attention.

Each alarm, either technical or physiological, has its own level. Some alarm's level can be set by the user while others cannot be changed once defined by the system.

Generally alarms in the monitor are divided into three levels, that is: high, medium and low.

- High-level alarm indicates the patient's life is in danger or the monitor under using has serious problem in technical respect. It is the most serious alarm.
- Medium-level alarm means serious warning.
- Low-level alarm is a general warning.

Learning activity 6.3:

Time: 5min

List the major components of a patient monitoring system and discuss about their functions

6.5 Safe handling procedures of P.M.S

Generally in using/operating, troubleshooting, or maintaining any components of a patient monitoring system, trainees and trainers have to apply and follow the appropriate safe handling procedures as per the manufacturer's service manual. In this sub section a general guidelines and procedures for safe handling of some patient monitoring system components are listed.

6.5.1 Safe handling of the power unit

- Before plugging any power cord, confirm whether the voltage of the external socket outlet match the power rating of the device or not.
- Always appropriately connect the ground line of the device with the ground line of the hospital socket outlet.
- Based on the service manual check whether the device has an appropriate earthling connection or not.
- The AC cord provided along with the instrument must be used for connection with AC power and no other electrical wires shall be used.
- To assure a fully charged battery which is ready for use, it is recommended that the system be plugged into AC power whenever it is not in use.
- Ensure that the battery is always fully charged when the device is placed in storage for an extended period of time.
- Check the battery status at least once every month and recharge the battery.

6.5.2 Safe handling of the ECG/HR/RESP measuring unit

- Before connecting the ECG cables to the monitoring system, please check if the lead wires and cables have been worn out or cracked.
- Based on the manufacturer's service manual plug the ECG cable into the ECG socket on the device.
- It is imperative to only use the ECG cables provided with the instrument by company.
- Put the EGG leads on the appropriate position on the patient based on the service manual.

- To avoid burning, when the electrotome operation is performed, the electrodes should be placed near the middle between ESU grounding pad and electrotome and the electrotome should be applied as far as possible from all other electrodes, a distance of at least 15 cm/6 in. is recommended.
- All the electrodes and conducting part shall not be into contact with any other conductors including the ground.
- For the sake of patient safety, all the leads on the ECG cables must be attached to the patient.
- When conducting defibrillation, it is imperative to only use the electrodes recommended by manufacturer.
- When the electro tome operation is performed, the ECG lead wires should be combined as much as possible.
- The main unit of the instrument should be placed at a distance from the operation table.
- Electrical wires and the ECG lead cables should be partitioned and should not be in parallel.

6.5.3 Safe handling of the SPO_2 measuring unit

- Based on the manufacturer's service manual plug the SpO2 sensor cable into the SpO2 socket on the device.
- Put the SpO2 sensor onto the finger of the patient, and the screen should display SpO2 waveforms, and the SpO2 value and pulse rate should be calculated.
- Based on the manufacturer's service manual set up the parameters relevant to SpO2 and pulse monitoring.
- The cable of sensor should not be pulled with force.
- In case NIBP and SpO2 are measured at the same time, please do not place the SpO2 sensor and the NIBP cuff on the same end of the limb, for the measurement of NIBP will block blood flow, affecting the measurement of SpO2.
- Do not conduct SpO2 measurement on the finger smeared with fingernail oil, otherwise unreliable measurement results might be produced.
- When using SpO2 sensor, care should be taken to shield external light sources, such as light of thermo therapy or ultraviolet heating light, otherwise the measurements may be disturbed. Under such conditions as shock, hypothermia, anemia or the use of blood

vessel-activating drugs, and with the existence of such substances as carboxyhemoglobin, met hemoglobin; methylene blue the result of the SpO2 measurement will be possibly not accurate.

- Do not use the sterile supplied SpO2 sensors if the packing or the sensor is damaged and return them to the vendor.
- Prolonged and continuous monitoring may increase jeopardy of unexpected change of dermal condition such as abnormal sensitivity, rubescence, vesicle, repressive putrescence, and so on. It is especially important to check the sensor placement of neonate and patient of poor perfusion or immature dermogram by light collimation and proper attaching strictly according to changes of the skin.

6.5.4 Safe handling of the temperature measuring unit

- Based on the manufacturer's service manual Plug the TEMP cables into the TEMP sockets on the device
- Place the TEMP sensors on body of patient and the screen will show the value of TEMP measurement.
- Based on the manufacturer's service manual set the parameters relevant to TEMP.

6.5.5 Safe handling of the NIBP and IBP measuring unit

- Based on the manufacturer's service manual plug the air tube of the cuff into the NIBP socket on the device and tighten it clockwise to ensure secure contact of the plug and the socket
- Tie the cuff on the arm of patient.
- Based on the manufacturer's service manual set the parameters and modes relevant to NIBP.
- Make sure that the air conduit connecting the blood pressure cuff and the monitoring system is neither blocked nor tangled, and avoid compression or restriction of air conduit.
- The accuracy of measurement of BP depends on the suitability of the cuff. Select the size of the cuff according to the size of the arm of patient. The width of the cuff should be 40% of the circumference of the upper arm or 2/3 of the length of the upper arm.
- You must not perform NIBP measurements on patients with sickle-cell disease or under any condition that the skin is damaged or expecting to be damaged.

- Prolonged non-invasive blood pressure measurements in Auto mode be associated with purport, ischemia and neuropathy in the limb wearing the cuff. When monitoring a patient, examine the extremities of the limb frequently for normal color, warmth and sensitivity. If any abnormality is observed, stop the blood pressure measurements.

Learning activity 6.4:

Time: 15min

List the appropriate safe handling procedures for each of the following patient monitoring system components:

- Power unit
- ECG/RESP measuring unit

6.6 Troubleshooting techniques

Generally troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device. So that one has to first perform the appropriate troubleshooting techniques to identify the problem before conducting a repair to any components of a patient monitoring system. In this section troubleshooting techniques for detecting the major failures of patient monitoring device is discussed.

6.6.1 Preparatory steps of troubleshooting technique

Before directly the conducting trouble shooting technique one has to first perform the following tasks:

- Receive maintenance request from users or organization
- Gather information about the equipment problem
- Ask users about the history of the device.
- Prepare:
    - Appropriate PPE(personal protective equipment)
    - Cleaning material
    - Multimeter to check electrical parameters
    - Mechanical and electrical tool kits to trouble shoot
    - Service manual
    - Checklists to check qualitative and quantitative data
    - Blower to remove dusts on the interior and exterior part of the device

- Physical inspection
    - Smell for burning cables and components
    - Hearing for abnormal noise ,
    - Looking at physical breakage of system components
    - Inspect cables

6.6.2 Troubleshooting procedures to detect major system component failures of a P.M.S

I) Power unit check up

- Check the functionality of external socket outlets.
    - Using multimeter measure the voltage of the external socket outlet
- Check the functionality of the main power cables
    - Using multimeter test the continuity of the power cables.
- Check the functionality of the fuse on the power supply unit of the system
    - Using multimeter test the continuity of the fuse.
- Check the functionality of the transformer on the power supply unit of the system
- Check the functionality of major electrical components like, resistors, diodes, transistors, capacitors, and inductors which are in found the board of power supply unit of the system.
- Test the battery's ability to receive and hold a charge.

II) ECG/HR and RESP unit check up

- Check whether all the ECG/RESP electrodes are working or not
- Check damage or corrosion to the electrode and electrode insulation
- Physically inspect all lead cables
- Check all lead cable functionality
    - If possible, attach patient simulator to patient cables,
- Check whether the placement of the leads on the patient is correct or not
    - Use service manual to know the exact positions of each electrode on the patent
- Check all lead cable connections to the patient monitoring system
- Make sure electrodes have proper contact with patient's skin.
- Check if there were a wandering baseline
- Check AC interference
- Check whether the ECG/HR processing module on the mother board is working or not
    - Use manufacturer's service manual to check the functionality of this module

- Based on manufacturer's service manual:
  - ✓ Use IC tester to check the functionality of the IC chip which is found on this module
  - ✓ Check the connections and functionality of electrical components like resistors, capacitors, inductors, diodes, and transistors which are found on this module

III) SPO_2 unit check up

- Check whether all the SPO_2 transducer is working or not
- Check damage or corrosion to the SPO_2 transducer
- Physically inspect the cables from the transducer to the system
- Check SPO_2 cable functionality
  - If possible, attach patient simulator to patient cables,
- Check whether the placement of the SPO_2 transducers on the patient is correct or not
  - Use service manual to know the exact positions of each electrode on the patent
- Check SPO_2 cable connections to the patient monitoring system
- Make sure SPO_2 transducer has proper contact with patient's skin.
- Check if there were a noise
- Check AC interference
- Check whether the SPO_2 processing module on the mother board is working or not
  - Use service manual to check the functionality of this module
  - Based on manufacturer's service manual:
    - ✓ Use IC tester to check the functionality of the IC chip which is found on this module
    - ✓ Check the connections and functionality of electrical components like resistors, capacitors, inductors, diodes, and transistors which are found on this module

IV) NIBP/IBP unit check up

- Check whether the NIBP cuff is working or not
- Check whether the IBP catheters is working or not
- Check damage to the NIBP and IBP transducers
- Physically inspect the cables from the NIBP and IBP transducer to the system
- Check NIBP and IBP cable functionality

- If possible, attach patient simulator to patient cables,

- Check whether the placement of the NIBP cuffs and IBP catheters on the patient is correct or not
  - Use service manual to know the exact positions of each transducers on the patent
- Check the NIBP and IBP cable connections to the patient monitoring system
- Make sure NIBP and IBP transducer has proper contact with patient's skin.
- Check if there were a noise
- Check AC interference
- Check whether the NIBP/IBP processing module on the mother board is working or not
  - Use service manual to check the functionality of this module
  - Based on manufacturer's service manual:
    - ✓ Use IC tester to check the functionality of the IC chip which is found on this module
    - ✓ Check the connections and functionality of electrical components like resistors, capacitors, inductors, diodes, and transistors which are found on this module

V) Temperature unit check up

- Check whether all the temperature sensors/probes are working or not
- Check damage or corrosion to the temperature probes
- Physically inspect the cables from the temperature probe to the system
- Check temperature probe cable functionality
  - If possible, attach patient simulator to patient cables,
- Check whether the placement of the temperature probes on the patient is correct or not
  - Use service manual to know the exact positions of the temperature probes on the patent
- Check the temperature probe cable connections to the patient monitoring system
- Make sure temperature probes have proper contact with patient's skin.
- Check if there were a noise
- Check AC interference
- Check whether the temperature processing module on the mother board is working or not
  - Use service manual to check the functionality of this module

- Based on manufacturer's service manual:
  - ✓ Use IC tester to check the functionality of the IC chip which is found on this module
  - ✓ Check the connections and functionality of electrical components like resistors, capacitors, inductors, diodes, and transistors which are found on this module.

VI) Monitor check up

- Physically inspect whether there is a damage of breakage in the monitor or not
- Check whether the LED power light on the monitor is working or not
- Check the cables/ data cables from the mother board of the system to the monitor
- Check whether the monitor is working or not

6.7 Maintenance Procedure for patient monitoring system

Learning activity 6.5:
Time: 2hrs

Arrange yourself in a group where each group can have a maximum of five persons. Then within your group perform a troubleshooting activity on the following system components of a patient monitoring device.

- Power unit
- ECG/RESP unit
- SPO_2 unit
- Pressure unit
- Temperature unit
- Monitor

After finishing the troubleshooting identify the system failures/problems (if there is any) of the device**.**

I) Power unit repair

- If the external socket outlets are not working properly unplug the power cable from it and plug it to another functional socket which meets the power specification of the device.
  - Use multimeter to measure the voltage of the external socket outlets.
- Fit loose electrical connection

- If the main power cables are not working substitute it with another functional cable which can meet the power specification of the device.
    - N.B. For replacement it is highly recommended to use power cables that are supplied by the manufacturer.
- If the fuse on the power supply unit of the system is not working replace it with another functional fuse whose power specification is identical with the previous one.
    - Use manufacturer's service manual to know the exact position and replacement mechanism of the fuse.
- If the transformer is burnet replace it with another functional transformer whose power specification is identical with the previous one.
    - Use manufacturer's service manual to know the exact position and replacement mechanism of the transformer.
- Based on the manufacturer's service manual try to repair or replace loose connections and damaged electrical components like resistors, capacitors, diodes, transistors, and inductors which are found on the power supply board of the system.
- If the battery is functional and hold empty charge try to reuse/test after charging it fully.
- If the battery's ability to receive and hold a charge is failed or if it is damaged replace it with another battery which has identical battery parameters with the previous one.
    - N.B. For replacement it is highly recommended to use batteries that are supplied by the manufacturer.

II) ECG/RESP unit repair

- If there is a physical damage or corrosion to the ECG/RESP electrodes and their insulation based on the appropriate service manual techniques perform the following general procedures:
    - Clean the ECG/RESP electrodes with the appropriate cleaning agent to fix the problem
    - Fix physical deformation/damage of electrodes.
- If there is a physical damage to the ECG/RESP cables as per the manufacturer's service manual procedures fix the problem.
- Fit loose connections between:
    - All ECG/RESP electrodes and patient skin.

- All ECG/RESP cables and the patient monitoring system

- Using the manufacturer's service manual correct the placement of:
  - All misplaced ECG/RESP electrodes on the patient body.
  - All wrongly connected ECG/RESP cables to the patient monitoring system
- If any one of the ECG/RESP electrodes are not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect it from the ECG/RESP cable and replace with another functional ECG/RESP electrode which is identical to the previous one.
  - If the problem is not fixed with the above technique replace both the non functional ECG/RESP electrode and its cable unit with another one.
  - N.B. For replacement it is highly recommended to use the ECG/RESP electrodes and cables that are supplied by the manufacturer.
- If any one of the ECG/RESP cables are not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect it from the ECG/RESP electrode and the patient monitoring system and replace with another functional ECG/RESP cable which is identical to the previous one.
  - If the problem is not fixed with the above technique replace both the non functional ECG/RESP electrode and its cable unit with another one.
  - N.B. For replacement it is highly recommended to use the ECG/RESP electrodes and cables that are supplied by the manufacturer.
- Based on the service manual correct:
  - Wandering baseline
  - AC interference
- If the ECG/HR processing module on the mother board is not working based on the appropriate service manual techniques perform the following general procedures:

  - Unplug the power cord and detach all transducers and electrodes from the system
  - Dismantle/disassemble the device (patient monitoring system)
  - Remove the ECG/HR processing module from the mother board of the system.

- If there is any damaged electrical component (such as resistors, capacitors, inductors, diodes, and transistors) on the ECG/HR module replace it with functional component.
- Fit loose electrical connections on the ECG/HR module (if there is any).
- If there is any damaged IC chip on the module replace it with functional component
- After assembling the system conduct a performance test to the whole patient monitoring system
- If the problem is not fixed with the above four steps, replace the whole ECG/HR module with another functional one which is supplied by the manufacturer.
- Finally after assembling the whole system conduct calibration and performance test to the system.

- Conduct calibration based on service manual
- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed

III) SPO_2 unit repair

- If there is a physical damage or corrosion to the SPO_2 transducers based on the appropriate service manual techniques perform the following general procedures:
  - Clean the SPO_2 transducers with the appropriate cleaning agent to fix the problem
  - Fix physical deformation/damage of SPO_2 transducers.
- If there is a physical damage to the SPO_2 cables as per the manufacturer's service manual procedures fix the problem.
- Fit loose connections between:
  - SPO_2 transducers and patient skin.
  - SPO_2 cables and the patient monitoring system
- Using the manufacturer's service manual correct the placement of:
  - Misplaced SPO_2 transducers on the patient body.
  - Wrongly connected SPO_2 cables to the patient monitoring system
- If SPO_2 transducer is not working based on the appropriate service manual techniques perform the following general procedures:

- Disconnect it from the SPO_2 cable and replace with another functional SPO_2 transducer which is identical to the previous one.
- If the problem is not fixed with the above technique replace both the non functional SPO_2 transducer and its cable unit with another one.
- N.B. For replacement it is highly recommended to use the SPO_2 transducers and cables that are supplied by the manufacturer.

- If the SPO_2 cable is not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect it from the SPO_2 transducer and the patient monitoring system and replace with another functional SPO_2 cable which is identical to the previous one.
  - If the problem is not fixed with the above technique replace both the non functional SPO_2 transducer and its cable unit with another one.
  - N.B. For replacement it is highly recommended to use the SPO_2 transducers and cables that are supplied by the manufacturer.
- Based on the service manual correct:
  - Noise
  - AC interference
- If the SPO_2 processing module on the mother board is not working based on the appropriate service manual techniques perform the following general procedures:

  - Unplug the power cord and detach all transducers and electrodes from the system
  - Dismantle/disassemble the device (patient monitoring system)
  - Remove the SPO_2 processing module from the mother board of the system.
  - If there is any damaged electrical component (such as resistors, capacitors, inductors, diodes, and transistors) on the ECG/HR module replace it with functional component.
  - Fit loose electrical connections on the SPO_2 module (if there is any).
  - If there is any damaged IC chip on the module replace it with functional component
  - After assembling the system conduct a performance test to the whole patient monitoring system

- If the problem is not fixed with the above four steps, replace the whole SPO_2 processing module with another functional one which is supplied by the manufacturer.
- Finally after assembling the whole system conduct calibration and performance test to the system.

- Conduct calibration based on service manual
- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed

IV) NIBP and IBP unit repair

- If there is a physical damage or corrosion to the NIBP cuffs and IBP catheters based on the appropriate service manual techniques perform the following general procedures:
  - Clean the NIBP cuffs and IBP catheters with the appropriate cleaning agent to fix the problem
  - Fix physical deformation/damage of NIBP cuffs and IBP catheters.
- If there is a physical damage to the cuff or catheter cables as per the manufacturer's service manual procedures fix the problem.
- Fit loose connections between:
  - NIBP cuffs and patient skin.
  - IBP catheters and patient artery
  - NIBP Cuff cables and the patient monitoring system
  - IBP catheter cables and the patient monitoring system
- Using the manufacturer's service manual correct the placement of:
  - Misplaced NIBP cuffs on the patient body.
  - Misplaced IBP catheters inside patients body
  - Wrongly connected NIBP cuff and IBP catheter cables to the patient monitoring system
- If NIBP cuffs or IBP catheters are not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect the NIBP cuffs /IBP catheters from the cuff/catheter cable and replace with another functional NIBP cuffs/IBP catheter which is identical to the previous one.

- If the problem is not fixed with the above technique replace both the non-functional NIBP cuff/IBP catheter and its cable unit with another one.
- N.B. For replacement it is highly recommended to use the NIBP cuff/IBP catheter and cables that are supplied by the manufacturer.

- If the cuff/catheter cable is not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect the cuff/catheter cable from the NIBP cuffs/IBP catheters and the patient monitoring system. Then replace it with another functional cuff/catheter cable which is identical to the previous one.
  - If the problem is not fixed with the above technique replace the non-functional NIBP cuffs/ IBP catheters and its cable unit with another one.
  - N.B. For replacement it is highly recommended to use the NIBP cuffs/IBP catheters and cables that are supplied by the manufacturer.
- Based on the service manual correct:
  - Noise
  - AC interference
- If the NIBP and IBP processing module on the mother board is not working based on the appropriate service manual techniques perform the following general procedures:

  - Unplug the power cord and detach all transducers and electrodes from the system
  - Dismantle/disassemble the device (patient monitoring system)
  - Remove the NIBP and IBP processing module from the mother board of the system.
  - If there is any damaged electrical component (such as resistors, capacitors, inductors, diodes, and transistors) on the NIBP and IBP module replace it with functional component.
  - Fit loose electrical connections on the NIBP and IBP module (if there is any).
  - If there is any damaged IC chip on the module replace it with functional component
  - After assembling the system conduct a performance test to the whole patient monitoring system

- If the problem is not fixed with the above four steps, replace the whole NIBP/IBP processing module with another functional one which is supplied by the manufacturer.
- Finally after assembling the whole system conduct calibration and performance test to the system.

- Conduct calibration based on service manual
- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed.

V) Temperature unit repair

- If there is a physical damage or corrosion to the temperature probes based on the appropriate service manual techniques perform the following general procedures:
  - Clean the temperature probes with the appropriate cleaning agent to fix the problem
  - Fix physical deformation/damage of the temperature probes.
- If there is a physical damage to the temperature probe cables as per the manufacturer's service manual procedures fix the problem.
- Fit loose connections between:
  - Temperature probes and patient skin.
  - Temperature probe cables and the patient monitoring system
- Using the manufacturer's service manual correct the placement of:
  - Misplaced temperature probes on the patient body.
  - Wrongly connected temperature probe cables to the patient monitoring system
- If temperature probes are not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect the temperature probes from the probe cables and replace with another functional temperature probes which is identical to the previous one.
  - If the problem is not fixed with the above technique replace both the non functional temperature probe and its cable unit with another one.
  - N.B. For replacement it is highly recommended to use the temperature probes and cables that are supplied by the manufacturer.

- If the temperature probe cable is not working, based on the appropriate service manual techniques perform the following general procedures:
    - Disconnect the temperature probe cable from the temperature probes and the patient monitoring system. Then replace it with another functional probe cable which is identical to the previous one.
    - If the problem is not fixed with the above technique replace the non functional temperature probe and its cable unit with another one.
    - N.B. For replacement it is highly recommended to use the temperature probesand cables that are supplied by the manufacturer.
- Based on the service manual correct:
    - Noise
    - AC interference
- If the temperature processing module on the mother board is not working based on the appropriate service manual techniques perform the following general procedures:

    - Unplug the power cord and detach all transducers and electrodes from the system
    - Dismantle/disassemble the device (patient monitoring system)
    - Remove the temperature processing module from the mother board of the system.
    - If there is any damaged electrical component (such as resistors, capacitors, inductors, diodes, and transistors) on the temperature module replace it with functional component.
    - Fit loose electrical connections on the temperature module (if there is any).
    - If there is any damaged IC chip on the module replace it with functional component
    - After assembling the system conduct a performance test to the whole patient monitoring system
    - If the problem is not fixed with the above four steps, replace the whole temperature processing module with another functional one which is supplied by the manufacturer.
    - Finally after assembling the whole system conduct calibration and performance test to the system.
- Conduct calibration based on service manual

- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed

VI) Monitor repair

- If there is a physical damage or breakage to the monitor based on the appropriate service manual techniques
    - Try to fix physical deformation/damage of the monitor.
- If there is a physical damage to the data cables of the monitor as per the manufacturer's service manual procedures try to fix the problem.
- Fit loose connections between:
    - The data cables and the monitor.
    - The main board and the data cables.
- If data cables that connects the mother board of the system to the monitor are not working based on the appropriate service manual techniques replace it with another functional data cable which is identical to the previous one.
    - N.B. For replacement it is highly recommended to use the data cables that are supplied by the manufacturer.
- If LED power light on the monitor is not working based on the appropriate service manual techniques replace it with another functional LED which is identical to the previous one.
- If the problem is not fixed with the above techniques replace the whole monitor with functional one which is supplied by the manufacturer. .
- Conduct calibration based on service manual
- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed.

Learning activity 6.6:

Time: 1:30hrs

Arrange yourself in a group where each group can have a maximum of five persons. Trainers will arrange six different maintenance scenarios per group on a set of different patient monitoring devices. Each maintenance scenarios are created by making the patient monitoring devices malfunctioned due to different system component failures. The maintenance scenarios are due to one of the following system component failures; i.e. failures due to:

- Power unit
- ECG/RESP unit
- SPO_2 unit
- Pressure unit

6.7.1 Preventive maintenance

Learning activity 6.7:

Time:15min

What are the major preventive maintenance procedures that are commonly applied in patient monitoring devices?

Preventive maintenance is a scheduled and planned maintenance technique whose aim is to prevent failures on the equipment/devices. For any device the schedule and preventive maintenance techniques must be performed as per the manufacturer's service manual.

The common preventive maintenance techniques on patient monitoring devices, that have to be applied periodically to prevent system component failures, are:

- Cleaning the exterior and interior parts of the system
  - Use blower to remove dusts in the external and internal part of the system
- Cleaning Electrodes and transducers with the appropriate cleaning agent
  - Using service manual periodically clean the ECG/RESP electrodes, SPO_2 transducers, NIBP cuffs, IBP catheters, temperature probes, etc.
- Sterilization Electrodes and transducers

- Disinfection Electrodes and transducers with the appropriate disinfecting agent
- Replacing deteriorated electrodes, transducers, and cables before use.
  - Replace deteriorated ECG/RESP electrodes and cables,
  - Replace deteriorated SPO_2 transducers and cables,
  - Replace deteriorated NIBP cuffs, IBP catheters,
  - Replace deteriorated cuff and catheter cables
  - Replace deteriorated temperature probes and cables, etc.
- Replacing weak battery
- Calibrating the system if needed.
- At the end of preventive maintenance conducting system performance test
- Recording history on a standard format including detailed activities performed.

6.8 Summary

Chapter summary

- Patient Monitoring devices are used to monitor patient's physiological parameters such as Electrocardiogram (ECG), respiration rate (RESP), blood oxygen and carbon dioxide saturation level (SPO2 and CO_2), non-invasive and invasive blood pressure (NIBP and IBP), and temperature (TEMP) continuously in a dynamic and long-time range.
- Generally the functions of patient monitoring systems are detecting/sensing, transducing, processing, recording and displaying of the various physiological parameters of the patient.
- Power unit, ECG measuring electrodes, Respiration rate measuring electrodes, ECG/RESP processing module, SPO_2 measuring transducer, SPO_2 processing module, Temperature probe, Temperature module, NIBP/IBP measuring transducers, NIBP/IBP processing module, Monitor, Alarm system
- There are many procedures we should follow whenever we operate and maintain an PMS
- Troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device following different steps we can troubleshoot patient monitor machines. .
- One should follow different steps to perform both preventive and corrective maintenance on patient monitor machines which is one of operation medical equipment.

Chapter 7
ECG Machine

Duration: 12hrs

Chapter Description

This chapter is designed to develop the necessary knowledge, skills and attitude of the learners to the standard required in operating room equipment maintenance for biomedical engineers and technicians. It covers basic working principles, purposes, and main components, troubleshooting techniques and safety procedures for ECG machine.

Chapter Objective

By the end of this session, the participants will be able to know how to handle, install, and maintain ECG machine.

Learning Objectives

At the end of this training participants will be able to:

- Explain the purpose and clinical application of ECG machine
- Explain the principle of operation for ECG machine
- Identify the basic instrumentation of ECG machine
- Follow the safe handling procedures of ECG machine components
- Perform appropriate troubleshooting procedure for ECG machine
- Perform preventive and corrective maintenance as per the service manual.
- Perform performance test and calibration to ECG machine as demanded

Chapter Outline:

7.1 Introduction

ECG (Electrocardiograph) machines are used to monitor the electrical activity of the heart and display it on a screen and record it on a memory or piece of paper. The recordings are used to diagnose the condition of the heart muscle and its nerve system. In this session the purpose/clinical application, working principles, basic instrumentation, safe handling, troubleshooting and repairing procedures of an EGG machine is presented briefly.

7.2 Purpose and clinical application of ECG machine

Learning activity 7.1:

Time: 7min

Discuss about the purpose and clinical applications of ECG machine**.**

The overall goal/purpose of performing electrocardiography is to obtain information about the structure and function of the heart. Electrocardiographs detect the electrical signals associated with cardiac activity and produce an ECG, a graphic record of the voltage versus time, using electrodes places on the skin. The electrodes detect the tiny electrical changes on the skin that arises from the heart muscle's electro physiologic pattern of depolarizing during each heartbeat. Multichannel electrocardiographs record signals from two or more leads simultaneously and are frequently used in place of single-channel units. The common 12 lead ECG system uses ten electrodes to measure the electrical activity of the heart from 12 different angles.

Performing ECG on a patient has various clinical applications. Some of the clinical applications, where ECG machines are used, include:

- To determine the heart rate
- To diagnose and assist in treating some types of heart disease and arrhythmias, such as:
    - Suspected myocardial infarction/heart attach
    - Suspected pulmonary embolism
    - Cardiac arrhythmias
    - Cardiac stress testing, etc.
- To determine the position and size of the heart
- To determine a patient's response to drug therapy, and
- To reveal trends or changes in heart function.

7.3 Working principles of ECG machines

Learning activity 7.2:

Time: 5min

Explain about:

- The electrical activity of the heart and the various ECG waveforms
- The working principle of 12 lead ECG system

7.3.1 Electrical activity of the heart

Cells in humans act like little batteries. These cells have different ion concentrations inside and outside of their membranes which create small electric potentials called bio-potentials. When there is a disturbance in a bio-potential this gives rise to an action potential which is the depolarization and repolarization of the cell as shown in Figure 7.1.

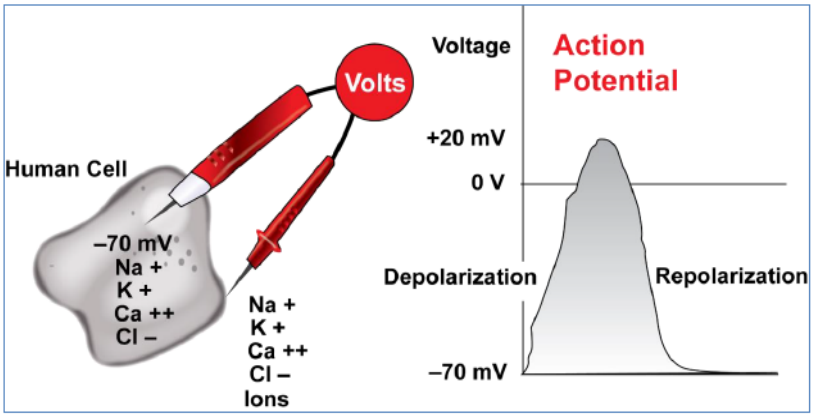


Figure 7.1: Each living cell acts as a small battery that depolarizes and repolarizes when there is a disturbance [25]

Essentially, the action potentials from different nodes in the heart are what make up electrocardiograph (ECG) signals. ECG signals are comprised of the superposition of the different action potentials from the heart beating as shown in Figure 7.2. The action potential starts from a point called the pacemaker or sinoatrial (SA) node which is located near the top of the right atrium. The action wave form propagates in all directions along the surface of both atria. The waveform reaches the junction of the atria and the ventricles. The waveform terminates at a point on this junction which is called the atrioventricular (AV) node. The propagation of excitation is delayed at AV node so that the ventricles can be filled up with the blood from the atria. Once the

period of delay is over, the excitation is spread to the all parts of the ventricles by the bundle of His. The fibers in the bundle (called Purkinje fibers), branch out into two parts to initiate action potential simultaneously in the myocardium of the ventricles. The action potential moves from the inside to the outside of the ventricular walls. The waveform terminates at the tip of the heart where the depolarization is completed. After 0.2 to 0.4 sec a wave of repolarization starts in which neighboring cells play no part but each cell returns to its resting potential independently.

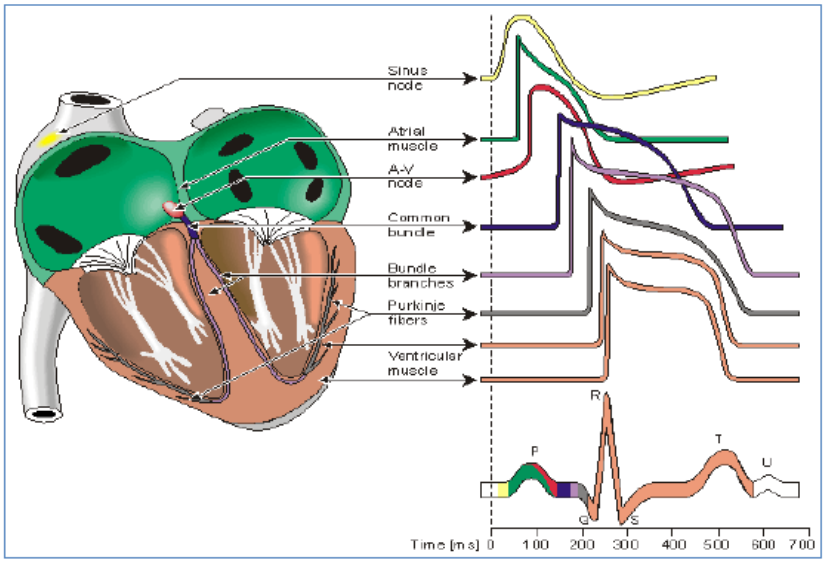


Figure 7.2: Superposition of all the action potentials produces the ECG signal [25]

If the bio-potential is recorded from the surface of the body, the curve is obtained which is called ECG. A typical ECG is as shown in the figure 7.2. If prominent features of the curve are given alphabetic designations, we can explain the events related to the action potential propagation with the help of these features. The horizontal portion right of the point P is considered as the baseline or equal potential line. The wave P represents depolarization of the atrial myocardium. The depolarization of ventricles and the repolarization of the atria take place simultaneously, which is indicated by QRS part of the curve. The wave T represents the repolarization of the ventricles. The after potential in the ventricles is given by the U wave. The P–Q part of the curve shows the period of the delay caused to excitation wave at the AV node.

The ECG helps in the diagnosis of malfunctioning of the heart. Longer cycle time or slow heart is called bradycardia while shorter cycle time or fast heart is called tachycardia. The cycles must be evenly spaced otherwise a patient has arrhythmia. If the duration between P and R is greater than 0.2 second, it suggests the blockage of the AV node. If any feature of the curve is missing, it indicates a heart block.

Electrocardiography is the instrument used to record ECG. The cardiac disorder, especially those involving the heart valves cannot be diagnosed by the ECG and other techniques like angiography (X-ray photos after injecting contrasting medium into the blood stream) and echocardiography (Ultrasound measurement of the heart) are used.

7.3.2 12 lead ECG system

In conventional 12 lead ECG machine 10 electrodes are used to measure the ECG of the patient from 12 different angles. From these 10 electrodes four of them are limb electrodes and the remaining are chest electrodes. The placement of the four limb electrodes is on the right arm (RA), right leg (RL), left arm (LA) and left leg (LL). The placement of the remaining six electrodes is on the intercostal chest lines of patient skin. As shown in figure 7.3. , in 12 lead EGG system, a total of 10 electrodes will be placed on the patient skin. Note that the electrode on the right leg (RL) has a zero potential and used as a ground electrode.

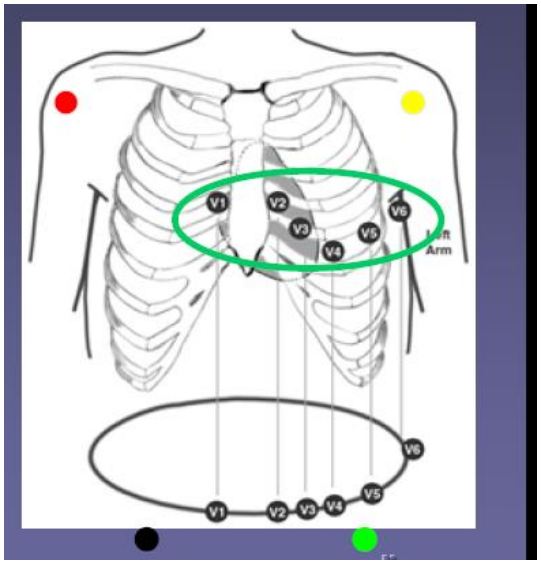


Figure 7.3: 10 electrode placements in 12 lead ECG system

Where the red, yellow, green, and black dots represents the RA, LA, LL, and RL electrodes respectively, and the six chest electrodes are represented by letters v1 up to v6 [26].

Lead means the potential difference between two electrodes, and Electrical impulse (wave of depolarization is sensed by measuring the current change across two electrodes, positive and negative electrodes. As shown in figure 7.4, if the electrical impulse of the heart travels towards the positive electrode this results in a positive deflection of the lead, and if the impulse travels away from the positive electrode this results in a negative deflection of the lead.

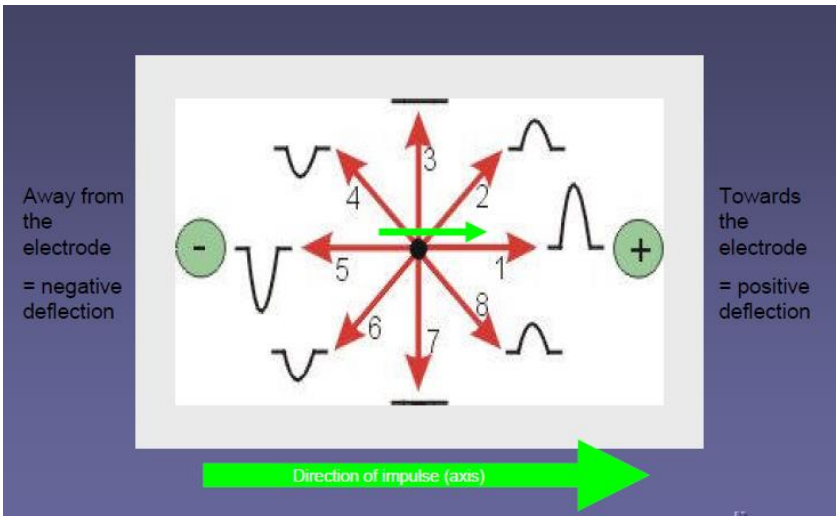


Figure 7.4:A plot of lead deflection versus electrical impulse direction [26]

In 12 lead ECG systems there are a total of 12 leads, these are:

- Limb leads: lead I, lead II, lead III, these are the potential difference between limb electrodes, where,
    - Lead I= LA-RA
    - Lead II= LL-RA
    - Lead IIII= LL-LA
- Augmented limb leads: aVL ,aVR , and aVF, these are the potential difference between one limb electrodes and the central potential of the remaining two electrodes , where,
    - AVR=RA-(LL+LA)/2=3*(RA-Vw)/2
    - AVL=LA-(RA+LL)/2=3*(LA-Vw)/2
    - AVF=LL-(RA+LA)/2=3*(LL-Vw)/2
    - where Vw is the heart's central potential and is found by taking the average of the three limb electrodes, i.e. Vw=(RA+LA+LL)/3
- Chest leads/ Precordial leads: V1, V2, V3, V4, V5, and V6, these are the potential difference between chest electrodes and the heart's central potential, Vw.

7.4 Basic components and functions of ECG machine

ECG machines use electrodes to convert the ionic signals from the body into electrical signals to be displayed and used for data analysis. However, due to the size of the signals and outside noise, ECG requires amplification and filtering to produce high quality signals. An ECG's job is to amplify the small signal measured from the heart as well as to filter outside and internal noise. The amplification is mainly implemented through a differential amplifier whereas filtering is

completed through common and differential mode filtering. There is also the Right Leg Drive circuit which cancels noise and maintains the common mode voltage.

7.4.1 Amplifier

ECG signals vary from the microvolt to the millivolt range. Due to this small range, the signals measured need to be amplified in order to be better interpreted. Typical bio-potential amplifiers have high input impedance and are designed for safety first. This is due to the fact that the signal amplified is being drawn from a living organism so precautions must be taken in order to prevent macro and micro shock. Isolation and protection circuitry are used to limit current through electrodes to safe levels. The output impedance of the amplifier should be very low to drive any external load with minimal distortion. Again, due to the small size of the signal, the gain should be large. Typically a gain of over 1000 is implemented in bio-potential amplifier circuits. The amplifiers should have a high common mode rejection ratio to eliminate large offset signals. Finally, most bio-potential amplifiers are differential. Differential amplifiers are used to make sure that noise from the inputs are not amplified thus yielding a higher integrity signal.

Differential amplifiers with such characteristics are difficult to find. Thus combinations of differential amplifiers are used to construct what is called an instrumentation amplifier. A basic three-op-amp instrumentation amplifier is shown in Figure 7.5.

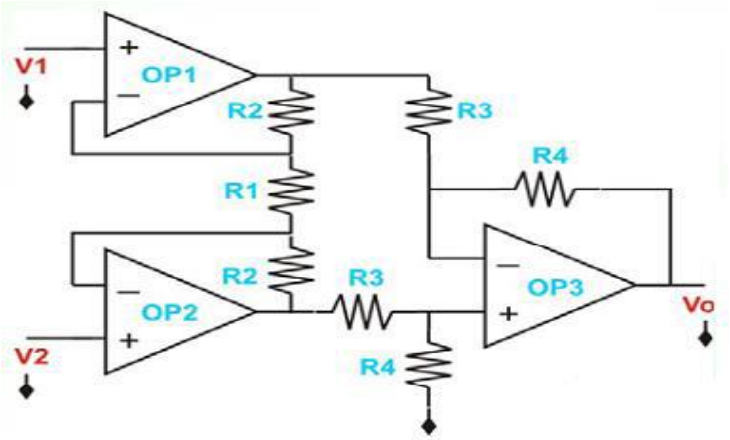


Figure 7.5: Basic Instrumentation Amplifier [25]

There are two stages for the instrumentation amplifier that help make it meet the characteristics of an ideal bio-potential amplifier. The first stage is the input stage of the amplifier followed by the gain stage. Figure 7.6 breaks down the two stages. The input stage ideally supplies no common mode gain thus eliminating common mode noise. The three op-amps give the input stage high input impedance and the configuration gives a resultant gain. The input stage also buffers the gain

stage. Finally, the outputs of the input stage are the inputs of gain stage. The gain stage has low impedance and supplies a differential gain. Overall the amplifier amplifies only the differential component with a gain and provides a high common mode rejection ratio.

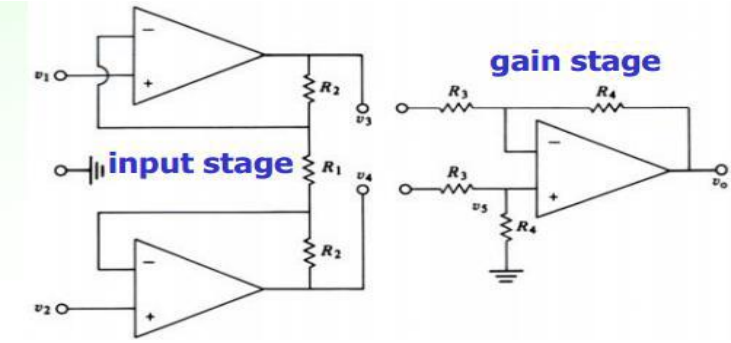


Figure 7.6: Input and gain stages of instrumentation amplifier [25]

7.4.2 Filtering

ECGs are subject to many different kinds of noise internally and externally. Figure 7.7 shows the different kinds of artifacts that ECGs typically experience.

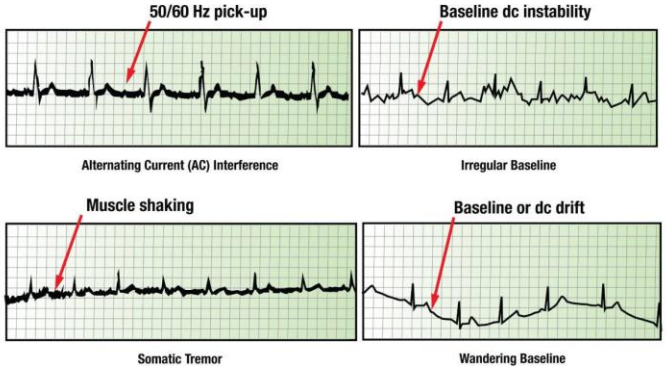


Figure 7.7: ECG artifacts [25]

These artifacts can be filtered digitally as well as through analog practices. For example, the analog band stop filter shown in figure 6.8 can be used to modulate 60 Hz noise from power lines based on what resistor, capacitor, and inductor values are chosen.

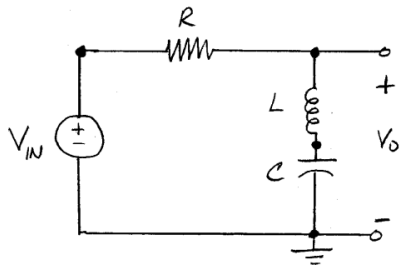


Figure 7.8: Second order band stop filter [25]

Digitally, Matlab allows one to implement filters with the help of FFTs. For example, an FFT can extract the ECG and muscle shaking frequency components. From there, one can design a filter to obtain only the ECG components of the signal. For ECG circuits however, typically low pass filters will suffice to eliminate outside noise due to the frequency of a heartbeat.

7.5 Safe handling procedures of ECG machine

Learning activity 7.3:

Time: 5min

List the appropriate safe handling procedures for the following ECG machine system components:

- Power unit
- ECG electrodes and cables

Safe handling of the power unit

- Before plugging any power cord, confirm whether the voltage of the external socket outlet match the power rating of the device or not.
- Always appropriately connect the ground line of the device with the ground line of the hospital socket outlet.
- Based on the service manual check whether the device has an appropriate earthling connection or not.
- The AC cord provided along with the instrument must be used for connection with AC power and no other electrical wires shall be used.
- To assure a fully charged battery which is ready for use, it is recommended that the system be plugged into AC power whenever it is not in use.
- Ensure that the battery is always fully charged when the device is placed in storage for an extended period of time.
- Check the battery status at least once every month and recharge the battery.

Proper patient positioning

- Place the patient in a superior or semi fowler's position. If the patient cannot tolerate being flat, do the ECG in more upright position

- Instruct patient to place their arms down by their side and to relax their shoulders
- Make sure the patient legs are uncrossed
- Move any electrical devices, such as cell phones, away from patients as they may interfere with the machine

Skin preparation

- Dry skin if it is moist
- Shave any hair that interferes with electrode placement
- Rub an alcohol prep pad or benzoin tincture on the skin to remove any oils and help with electrode adhesion

Proper electrode application

- Check the electrodes to make sure the gel is still moist
- Do not place the electrodes over bones
- Do not place the electrodes over areas where there is a lot of muscle movement.
- Before connecting the ECG cables to the ECG machine, please check if the lead wires and cables have been worn out or cracked.
- Based on the manufacturer's service manual plug the ECG cable into the ECG socket on the machine.
- It is imperative to only use the ECG cables provided with the instrument by company.
- Put the EGG leads on the appropriate position on the patient based on the service manual.
- All the electrodes and conducting part shall not be into contact with any other conductors including the ground.
- For the sake of patient safety, all the leads on the ECG cables must be attached to the patient.
- The main unit of the instrument should be placed at a distance from the operation table.
- Electrical wires and the ECG lead cables should be partitioned and should not be in parallel.

7.6 Troubleshooting techniques

Learning activity 7.4:

Time: 10min

Arrange yourself in a group where each group can have a maximum of five persons. Then within your group perform a troubleshooting activity on the following components of an ECG machine.

- Power unit
- ECG electrodes
- ECG cables
- ECG machine mother board
- Monitor
- Printer

After finishing the troubleshooting identify the system failures/problems (if there is any) of the device.

Generally troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device. So that one has to first perform the appropriate troubleshooting techniques to identify the problem before conducting a repair to any component of an ECG machine. In this section troubleshooting techniques for detecting the major failures of ECG machine is discussed.

7.6.1 Preparatory steps of troubleshooting technique

Before directly the conducting trouble shooting technique one has to first perform the following tasks:

- Receive maintenance request from users or organization
- Gather information about the equipment problem
- Ask users about the history of the device.
- Prepare:
    - Appropriate PPE (personal protective equipment)
    - Cleaning material
    - Multimeter to check electrical parameters

- Mechanical and electrical tool kits to trouble shoot
- Service manual
- Checklists to check qualitative and quantitative data
- Blower to remove dusts on the interior and exterior part of the device

- Physical inspection
  - Smell for burning cables and components
  - Hearing for abnormal noise ,
  - Looking at physical breakage of system components
  - Inspect cables

7.6.2 Troubleshooting procedures to detect major failures of ECG machine

Power unit check up

- Check the functionality of external socket outlets.
  - Using multimeter measure the voltage of the external socket outlet
- Check the functionality of the main power cables
  - Using multimeter test the continuity of the power cables.
- Check the functionality of the fuse on the power supply unit of the system
  - Using multimeter test the continuity of the fuse.
- Check the functionality of the transformer on the power supply unit of the system
- Check the functionality of major electrical components like, resistors, diodes, transistors, capacitors, and inductors which are in found the board of power supply unit of the system.
- Test the battery's ability to receive and hold a charge.

ECG electrodes, cables, and system check up

- Check whether all the ECG electrodes are working or not
- Check damage or corrosion to the electrode and electrode insulation
- Physically inspect all lead cables
- Check all lead cable functionality
  - If possible, attach patient simulator to patient cables,
- Check whether the placement of the leads on the patient is correct or not
  - Use service manual to know the exact positions of each electrode on the patent
- Check all lead cable connections to the ECG machine
- Make sure electrodes have proper contact with patient's skin.

- Check if there were a wandering baseline
- Check AC and muscular interference
- Check whether the ECG processing board is working or not
    - Use manufacturer's service manual to check the functionality of this board
    - Based on manufacturer's service manual:
        - ✓ Use IC tester to check the functionality of the IC chip which is found on this board
        - ✓ Check the connections and functionality of electrical components like resistors, capacitors, inductors, diodes, and transistors which are found on this board

Monitor check up

- Physically inspect whether there is a damage of breakage in the monitor or not
- Check whether the LED power light on the monitor is working or not
- Check the cables/ data cables from the mother board of the system to the monitor.
- Check whether the monitor is working or not.

Printer check up

- Physically inspect whether there is a damage of breakage in the printer or not
- Check the cables/ data cables from the mother board of the system to the printer
- Check whether the printer is working or not

7.7 Maintenance procedure

7.7.1 Corrective maintenance

Power unit repair

- If the external socket outlets are not working properly unplug the power cable from it and plug it to another functional socket which meets the power specification of the device.
    - Use multimeter to measure the voltage of the external socket outlets.
- Fit loose electrical connection
- If the main power cables are not working substitute it with another functional cable which can meet the power specification of the device.

    - N.B. For replacement it is highly recommended to use power cables that are supplied by the manufacturer.
- If the fuse on the power supply unit of the system is not working replace it with another functional fuse whose power specification is identical with the previous one.
    - Use manufacturer's service manual to know the exact position and replacement mechanism of the fuse.
- If the transformer is burnet replace it with another functional transformer whose power specification is identical with the previous one.
    - Use manufacturer's service manual to know the exact position and replacement mechanism of the transformer.
- Based on the manufacturer's service manual try to repair or replace loose connections and damaged electrical components like resistors, capacitors, diodes, transistors, and inductors which are found on the power supply board of the system.
- If the battery is functional and hold empty charge try to reuse/test after charging it fully.
- If the battery's ability to receive and hold a charge is failed or if it is damaged replace it with another battery which has identical battery parameters with the previous one.
    - N.B. For replacement it is highly recommended to use batteries that are supplied by the manufacturer.

ECG electrodes, cables, and system repair

- If there is a physical damage or corrosion to the ECG electrodes and their insulation based on the appropriate service manual techniques perform the following general procedures:
    - Clean the ECG electrodes with the appropriate cleaning agent to fix the problem
    - Fix physical deformation/damage of electrodes.
- If there is a physical damage to the ECG cables as per the manufacturer's service manual procedures fix the problem.
- Fit loose connections between:
    - All ECG electrodes and patient skin.
    - All ECG cables and the ECG machine
- Using the manufacturer's service manual correct the placement of:
    - All misplaced ECG electrodes on the patient body.
    - All wrongly connected ECG cables to the ECG machine

- If any one of the ECG electrodes are not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect it from the ECG cable and replace with another functional ECG electrode which is identical to the previous one.
  - If the problem is not fixed with the above technique replace both the non-functional ECG electrode and its cable unit with another one.
  - N.B. For replacement it is highly recommended to use the ECG electrodes and cables that are supplied by the manufacturer.
- If any one of the ECG cables are not working based on the appropriate service manual techniques perform the following general procedures:
  - Disconnect it from the ECG electrode and the ECG machine and replace with another functional ECG cable which is identical to the previous one.
  - If the problem is not fixed with the above technique replace both the non functional ECG electrode and its cable unit with another one.
  - N.B. For replacement it is highly recommended to use the ECG electrodes and cables that are supplied by the manufacturer.
- Based on the service manual correct:
  - Wandering baseline
  - AC interference
  - Muscular interference
- If the ECG board is not working based on the appropriate service manual techniques perform the following general procedures:
  - Unplug the power cord and detach all electrodes from the system
  - Dismantle/disassemble the ECG machine
  - Remove the mother board of the system.
  - If there is any damaged electrical component (such as resistors, capacitors, inductors, diodes, and transistors) on the board replace it with functional component.
  - Fit loose electrical connections on the board (if there is any).
  - If there is any damaged IC chip on the board replace it with functional component
  - After assembling the system conduct a performance test to the ECG machine

    - If the problem is not fixed with the above four steps, replace the whole board with another functional one which is supplied by the manufacturer.
    - Finally after assembling the whole system conduct calibration and performance test to the system.
- Conduct calibration based on service manual
- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed

Monitor repair

- If there is a physical damage or breakage to the monitor based on the appropriate service manual techniques
    - Try to fix physical deformation/damage of the monitor.
- If there is a physical damage to the data cables of the monitor as per the manufacturer's service manual procedures try to fix the problem.
- Fit loose connections between:
    - The data cables and the monitor.
    - The main board and the data cables.
- If data cables that connects the mother board of the system to the monitor are not working based on the appropriate service manual techniques replace it with another functional data cable which is identical to the previous one.
    - N.B. For replacement it is highly recommended to use the data cables that are supplied by the manufacturer.
- If LED power light on the monitor is not working based on the appropriate service manual techniques replace it with another functional LED which is identical to the previous one.
- If the problem is not fixed with the above techniques replace the monitor with functional one which is supplied by the manufacturer. .
- Conduct calibration based on service manual
- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed.

Printer repair

- If there is a physical damage or breakage to the printer based on the appropriate service manual techniques
    - Try to fix physical deformation/damage of the printer.
- If there is a physical damage to the data cables of the printer as per the manufacturer's service manual procedures try to fix the problem.
- Fit loose connections between:
    - The data cables and the printer.
    - The main board and the data cables.
- If data cables that connects the mother board of the system to the printer are not working based on the appropriate service manual techniques replace it with another functional data cable which is identical to the previous one.
    - N.B. For replacement it is highly recommended to use the data cables that are supplied by the manufacturer.
- If the problem is not fixed with the above techniques replace the printer with functional one which is supplied by the manufacturer. .
- Conduct calibration based on service manual
- Conduct system performance test based on service manual
- Record history on a standard format including detailed activities performed.

7.7.2 Preventive maintenance

Learning activity 7.5:
Time: 5min
What are the major preventive maintenance procedures that are commonly applied in ECG machine?

Preventive maintenance is a scheduled and planned maintenance technique whose aim is to prevent failures on the equipment/devices. For any device the schedule and preventive maintenance techniques must be performed as per the manufacturer's service manual.

The common preventive maintenance techniques on ECG machines, that have to be applied periodically to prevent failures, are:

- Cleaning the exterior and interior parts of the system
  - Use blower to remove dusts in the external and internal part of the system
- Cleaning Electrodes with the appropriate cleaning agent
  - Using service manual periodically clean all ECG electrodes
- Sterilization of Electrodes
- Disinfection of Electrodes
- Replacing deteriorated electrodes and cables.
- Replacing weak battery
- Calibrating the system if needed.
- At the end of preventive maintenance conducting system performance test
- Recording history on a standard format including detailed activities performed.

7.8 Summary

Chapter summary

- ECG (Electrocardiograph) machines are used to monitor the electrical activity of the heart and display it on a screen and record it on a memory or piece of paper.
- Electrocardiographs detect the electrical signals associated with cardiac activity and produce an ECG, a graphic record of the voltage versus time, using electrodes places on the skin.
- These are major parts of ECG machines power unit, ECG electrodes, ECG cables, ECG machine mother board, monitor, printer
- There are many procedures we should follow whenever we operate and maintain an autoclave
- Troubleshooting is a form of problem solving technique, often applied to repair failed products or processes of a system or a device. Following the techniques we can solve any problems
- Basically we can solve problems following both preventive and corrective maintenance procedures.

Annex 1: Learning Guide for Electrosurgical Maintenance Skill

Rate the performance of each task observed using the following rating scale

1. **Needs improvement:** tasks not performed correctly or out of sequence.

2.Comptently performed: tasks performed correctly in a proper sequence but no efficient Progress from step to step.

3. Proficiently performed: tasks are performed precisely and efficiently in a proper sequence**.**

Learning Guide for Electrosurgical Unit Maintenance Skill					
Steps/Tasks	**Cases**				
Preparation for troubleshooting					
1. Gather information/ receive maintenance request					
2. Ask user					
3. Prepare: o PPE(personal protective equipment) o Cleaning material o Multimeters to check electrical parameters o Mechanical and electrical tool kits to trouble shoot o Service manual o Checklists to check qualitative and quantitative data o Blower					
4. Physical observe o Smell for burning cables and components o Hear for abnormal noise , o Look at physical breakage or damage					
Trouble shoot					
5. Unplug power cord from wall outlet					
6. Inspect the cables					
7. Examine all fittings and electrical cable connectors					
8. Check power unit of the machine • Check the functionality of external socket outlets.					

○ Using multimeters measure the voltage of the external socket outlet • Check the functionality of the main power cables ○ Using multimeters test the continuity of the power cables. • Check the functionality of the fuse on the power supply unit of the system ○ Using multimeters test the continuity of the fuse. • Check the functionality of the transformer on the power supply unit of the system • Check the functionality of major electrical components like, resistors, diodes, transistors, capacitors, and inductors which are in found the board of power supply unit of the system.					
9. Check all accessories cords are connected properly.					
10. Check for the firm contact of Bipolar Instrument receptacle on front panel for obstruction and damage.					
11. Check for the firm contact of Mono-polar instrument receptacle on front panel for any obstruction and damage.					
12. Check the patient return electrode receptacle for any broken pins and obstruction.					
13. Ensure proper connections of the patient monitoring system with the various electrodes					
14. Ensure patient is not moving.					
15. Make sure the various electrodes have proper contact with patient's skin.					
16. Check AC interference and noise					
17. Check whether the RF output board is working or not.					
18. Check whether the Memory board is working or not					
19. Check whether the Logic Board / Relay Board is working or not					
20. Check whether Display Board is working or not					
21. Check whether Audio Tone Generator is working or not					
22. Check whether Isolation Board is working or not					
Maintenance					

23. Substitute damaged /short cable					
24. Fit loose connections between: o All electrodes and patient skin. o All electrode cables and the patient monitoring system					
25. Fit loose electrical connection • Fit loose electrical connections in the power supply board • Fit loose electrical connections in the various processing modules					
26. Substitute burnt and failed switch and control					
27. Replace damaged fuse					
28. Adjust the placement of electrodes on the patient					
29. Replace damaged monitor					
30. Replace damaged electrodes and cables					
31. Replace RF output Board					
32. Replace Memory Board					
33. Replace Logic Board / Relay Board					
34. Replace Display Board					
35. Replace Audio Tone Generator					
36. Replace Isolation Board					
37. Preventive maintenance procedure • Clean exterior of unit and inspect general physical condition. • Clean the various electrodes • Sterilize and disinfect the various electrodes • Be sure that plastic housings are intact, that all hardware is present and fitting are firm and tight. • Inspect AC power plug for damage. . • Inspect the cord for damage & excessive bending. • Replace deteriorated electrodes, cables • Confirm that probes for their physical condition. For disposable probes check expiry date. • Confirm the operation of all indicators on the unit that all segments of a digital display function and functioning of					

Alarms. • Activate any audible signals. • Calibrate if needed					
38. Performance test					
39. Record history					

Annex 2: Learning Guide for Suction unit Maintenance Skill

Rate the performance of each task observed using the following rating scale

1. **Needs improvement:** tasks not performed correctly or out of sequence.

2.Comptently performed: tasks performed correctly in a proper sequence but no efficient Progress from step to step.

3. Proficiently performed: tasks are performed precisely and efficiently in a proper sequence**.**

Learning Guide for Suction Unit Maintenance Skill					
Steps/Tasks	**Cases**				
Preparation for troubleshooting					
1. Gather information/ receive maintenance request					
2. Ask user					
3. Prepare: o PPE(personal protective equipment) o Cleaning material o Multimeters to check electrical parameters o Mechanical and electrical tool kits to trouble shoot o Service manual o Checklists to check qualitative and quantitative data o Blower					
4. Physical observe o Smell for burning cables and components o Hear for abnormal noise , o Look at physical breakage or damage					
Trouble shoot					

5. Unplug power cord from wall outlet					
6. Inspect the cables					
7. Examine all fittings and electrical cable connectors					
8. Check power unit of the machine • Check the functionality of external socket outlets. o Using multimeters measure the voltage of the external socket outlet • Check the functionality of the main power cables o Using multimeters test the continuity of the power cables. • Check the functionality of the fuse on the power supply unit of the system o Using multimeters test the continuity of the fuse. • Check the functionality of the transformer on the power supply unit of the system • Check the functionality of major electrical components like, resistors, diodes, transistors, capacitors, and inductors which are in found the board of power supply unit of the system.					
9. Check all accessories cords are connected properly.					
10. Verify tubing connection security.					
11. Check for leaks or tubing kinks					
12. Ensure that float shut-off is not activated					
13. Check for bottle leaks and cracks					
14. Check as the valve is clean.					
15. Check the floating valve					
16. Check AC interference and noise					
Maintenance					
17. Substitute damaged /short cable					
18. Fit loose tubing connections					
19. Fit loose electrical connection • Fit loose electrical connections in the power supply board • Fit loose electrical connections in the					

various processing modules					
20. Substitute burnt and failed switch and control					
21. Replace damaged fuse					
22. Clean outlet valve					
23. Clean piping and strainers.					
24. Replace battery					
25. Replace filter or unblock tube.					
26. Change filter, clean or replace floating valve					
27. Perform greasing					
28. Adjust seal flow rate.					
29. Realign coupling. 30. Balance rotor. 31. Make sure mounting surface is level					
32. Anchor pump or motor properly.					
33. Preventive maintenance procedure • Clean filters • Clean air vents • Disinfect jars, tubing, other components that come into contact w/ patient fluids between each use in solution of water, detergent, and disinfectant • When applicable, check the canister to determine if the expiration date has passed. If the expiration date has passed, replace the canister. • Change bacteria filter if wet or discolored • Check collection bottle/jar for cracks, chips, and other damage • Make sure there is a sufficient supply of bacterial filters • Check that float valve moves freely • Clean or replace air intake filter • Clean brushes on motors as necessary • Inspect power cord and plug • Test the health of the battery • Determine if the gauge is properly calibrated • Ensure vacuum works over full range of suction pressures if there is a control/knob Verify that overflow valve					

(float valve) works properly when container is filled with water • Grounding resistance between chassis and ground pin should not exceed 0.5 ohms • Verify that the unit is not damaged and that it is clean. • Verify that the feet are not damaged or missing. • Using an independent vacuum gauge verify that the unit provides a maximum vacuum level. • Check the airflow.					
34. Performance test					
35. Record history					

Annex 3: Learning guide for anesthesia machine:

Rate the performance of each task observed using the following rating scale

1. **Needs improvement:** tasks not performed correctly or out of sequence.

2.Comptently performed: tasks performed correctly in a proper sequence but no efficient Progress from step to step.

3. Proficiently performed: tasks are performed precisely and efficiently in a proper sequence**.**

Tasks		Case	
Preparation			
1. Preparing the following things before starting maintenance ➢ Gas leak detector ➢ Gas analyzer , oxygen analyzer ➢ Melt meter , adjustable wrench ,Teflon, screwdriver, personal protective equipments ➢ pressure regulators ➢ ask about the failure ➢ read history card and recorded document about the equipment			
Troubleshooting			
2. Power :	Check main power supply source using multimeter		
	Read the output power and compare with the power		

	rate required by the machine		
	Check for power cord and its connection		
	Check for fuse rate of the machine		
Gas sources :			
➢ **Check the tubes of the gas input end whether they are open or close**			
➢ Recognize that all gas sources are ready to be used			
➢ Open gas sources for each gases (O2,N2o,Air) and Inspect that pressure regulators are working well			
➢ Read for each gases on pressure regulators whether they have enough amount or not			
➢ Adjust gasses supply pressures to appropriate ranges the based on the manufacturer order that is required by anesthesia machine			
➢ Check the connection of the pipeline and re-connect			
➢ Connect oxygen analyzer on the gas source out let of Oxygen gas(O2) and measure the values			
➢ Identify the connection place for each gases at the back of the machine by using color code			
➢ Connect black and white hose /color with air inlet			
➢ Connect white with O2			
➢ Connect blue with N2O			
➢ Tell the user to have back up gas source before stare the operation			
flow meters	Float type read at the top		
	Ball type read in middle Rotate the flow controller and observe if it is in good condition to increase and decrease the flow of gases		
scavenging system	Check that it is out let from OR room to remove breathing circuit and ventilator gases		
	Check that it is not affect the environment for others		
	Visual and audible alarm for cylinder or pipeline pressure		
Breathing circuit	Install the circuit assembly and make sure it is installed in place		
	Inspect the tubes are not cracked and over stretched		
	Check inspiration and expiration valve functioning well and have no moisture and clean		
Vaporizer	Inspect that vaporizer gasket are in good condition		
	Check Concentration control dial is working or not		
	Check for any leak		
	Check inside the vaporizer is there any anesthetic residual? if so clean it		

	pressed snugly manifold inlet and outlet adapters onto vaporizer manifold		
	Tightened the vaporizer's drain		
	Tightened down the vaporizer fill cap		
CO_2 absorber	Check for any leak if there is any try to fix it		
	Check for soda lime expired and not consumed more than 3/4 of the total amount if it necessary change it.		
APL valve	Perform test when using auto/manual ventilation Whether it is working well or nor		
	Open the APL valve and turn the ventilation on manual switch.		
	Close when automatic ventilation is used		
	Close APL valve when leak test is performed		
Auto/manual switch	Check if it is switch from manual to automatic ventilation and vase versa		
Leak test	**Check any leak** : ▪ Connect re breathing circuit and reservoir bag and close APL valve Push o2 flush ▪ After closing gas source See patient manometer or bag **If it is goes down quickly check the following part** • High-Pressure system • Low-Pressure system • Scavenging system • Breathing system check for crack and over stretch • carbon dioxide absorber check for correct assembly • vaporizer check for gasket • Manual and automatic ventilation system(bellow)		
Disassemble and Assemble	Breathing circuit		
	Canister		
	Vaporizer		
	APL valve		
	Bellow assembly		

Annex 4: Learning guide for Autoclave

Rate the performance of each task observed using the following rating scale
1. **Needs improvement:** tasks not performed correctly or out of sequence.
2.Comptently performed: tasks performed correctly in a proper sequence but no efficient Progress from step to step.
3. Proficiently performed: tasks are performed precisely and efficiently in a proper sequence**.**

Steps/Tasks		Case	
Gathering information /receive maintenance request			
Prepare :	Asking user about the problem		
	PPE(personal protective equipment)		
	Cleaning material		
	prepare adjustable wrench ,multimeter Teflon, screwdriver, personal protective equipments		
	Mechanical and electrical tool kits to trouble shoot		
	Service manual		
	Checklists to check qualitative and quantitative data **water in tank** Fill the tank if there is not enough water. Make the residual water come out of the tank2 before filling the reservoir with water fill the tank with dematerialized water until the level is reached, and close		
Trouble shoot			
Physical observe :	Smell for burning cables and components ,		
	Hearing for abnormal noise , observe the display part		
	Looking at physical breakage		
	inspect the equipment physically		
	make the environment suitable for maintenance		
	insect any physical damage and parts of the equipment		
Power sources and	use multimeter and check power source from power out let		

Power supply :	read the rating power of the machine		
	check power cord of the machine		
	use multimeter and check for fuse		
	push power switch and turn on the machine then observe the power indicator illuminate		
	Inspect the cables		
	Examine all fittings and electrical cable connectors		
	Unplug power cord from wall outlet		
Alarm	turn on emergence switch then listen any alarm		
	listen for any sound for power off		
	listen for any water shortage alarm		
Heating element	measure the resistance of the heating element and if it is not between the expected range replace it		
	check the continuity of the heating elements		
	look for rusted and if there is any clean it cracked on the heating element if there is any replace it with new one		
	Clean for rusted one and Replace for cracked heating element Examine heating element for severe discoloration or foreign deposits if so remove it		
Temperature gauge , pressure gauge timer	observe that the temperature and pressure gauges are moving during the cycle inspect gauge components(needles) Remove gauge from autoclave and examine interior. clean and vent the temperature gauge clean and vent the pressure gauge if gauges are not move, Flush vent with distilled water to remove blockage. adjust the timer according to the target period		
Valves, and tubes leaks	Visually inspect for steam escaping from autoclave		
	check the exhausting valves is open		
	evaluate the valves are open and close during the cycle		
	do leak test on the pipe line		
	check functionality of valve components by ensuring they are able to open and close during the cycle		

	examine all parts of autoclave to find any leak on the pipe line check if there is any leak on tubes Check inlet/outlet tubing for leaks		
lid/door seal for leaks			
	Examine points at which valves connect to autoclave to ensure that they are adequately sealed		
	I f autoclave door/lid has a metal---to---metal seal, lubricate seal. If autoclave door/lid has a gasket seal, determine adequacy of gasket. If gasket is dry or cracked, it needs to be replaced		
	check if the contactors are working well		
	suggest for the user to open the door when the pressure and temperature gauge read at zero write report what you observe and perform		
	Disassembling and Assembly:		
	Before dismantling, check if the autoclave is under pressure, always open the steam release cock and wait until pressure has come to zero		
	in out water from the instrument completely by opening the drain plug once in a fortnight to remove sediments		
	During dismantling check rubber gasket. Rubber gasket should normally check periodically.		
	The instrument should be at normal temperature and pressure when the lid holding nuts are moved anticlockwise		
	The autoclave can be dismantled for cleaning, servicing and repair.		
Repair	Fit loose electrical connection		
	Substitute burnt and failed switch and control		
	Replace heating elements		
	Replace pressure and temperature gauges		
	Replacement of gasket		
	Insert a tip of screw driver in to a gap between the gasket and the body then twist the gasket to take it out		
	Fix a new gasket in and press down the whole part		

	Replacement of water supply Valve:		
	Drain the water in the water storage tank through the drain hose in front removing the cap		
	Remove the silicone hose		
	While taking this step, be sure that the water left in the hose should not be split on the electrical part		
	Remove the Elbow		
	Remove the any nut and then take out the water supply valve		
	Reassembling the parts is to be made in the reverse order of the above procedures.		
	For fixing the silicon hose to the hose joint, make sure that the hose is firmly set to the end		
	Circuit Breaker Reset		
	When a breaker faces an abnormal voltage checking and remedying the cause, push the red button down Then the breaker will be reset		
	Adjustment of Safety Valve		
	The safety valve is the most critical part of the Autoclave to maintain safely		
	In order to keep the fixed pressure in the housing has precisely been adjusted by Spring Nut and Lock Nut on the surface of the housing		
	Hence, DO NOT TOUCH Spring Nut and Lock Nut		
	After years of operation of autoclave, silicon gasket may cause wear (and tear), which may require the replacement		
	In case of replacement of the safety valve, it should be replaced completely by new		
Preventive Maintenance:			
Check periodically that the electrical wiring is as per prescribed rules and the instrument for any current leakage			
Examine the cable for any damage and replace if it is damaged.			
Check periodically kettle connectors, power plugs, heating elements for any breakage or fault. Replace if defective			
Examine heating element and inside of the instrument body for any unwanted deposits and clean them			
Examine rubber packing on the lid and replace if defective			
Examine hinges for their proper working and lubricate them periodically			
Examine periodically supports, tray and handles for any defective and replace/repair if defective			
Check periodically leakage of water through heating element system for flow outside the body and arrange proper packing			

water in the tank is required to be changed at least once a week.		
clean drain filter once a week		
Operation procedure		
Connect The power cord plug is connected properly to AC outlet		
Check Water is filled in the storage tank to the marked level		
Check The overflow hose is set properly		
Place the articles to be sterilized in the chamber ,articles are to be placed in the dressing tray/dram and then the tray/dram is to be placed in the chamber		
Placing the sterilizing articles directly on the drain board is strictly prohibited		
Turn the water supply valve toward the OPEN position, and fill up to the mark level at the drain board. Then turn the valve to the other way toward CLOSE stops the water		
Close the door with check the "click" sounds of limit switch		
Set the "sterilization Timer" to desired sterilization time Minimum 20 minute shall be required for sterilization		
Once the timer is set, you need not to repeat the setting of the timer for next operations		
Loading Autoclave Wear lab coat, eye protection, heat-insulating gloves, and closed-toe shoes. Place material in autoclave. Do not mix incompatible materials. Do not overload; leave sufficient room for steam circulation. If necessary, place the container on its side to maximize steam penetration and avoid entrapment of air. Close and latch door firmly.		
After Complete the operation		
Take the sterilized materials out with opening the door after confirmation of chamber pressure, 0kg/cm² on the chamber pressure gauge		
In case of repeat use for the unit, confirm the water level of boiler and make an operation from preparation cycle		
Turn the power switch OFF and put the cycle select lever to the position of Vacuum		
Open the exhaust valve slightly to make exhaust and drainage		
Put the cycle select lever to the position of complete		
Turn the switch of safety breaker OFF after confirmation of jacket pressure, 0kg/cm² on the jacket pressure gauge.		

Annex 5: Learning Guide for patient monitor maintenance skill

Rate the performance of each task observed using the following rating scale

1. **Needs improvement:** tasks not performed correctly or out of sequence.

2.Comptently performed: tasks performed correctly in a proper sequence but no efficient Progress from step to step.

3. Proficiently performed: tasks are performed precisely and efficiently in a proper sequence**.**

Learning Guide for patient monitor maintenance skill					
Steps/Tasks	**Cases**				
Preparation for troubleshooting					
1. Gather information/ receive maintenance request					
2. Ask user					
3. Prepare: o PPE(personal protective equipment) o Cleaning material o Multimeter to check electrical parameters o Mechanical and electrical tool kits to trouble shoot o Service manual o Checklists to check qualitative and quantitative data o Blower					
4. Physical observe o Smell for burning cables and components o Hear for abnormal noise , o Look at physical breakage or damage					
Trouble shoot					
5. Unplug power cord from wall outlet					
6. Inspect the cables					
7. Examine all fittings and electrical cable connectors					
8. Check power unit of the machine					

• Check the functionality of external socket outlets.
  o Using multimeter measure the voltage of the external socket outlet
• Check the functionality of the main power cables
  o Using multimeter test the continuity of the power cables.
• Check the functionality of the fuse on the power supply unit of the system
  o Using multimeter test the continuity of the fuse.
• Check the functionality of the transformer on the power supply unit of the system
• Check the functionality of major electrical components like, resistors, diodes, transistors, capacitors, and inductors which are in found the board of power supply unit of the system.					

9. Test the battery's ability to receive and hold a charge					
10. Check whether monitor is working or not. • Physically inspect whether there is a damage of breakage in the monitor or not • Check whether the LED power light on the monitor is working or not • Check the cables/ data cables from the mother board of the system to the monitor • Check whether the monitor is working or not.					

11. Check whether the various electrodes, transducers, and their cables are working or not
  o Check damage or corrosion to the EGG/RESP electrodes and electrode insulation
  o Check damage to the SPO_2 transducers and cables
  o Check damage to the NIBP cuffs and IBP catheters
  o Check damage to the cuff and catheter cables
  o Check damage to the temperature probes and cables					

12. Check various cable connections to the system					
13. Ensure proper connections of the patient monitoring system with the various electrodes and transducers.					

14. Ensure patient is not moving.					
15. Make sure the various electrodes and transducers have proper contact with patient's skin.					
16. Check if there were a wandering baseline					
17. Check AC interference and noise					
18. Check whether the SPO_2 processing module on the mother board is working or not.					
19. Check whether the ECG/RESP processing module on the mother board is working or not					
20. Check whether the blood pressure (NIBP/IBP) processing module on the mother board is working or not					
21. Check whether the temperature module on the mother board is working or not					
Maintenance					
22. Substitute damaged /short cable					
23. Fit loose connections between: o All electrodes/transducers and patient skin. o All electrode/transducer cables and the patient monitoring system					
24. Fit loose electrical connection • Fit loose electrical connections in the power supply board • Fit loose electrical connections in the various processing modules					
25. Substitute burnt and failed switch and control					
26. Replace damaged fuse					
27. Substitute failed battery					
28. Adjust the placement of electrodes and transducers on the patient					
29. Replace damaged monitor					
30. Replace damaged ECG/RESP electrodes and cables					
31. Replace damaged SPO_2 transducers and cables					
32. Replace damaged NIBP/IBP transducers and cables					
33. Replace damaged temperature probes and cables					
34. Fix noise, muscular and, AC interference					

problems					
35. Replace SPO_2 processing module on the mother board					
36. Replace the ECG/RESP processing module on the mother board					
37. Replace the blood pressure module on the mother board					
38. Replace the temperature processing module on the mother board					
39. Preventive maintenance procedure • Clean the exterior and interior parts of the machine • Clean the various electrodes and transducers • Sterilize and disinfect the various electrodes and transducers • Replace week battery • Replace deteriorated electrodes, cables and transducers • Calibrate if needed					
40. Performance test					
41. Record history					

Annex 6: Learning Guide for ECG machine maintenance skill

Rate the performance of each task observed using the following rating scale

1. **Needs improvement:** tasks not performed correctly or out of sequence.

2.Comptently performed: tasks performed correctly in a proper sequence but no efficient Progress from step to step.

3. Proficiently performed: tasks are performed precisely and efficiently in a proper sequence**.**

Learning Guide for ECG machine maintenance skill					
Steps/Tasks	Cases				
Preparation					
1. Gathering information/ receive maintenance request					
2. Asking user					

3. Prepare: o PPE(personal protective equipment) o Cleaning material o multimeter to check electrical parameters o Mechanical and electrical tool kits to trouble shoot o Service manual o Checklists to check qualitative and quantitative data o Blower					
4. Physical observe o Smell for burning cables and components o Hearing for abnormal noise , o Looking at physical breakage/damage					
Troubleshoot					
5. Unplug power cord from wall outlet					
6. Inspect the cables					
7. Examine all fittings and electrical cable connectors					
8. Check power supply of the machine • Check the functionality of external socket outlets. o Using multimeter measure the voltage of the external socket outlet • Check the functionality of the main power cables o Using multimeter test the continuity of the power cables. • Check the functionality of the fuse on the power supply unit of the system o Using multimeter test the continuity of the fuse. • Check the functionality of the transformer on the power supply unit of the system • Check the functionality of major electrical components like, resistors, diodes, transistors, capacitors, and inductors which are in found the board of power supply unit of the system.					
9. If there is a battery, test its ability to receive and hold a charge					
10. Check whether the electrodes and cables are working or not • Check damage or corrosion to the electrode and					

electrode insulation					
11. Check lead connections: If possible, attach patient simulator to patient cables,					
12. Ensure proper connections between ECG machine and electrodes					
13. Ensure patient is not moving.					
14. Make sure electrode has proper contact with patient's skin.					
15. Check if there were a wandering baseline					
16. Check AC and muscular interference					
17. Check whether the monitor is working or not • Physically inspect whether there is a damage of breakage in the monitor or not • Check whether the LED power light on the monitor is working or not • Check the cables/ data cables from the mother board of the system to the monitor					
18. Check whether the printer is working or not • Physically inspect whether there is a damage of breakage in the printer or not • Check the cables/ data cables from the mother board of the system to the printer					
Maintenance					
19. Substitute damaged /short cable					
20. Fit loose connection between o All electrodes and patient skin. o All electrode cables and the ECG machine					
21. Fit loose electrical connection • Fit loose electrical connections in the power supply board • Fit loose electrical connections in the mother board of the ECG machine					
22. Substitute burnt and failed switch and control					
23. Replace damaged fuse					
24. Substitute failed battery					
25. Adjust electrode placement on the patient					
26. Replace damaged cable					
27. Replace damaged electrodes					
28. Correct baseline wandering					

29. Fix muscular and AC interference					
30. Fix printer problem					
31. Fix monitor problem					
32. Perform preventive maintenance • Clean the exterior and interior parts • Clean the various electrodes • Sterilize and disinfect the various electrodes • Replace week battery • Replace deteriorated electrodes, cables and transducers • Calibrate if needed					
33. Performance test					
34. Record history					

Annex 7: Trainer Evaluation (for each chapter)

(To be completed by the participants)

Name of Trainer: _____ Course: _____

Instructions: Please circle the rating that reflects your opinion about the trainer's performance of each task activities, using the following rating scale.

1. Agree 2. Disagree N/O- Not Observed N/A-Not Applicable

The Trainer		Rating			
1	Made me feel welcome	1	2	N/O	N/A
2	Was sensitive to any feelings of fear or anxiety I may have exhibited when learning new skills.	1	2	N/O	N/A
3	Clearly started learning objectives	1	2	N/O	N/A
4	Outlined clearly the standard of performance expected of me by the end of the course.	1	2	N/O	N/A
5	Gave reasons why each step of the skill is important.	1	2	N/O	N/A
6	Demonstrated the skill through by using simulations before demonstrating with machines	1	2	N/O	N/O
7	Used a skills checklist to give me feedback on my performance.	1	2	N/O	N/A
8	Gave constructive feedback on my performance.	1	2	N/O	N/A
9	Provided me with adequate opportunity to practice and achieve competence in the new skills.	1	2	N/O	/A

10	Assessed my skills before initiating the skills training component.	1	2	N/O	N/A
11	Encouraged interaction among participants.	1	2	N/O	N/A
12	Made it easy for me to ask questions express my concerns.	1	2	N/O	N/A
13	Met with me to discuss my performance following each practice session with a client.	1	2	N/O	N/A

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