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REVIEW ARTICLE

Planning and Designing of Clinical Engineering Department in a Hospital

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ABSTRACT

Biomedical/clinical engineering departments (CED) with expertise in engineering and technology management have a vital role to play in determining the potential for implementation and cost-effectiveness of new medical technologies through technology assessment. It provides planned preventive maintenance and repair facility in a state of optimum operational efficiency along with conducts training and research in clinical engineering. For a successful design, the workflow should be kept in mind in terms of its functional needs that are related to space. The clinical engineering and maintenance unit may consist of functional areas dependent on the operational policy and service demand. Heating, ventilation and air-conditioning (HVAC), lighting and acoustic, electrical, fire planning should be done with deliberation and as per specification.

Keywords: Biomedical/clinical engineering, Planned preventive maintenance, Repair facility.

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INTRODUCTION

The American College of Clinical Engineering defines a clinical engineer (CE) as: 'a professional who supports and advances patient care by applying engineering and managerial skills to healthcare technology.' Clinical engineering is a subset of biomedical engineering. Whereas biomedical engineering is practiced primarily in academic institutions, the research laboratory, and manufacturing, clinical engineering is practiced in hospitals and other environments where medical device technologies are utilized.[1]

Clinical engineering emerged as a discipline in the latter half of the twentieth century as increasing numbers of complex electronic and mechanical medical devices entered the healthcare environment for preventive, therapeutic, diagnostic and restorative applications. Within the complex environment of the modern hospital, clinical engineering is concerned primarily with devices but recognizes that interactions between drugs, procedures, and devices commonly occur and must be understood and managed to ensure safe and effective patient care.

Objective of Clinical Engineering Department

- To plan and implement planned preventive maintenance and repair facility to hospitals, medical institutions.
- To ensure all the facilities, systems and services under the scope of engineering services are in a state of optimum operational efficiency.
- To provide consultancy service to various department on electromedical equipment in the area of pre installation and operation of equipment; and
- To conduct training and research in clinical engineering.[2]

Function of Clinical Engineering Department[3]

- Supervision of a hospital clinical engineering department that includes clinical engineers and biomedical equipment technicians (BMETs)
- Pre-purchase evaluation and planning for new medical technology
- Design, modification, or repair of sophisticated medical instruments or systems
- Cost-effective management of a medical equipment calibration and repair service
- Safety and performance testing of medical equipment by BMETs
- Inspection of all incoming equipment (new and returning repairs)
- Establishment of performance benchmarks for all equipment

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- Medical equipment inventory control
- Coordination of outside services and vendors
- Training of medical personnel in the safe and effective use of medical devices and systems
- Clinical applications engineering, such as custom modification of medical devices for clinical research or evaluation of new noninvasive monitoring systems
- Biomedical computer support
- Input to the design of clinical facilities where medical technology is used [e.g. operating rooms (ORs) or intensive-care units]
- Development and implementation of documentation protocols required by external accreditation and licensing agencies
- Equipment audit
- Academic affiliation/teaching
- Applications research and design
- Consulting
- Information systems support
- In-service training
- Technical/clinical investigation—clinical trials support
- Technology management
- Technology assessment.

Planning Premises of Clinical Engineering Department Location[4]

The clinical engineering and maintenance unit should be located on the ground floor to facilitate delivery and despatch of heavy items of equipment. Access to a loading dock is desirable. The unit will require ready access to all areas of the hospital and in particular, to plant rooms and areas. Depending on the size of the unit and the operational policy, considerable noise and fumes may be generated by the unit and care should be taken in locating the unit relative to other units, such as inpatient accommodation units as shown in Figure 1. The dept should be located at the rear of the building where all engineering services are clubbed together. It should have safe access for maintenance and when components have a service life less than the planned life of the principal asset, e.g. the building they serve, be installed with provision for replacement. Access points shall be following:

- Be positioned to avoid interference with healthcare delivery
- Be provided with appropriate access control for safety and security
- Provide for safe handling of any goods requiring access
- Access for fire fighting on all sides of all buildings and for truck and crane access to install and remove any items of equipment requiring truck transportation or crane placement
- Nondisruptive impact on the neighborhood.

General Planning Consideration[6]

For a successful design, the workflow should be kept in mind in terms of its functional needs that are related to space. This will include an exhaustive listing of physical resources, such as gas and water, that are needed for

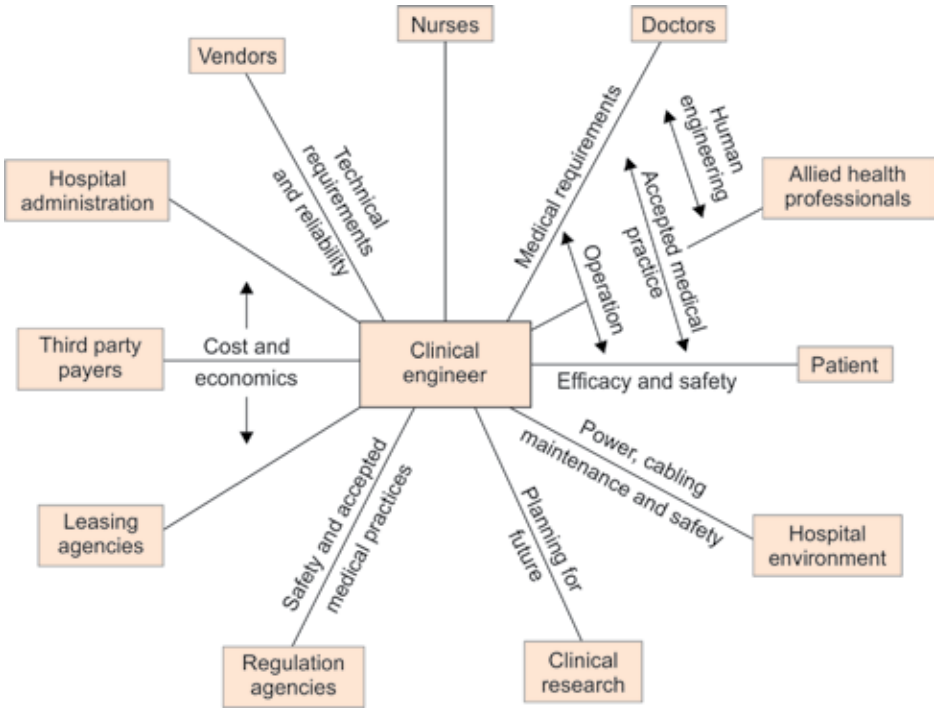


Fig. 1: Diagram illustrating the range of interactions in which a clinical engineer might be required to engage in a hospital setting

various tasks, as well as quantification of space needed, such as the number of linear feet required for storage of equipment manuals and equipment files. Using this approach, the space can be designed in a methodical manner to match the needs while fulfilling all applicable codes. For example, if there is only one water source in the department, that is the location where servicing of dialysis machines will take place unless funding is available for additional plumbing. Other equipment requiring a water source, such as humidifiers or lasers, will also be serviced in that location.

Functional Areas

The clinical engineering and maintenance unit may consist of the following functional areas dependent on the operational policy and service demand as shown in Figure 2:

- *Reception area*: The needs of a reception area are distinctly different from the equipment service area. The reception area will be used to receive the customers and business partners of the clinical engineering department. Comfortable seating in good repair is needed to accommodate these guests. The design of the reception area typically supports the administrative work processes of the department and hence typically includes such things as computers, printers, fax machines, copiers, filing cabinets, and desk furniture. Much of the office equipment can be hidden in well designed closets that are opened as needed for access. In this manner, the clutter of the workspace is minimized while accommodating convenient access.
- Workshop areas which may include separate areas for mechanical, sophisticated medical equipment and electrical services. There should be a separate space for the biomedical/electronic engineering section with a dust proof enclosure.
- Storage areas for all specialty services/trades including paint, gardening and flammable liquids
- Office area for administrative and clerical activities
- Training area
- A mechanical and electrical equipment room
- A maintenance shop

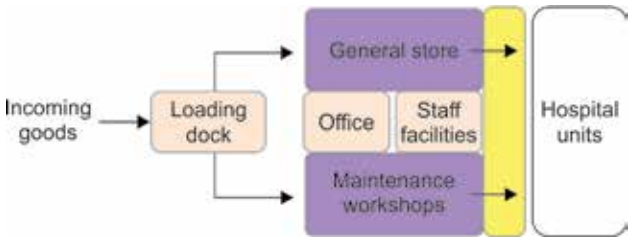


Fig. 2: Functional layout of clinical engineering department

- Staff amenities which may be shared
- A refuse room for trash storage located conveniently to a service entrance; and one janitor's closet on each floor.

Electronics Workshop

A separate workshop may be provided specifically for the storage, repair and testing of electronic and other medical equipment. The amount of space and type of utilities will vary with the type of equipment involved and types of service and maintenance contracts used.

Engineer's Office

If on-staff, an engineer's office shall be provided with file space and provision for protected storage of facility drawings, records and manuals. Provision of daylight shall be maximized throughout the unit especially for those who spend most of their working hours in a single confined space. Offices should be provided with external windows, where possible.

Storage Areas

A storage room shall be provided for the storage of building maintenance supplies. Storage for solvents and flammable liquids shall comply with relevant statutory requirements. Storage space must be designed to accommodate storage of chemicals and test gases, parts, equipment, office supplies, and service documentation. Also consider the items, such as office supplies, that essentially are utilized throughout the workspace. These items might be stored in a central storage depot or interspersed throughout the workspace. Some storage areas may need to be secured. For example, the department's practice may be to restrict access to service documentation. Storage space for staging equipment is necessary.

Infrastructure resource considerations for clinical engineering department are as below:[7]

- Anesthesia/respiratory therapy repair counter should include phone and data outlet, ample power outlets, gas outlets (nitrous oxide, oxygen, air, vacuum), large sink and cup sinks, parts storage.
- Dialysis machine repair counter should include phone and data outlet, GFI outlets, compressed air, recessed water spigots with raised drains, parts storage, sealed-membrane floor with floor drain.
- Radiology machine repair counter should include phone and data outlet, 50A, 220V single-phase power, portable lead shield, lead-lined doors, 10′ ceiling, wide-access door (48"), incandescent light on dimmer

switch, beam and hoist with 1-ton load capacity, deep-utility sink, 'room in use' light, power for wall-mounted view box.

- General workbench should include ample power outlets, static mat, electrostatic-free outlet, durable countertop, lockable drawers, manometer mount, vacuum, air, and phone and data outlet. Since the core work of the clinical engineering department takes place at the workbench, this area deserves the most investment of attention and resources. The workbench design optimally will incorporate sufficient countertop space, adequate storage space for test equipment and tools, and appropriate resources, such as vacuum, grounding mats, and access to sufficient quantities of electrical outlets. To make efficient use of the workbench space, shared resources can be mobilized by mounting on a cart. For example, a mobile solder station can be conveniently brought to the workbench, where a device is already disassembled, instead of bringing printed circuit boards to the stationary solder station.
- Lighting is a critical factor in creating a desirable ambience, as it is a essential requirement for engineering to work.
- An artwork can be very effective in humanizing a technical environment. Mounting of personalized name plates on the workbenches of employees is an example of an inexpensive approach to creating an environment of mutual respect. Personalization of workspace is also a work satisfaction issue that can be accommodated easily.
- Provision of small bulletin boards for the posting of family pictures allows for this personalization while avoiding the taping and tacking of things, such as pictures and calendars to the walls.
- The basin should be a medium wall mounted basin. The taps are either wall mounted or basin mounted with hands-free operation (elbow or wrist). This basin is used in areas requiring general staff hand-washing.
- Vinyl flooring is to be located under all hand wash basins. The flooring should be easily cleanable and in good condition. Floor surfaces, including joints in tiles in such areas, shall be resistant to food acids (epoxy grout). In all areas subject to frequent wet cleaning methods, floor materials shall not be physically affected by germicidal cleaning solutions.
- Clinical engineering department requires the following security considerations:
  - Doors to all offices shall be lockable
  - Rooms located on the perimeter of the unit shall be locked at any time when they are not occupied by staff.
  - Rooms used for storing equipment and files must be lockable.
  - Provision of after-hours access and security for staff.

HVAC System in CED

Heating systems shall be capable of maintaining all rooms at a minimum temperature of 70 to 76° Fahrenheit. Air conditioning systems shall be provided, capable of maintaining temperature and relative humidity at or between the following ranges:

Temperature (°Fahrenheit)	Relative humidity (%)
70–76	50–60

Acoustic performance: Noise levels shall not exceed those defined in the BCA and AS/NZS 2107: Acoustics—recommended design sound levels and reverberation times for building interiors. Acoustic isolation between spaces shall prevent the noise level in one space transmitting to an adjacent space and exceeding the allowable level in that space.

Acoustic Guidelines for CED

Room/space	*(dBA)**	*RT(sec)***
Assembly/preparation, reception/ clerical lounge/activity room	40–50	< 0.5
Staff room, staff station	40–45	< 0.7
Office staff and technical support	35–45	< 0.7

*A-weighted decibels; **Reverberation time

Vibration: Vibration in occupied spaces shall not exceed the just perceptible level defined by AS 2670.1. Vibration precautions shall include as follows:

- Dynamic balancing of machines
- Isolation of sources of vibration from vibration transmission paths (e.g. machines from pipes, ducts, support structures, etc.).
- Piping being designed to avoid pressure pulse noise or being fitted with effective pulse dampers.
- Structures being isolated from ground transmitted vibrations.
- Equipment being selected and supported to avoid operation at resonant frequencies.

Data Communications[8]

There shall be a data network linking information and computing workstations.

The data network shall at least the following:

- Provide a locked accommodation allocated exclusively to network servers and a main cable distribution hub
- Have cabling from main to sub distribution hubs run in dedicated channels in ducts or on tray

- Have sub distribution hubs located in locked cupboards where required
- With the exception of sub compartments within compartments required by the building code of Australia (BCA), a hub shall not serve more than one fire compartment
- Have cabling between sub hubs and data workstations terminating in wall sockets within 2000 mm of the computing equipment to be connected.

Cabling

It is important that cabling be labelled at each connection to servers, hubs and wall outlets. It should be neatly installed and supported and not run across floors. It should be routed away from electromagnetic interference and vulnerability to mechanical damage.

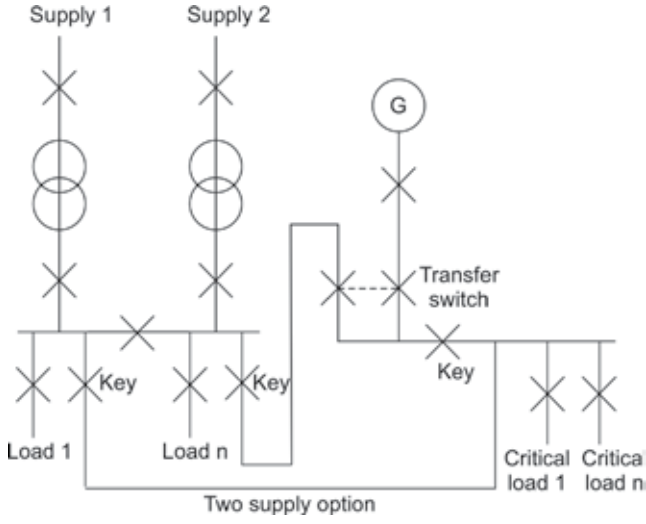
Servers and hubs shall be securely supported. Servers shall have an uninterruptible electricity supply connected to a delayed vital (30 seconds) circuit providing at least a 4 hours capacity at full load. Server rooms shall provide environments complying with server maker's specifications. The facility data network shall not be a limiting factor in the delivery of timely and competent healthcare outcomes.

There shall be emergency assistance call facilities, for use by staff, in every patient room, patient bathroom, treatment room and anywhere else where staff may be alone with a patient and need help to deal with a patient emergency. Requirements for system operation shall meet requirements of the facility risk management plan.

Electrical Services for CED shall Include[9-11]

- Provision of normal, vital (30 seconds), instantaneous (1 second), and uninterruptible (no break) electricity supplies
- Switchgear and circuit protection to safely operate and control the supplies
- Distribution arrangements to supply electricity to each end use
- Equipment to transform and condition voltages from supply voltage to end use voltage and within voltage and frequency tolerances
- Equipment to use the electricity for lighting, heating and motive power
- Where an electrical supply is denoted as being on an 'essential supply' then this shall be arranged as a vital (30 seconds) supply.

The following diagram illustrates the principles of the required supply configurations but will require adaptation to suit particular site distribution requirements:



Lighting Design[12]

It shall take into account for lux requirement of clinical engineering department. Special precaution for security requirements; entry points, car park and unattended areas shall be given.

Lightning Protection in CED

Its risk assessments shall be carried out on all facilities to comply with AS/NZS 1768 a presented to the proprietor. Risk assessment outcomes and mitigation strategies shall be agreed and recorded. Risks shall be mitigated, and as a minimum be in accordance with the recommendations of AS/NZS 1768.[13,14]

Fire Services in CED

It shall be provided to comply with requirements of the NBC 2005 and the proprietor's risk management plan and may include but not be limited to:

- Provision of materials and methods of construction complying with codes and regulations
- Compartmentation of the building(s) into fire and smoke control compartments
- Provision of complying fire egress arrangements
- Provision of fire and smoke alarms
- Storage arrangements for fire fighting water
- Fire fighting water pressure boosting arrangements
- Provision of smoke clearing ventilation
- Smoke mode controls for ventilation plant
- Provision of escape route air pressurization
- Provision of emergency warning and information equipment
- Provision of hose reel and hydrant fire extinguishing equipment
- Provision of automatic fire extinguishing systems
- Provision of portable fire extinguishers and fire blankets

- Provision of equipment to aid transportation of disabled persons
- Provision of escape diagrams.

Schedule of Accommodation

Area	*Area (m^2)*
Reception/clerical	1 × 12
Equipment collection bay	2 × 9
Bay-mobile equipment	1 × 4
Flammable liquid store	1 × 2
Bay-clean-up	1 × 3
Staff room	1 × 30
Workshop for equipment repair	1 × 25
Toilet-staff	2 × 2
Office—single person	1 × 12
Office—4 person shared	1 × 20
Office—workstation	2 × 6
Discounted circulation	Circulation will depend on size of unit (25–30%)

CONCLUSION

Biomedical/clinical engineering departments with expertise in engineering and technology management have a vital role to play in determining the potential for implementation and cost-effectiveness of new medical technologies through technology assessment. Each clinical engineering department will require some customization based on the services that it will provide and the resources that will be provided to it. However, every clinical engineering manager will need to consider and incorporate staffing, space, test equipment, tools, communications equipment, training, and a computerized maintenance management system into the department's plan.

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