VOLUME-8, ISSUE-5, MAY-2019 • PRINT ISSN No. 2277 - 8160

Original Research Paper

Medical Science

PLANNING PREMISES AND DESIGN CONSIDERATIONS FOR HOSPITAL LABORATORY

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ABSTRACT A medical laboratory or clinical laboratory is a laboratory where clinical pathology tests are carried out on clinical specimens to obtain information about the health of a patient to aid in diagnosis, treatment, and prevention of disease[1]. Laboratory construction, whether new construction, expansion, or renovation project, it is not only simple to buy the reasonable equipment, but also comprehensive consideration of the overall planning laboratory, rational layout, and graphic design, as well as electricity, water, air, ventilation, air purification, safety, environmental protection, infrastructure and basic conditions[2].

KEYWORDS : Laboratory planning, rational layout, modular design, safety

INTRODUCTION

A medical laboratory or clinical laboratory is a laboratory where clinical pathology tests are carried out on clinical specimens to obtain information about the health of a patient to aid in diagnosis, treatment, and prevention of disease. Modern medicine is increasingly dependent on laboratory services for the prevention, diagnosis and control of diseases; Medical laboratory services generate patient related information that enhances care and are an important link in the chain process of medical care. Fundamental to the process of laboratory facility planning is an understanding of some basic design principles that ensure future adaptability. Laboratories must have the flexibility to adapt to future, as-yet-unknown changes in technology and scientific processes. Modular design is by no means a cookie-cutter approach but rather a simplified approach to achieving a wide range of goals in laboratory design. Medical laboratories vary in size and complexity and so offer a variety of testing services. More comprehensive services can be found in acute-care hospitals and medical centers, where 70% of clinical decisions are based on laboratory testing[3].

Functions[4]

The functions of laboratories are manifold. Amongst the important functions are

- Provision of comprehensive and accurate analytical test results
- Assistance in confirming/rejecting a diagnosis, prognosis and follow up therapy.
- Detecting disease
- Training and research

Departments

In hospitals and other patient-care settings, laboratory medicine is provided by the Department of Pathology, and generally divided into two sections, each of which will be subdivided into multiple specialty areas. The two sections are[1]:

- **General Pathology** - involves a mixture of anatomical and clinical pathology specialties in the one Unit
- **Anatomic pathology:** areas included here are histopathology, cytopathology, and electron microscopy.
- **Clinical pathology,** which typically includes the following areas:
- **Clinical Microbiology**: This encompasses several different sciences, including bacteriology, virology, parasitology, immunology, and mycology.
- **Clinical Chemistry**: This area typically includes automated analysis of blood specimens, including tests related to enzymology, toxicology and endocrinology.
- **Hematology:** This area includes automated and manual analysis of blood cells. It also often includes coagulation.
- **Blood Bank** involves the testing of blood specimens in order to provide blood transfusion and related services.
- **Molecular diagnostics DNA testing** may be done here, along with a subspecialty known as cytogenetics.
- **Reproductive biology** testing is available in some laboratories, including Semen analysis, Sperm bank and assisted reproductive technology.

Fig 1: General layout of a modern hospital laboratory work station

Fig 2 : Clinical laboratory room with automated analyzers.

Classification of lab

The National Fire Protection Association (NFPA) codes give three classifications for labs depending upon the amounts of flammable and combustible chemicals that are stored.

Laboratory Classifications

Class A

- High Hazard
- 10 to 20 gal. of various flammable or combustible liquids allowed

Class B

- Intermediate Hazard
- 5 to 10 gal. of various flammable or combustible liquids allowed

Class C

- Low Hazard

- 2 to 4 gal. of various flammable or combustible liquids allowed

NABL classification[5]

- **Small Laboratory**: A laboratory receiving up to 100 patients per day
- **Medium Laboratory**: A laboratory receiving up to 101-400 patients per day
- **Large Laboratory**: A laboratory receiving above 400 patients per day

PLANNING PREMISES AND DESIGN CONSIDERATIONS

Functional Areas (req as per ISO 15189:2007 & NABL)

The Lab Unit will consist of the following Functional Areas[6]:

- Entry/ Reception area with patient waiting
- Specimen collection area including patient toilets (this area may also be located remotely in Ambulatory Care areas); the collection area shall have a workbench, space for patient seating and hand washing facilities
- Specimen Reception registration and sorting area
- Laboratories, which may include specialists laboratories
- Support areas, including Clean-up, Sterilisation area, Storage areas for reagents, appropriate storage for flammable liquids, general supplies, refrigerated storage for slides and reagents, disposal facilities for contaminated waste.
- Refrigerated blood storage
- Staff Areas including Offices, Meeting Rooms, Staff Room, Lockers and Toilets.

Functional relationship diagram of a Lab Unit[6]

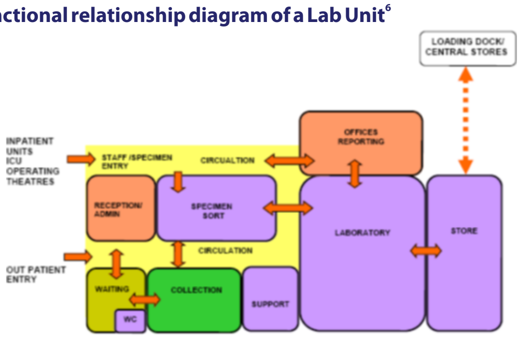

Fig 3 : Functional relation in lab unit

Number of laboratory units - The nature and type of healthcare facility, volume of tests and available resources should determine whether a central laboratory is sufficient or sub units are required in acute and ambulatory patient care units.

FLOW DIAGRAM OF LABORATORY SERVICES

The flow diagram of laboratory services is essential to plan the location of lab.

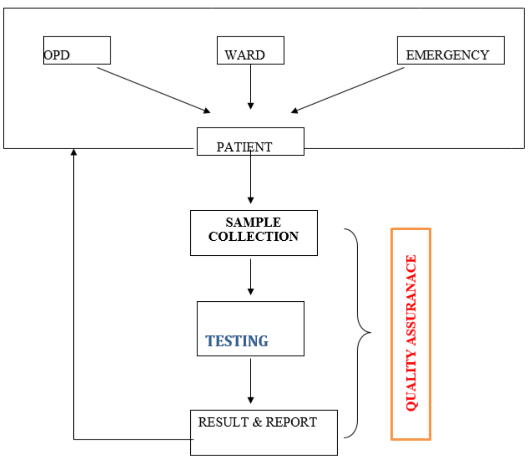

Fig 4 : Flow diagram of laboratory services

Locations

Laboratory should preferably be situated on the ground floor in close proximity to the ambulatory and acute patient care areas as well as in-patient areas.

Space Requirements

Extent of automation and type of technology used are the main space determinant in a laboratory. Rule of thumb is 5-7.5 sq. ft/bed or 0.7-0.8 m^2 / bed.

U.S. Public Health Service (**USPHS) specified the area required for hospital lab**[7]**:**

- 50 bed hospital area = 25 m^2
- 100 bed hospital area = 60 m^2
- 200 bed hospital area = 103 m^2

Or area can be counted by the number of the beds, 0.7-0.8 m^2 / bed.

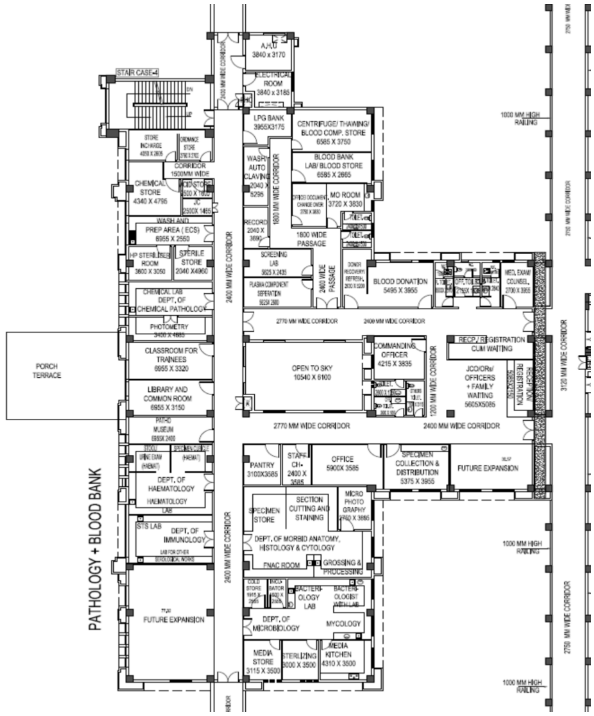

Fig 5: Layout of Standard hospital lab

Department in Lab

Histopathology - Electron Microscopy Room8

A separate room shall be allotted for tissue processing with a fume hood for handling osmium tetroxide.

A separate dust-free facility, with air-conditioning shall be available for preparation of specimen and performing electron microscopy. The electron microscopy room shall have:

- Facilities in place for temperature control and chilled water supply
- Insulated cabling kept away from the work areas
- Proper seating available to allow for optimal ergometric positioning of the person using the microscope
- Dark room with adequate ventilation.
- Warning light on the door of the dark room indicating usage.

Cytopathology

The laboratory shall have a dedicated space for FNAC procedure.

Microbiology[9]

A separate biological safety cabinet, certified at least annually to ensure that filters are functioning properly and that air flow rates meet specifications, must be available for mycobacteriological work and for mycological work.

The laboratory performing fungus culture shall be equipped with heating and cooling (BOD) incubator to meet with the environmental conditions for the isolation of fungi.

SUPPORTIVE SERVICES[10-11]

Lighting

Natural light should be used for providing the requisite illumination. Fixtures should be positioned to provide uniform, shadow-free and glare-free illumination of the laboratory bench top. The light required is as under

- Reception areas and stores : 200 lux
- Offices : 400 lux
- Working places : 600 lux (1 lux = 11 lumen/m^2).

General lighting for laboratories should be fluorescent fixtures. Fluorescent light fixtures should be directly above and parallel to the front edge of the laboratory bench to prevent shadows. Essential equipment should be on emergency power backup systems and uninterrupted power supply (UPS).

Electricity[12]

The laboratory shall ensure that adequate electrical service is available so that there is no interruption in power supply that may lead to compromise of stored data. All computers, peripherals, equipment and communication devices should be supported in such a way that service is not likely to be interrupted. The laboratory shall have procedures in place to ensure the integrity of refrigerated and/or frozen stored samples/reagents/consumables in the event of an electrical failure. The use of exposed cables should be minimum. Department wise distribution of electricity load is illustrated in table 2 & 3.

Floors

It should be of materials that may be cleaned and disinfected easily. Floor materials should be non-absorbent, skid-proof, resistant to wear, and resistant to the adverse effects of acids, solvents, and detergents. Materials may be monolithic (sheet flooring) or have a minimal number of joints such as vinyl composition tile (VCT) or rubber tile. Floor materials should be installed to allow for decontamination with liquid disinfectants and to minimize the potential spread of spills. They should be acid, alkaline and salt resistant. Seamless or self leveling Epoxy flooring is preferable. The **load bearing capacity of the floor** should not be less than 500kg/sqm. Labs handling radio-isotope should have 2000 kg/sqm. The vibrating equipment exerts a load of two or three times its static weight, hence requires a high load bearing capacity. It may be desirable to have some sections of floor isolated from their surroundings to prevent vibration from one piece of equipment affecting other equipment[13].

Wall

Wall surfaces should be free from cracks, unsealed penetrations, and imperfect junctions with ceiling and floors. Materials should be capable of withstanding washing with strong detergents and disinfectants and be capable of withstanding the impact of normal traffic[14].

Doors

Laboratory doors should not be of less than 1m wide. Some double doors of total width of 1.50 m should be constructed one of the doors in these may be 1.0 m width and the other of 0.50 m. Vision panels are recommended for all laboratory doors. In laboratories where the use of larger equipment is anticipated, wider/higher doors should be considered. Laboratory doors should be recessed and swing outward in the direction of egress. Door assemblies should comply with all appropriate codes. Biosafety Level 2 (BSL-2) laboratories should have doors that are self-closing and have locks. Laboratory doors are considered high-use doors. All hardware should be appropriately specified to withstand this type of use. Light commercial grade hardware will not be specified. All appropriate hardware to meet security, accessibility, and life safety requirements should be provided.

Ceilings

Ceilings such as washable lay-in acoustical tiles (Mylar face with smooth surface or equivalent) should be provided for most laboratory spaces. Open ceilings are acceptable provided minimal ducting and piping is present and all exposed surfaces are smooth and cleanable.

Windows and Window Treatment

Windows should be non-operable and should be sealed and caulked. Window systems that use energy-efficient glass are recommended. Treatments should meet all functional and aesthetic needs and standards.

Corridors

Width should be 2m to 2.5 m to facilitate movement of patients including those on wheelchairs.

Benches[14]

Height for counter top should be 750-mm and 900 mm for standing works. Depth of wall tables 700 mm. The height of competently reached overhead table cupboards should be 1500 mm. Length of bench needed for each technician ranges from 1.6 m to 1.8 m. Each lab bench should have lab sink with swan neck fittings with facilities (cool & hot water supply). In planning the under bench units, adequate knee space should be left at intervals for the convenience of workers. The bench tops are to be seamless and acid / alkali resistant .

Fig 6 : Length & Height of benches in Lab

Service Spines

In order to satisfy the servicing demands of said procedures as well as to allow for the rearrangement of working position under bench storage and each of repair and maintenance the bench services should be run in a spine behind and completely independent of benches themselves. This should permit easy access to service pipe, electrical fittings, plumbing and other fittings in service pipes.

Plumbing

The plumbing systems should be coordinated with the laboratory-planning module. A piping distribution method (i.e. mains, risers, and branch lines) should be designed to accommodate easy service isolation and system maintenance while minimizing disruption to laboratory functions. Piping systems should be designed for flexibility and have redundant components to provide reliable and continuous operation. Adequate fluid temperature, pressure, and volume should be delivered to required lab functions through conservatively sized pipe mains. Future capacity allowances need to be considered in building designs. Emergency isolation valves should be conveniently located on branch lines so that segments can be taken offline quickly in the advent of failures[15].

Sinks

Laboratories must have a sink for hand washing. The sink may be manually, hands-free, or automatically operated. Biosafety Level 2 (BSL-2) laboratories should have the sink located near the exit door. When a separate tissue culture room is located within a main lab room, there should be a hand washing sink located inside the tissue culture room[16].

Fig 7 : Laboratory Sink

Emergency Showers and Eyewash Stations[17]

At least one emergency shower and eyewash station should be available in each laboratory. These emergency showers and eyewash stations should be tapped to the laboratory water supply. When installing showers, the pull handle should be located in direct proximity to the shower head. Safety showers should be no more than 25 feet from the chemical fume hood or other area where corrosive chemicals will be used. An eyewash station must be readily available in all Biosafety Level 2 (BSL-2) laboratories. When a tissue culture room is located within a main lab room, the eyewash station should be installed next to the hand washing sink located inside the tissue culture room.

Emergency Eyewash should have following criteria

- Water remains on without use of hands (hands to hold eyes open)
- Goes from off to on in one second or less
- Large and easy to operate controls
- Delivers 0.4 gal of water per minute
- Water nozzles 33 to 45 inches above floor
- Visible sign
- Checked and flushed weekly

Emergency Shower should have following criteria

- Opens in one second
- Water remains on without use of hands
- Delivers 30 gal of water per minute
- Easy to locate and accessible controls
- Head at 84" from floor
- Adjustable water supply
- Visible sign
- Checked and flushed weekly

Pneumatic tube transport system

The transportation of sample requires a reliable solution that ensures a safe and efficient delivery. Rapid sample delivery systems, usually pneumatic tube system (PTSs), have been installed in hospitals to transport blood specimens from the phlebotomy site to the core laboratory and deliver patient reports to clinicians Transport of samples for blood gas analysis via a modern pneumatic tube system is safe when samples are correctly prepared. The use of rapid sample delivery systems can significantly reduce the turnaround times (TATs) of results, which account for approximately 40% in the laboratory median TATs.

Fig 8: Pneumatic tube transport system

Vacuum Systems

Vacuum pump systems will have hydrophobic (water-resistant) filters on the suction side, with the exhaust to the outside of the facility. Vacuum system exhaust should be vented to the outside of the building and not re-circulated to the mechanical room. A sampling port may be needed to sample exhaust. Filter housing should be designed for easy replacement of the filter, with maximum protection for maintenance employees from possible contamination.

Vacuum systems should be protected with appropriate filtration (0.2 micron hydrophobic filter or equivalent) to minimize the potential contamination of vacuum pumps. Filters should be located as close as possible to the laboratory in order to minimize potential contamination of vacuum lines. Some mechanism for the decontamination of filters should be incorporated in the design of the vacuum system.[18]

Ventilation

Mechanical ventilation system is required with 10-15 air changes per hour in areas where ferns are expected and 4-8 air changes in other areas. Systems should have adequate ventilation capacity to control fumes, odors, and airborne contaminants, permit safe operation of fume hoods, and cool the significant heat loads that can be generated in the lab.

Laboratory HVAC systems should utilize 100 percent outdoor air, conditioned by central station air handling systems to offset exhaust air requirements. Laboratory supply air should not be re-circulated or reused for other ventilation needs. Laboratories containing harmful substances should be designed and field balanced so that air flows into the laboratory from adjacent (clean) spaces, offices, and corridors. This requirement for directional airflow into the laboratory is to contain odors and toxic chemicals, i.e., negative pressurization. Air supplied to the corridor and adjacent clean spaces should be exhausted through the laboratory to achieve effective negative pressurization. Laboratories should remain at a negative air pressure in relation to the corridors and other non-laboratory spaces. Laboratory air should flow from low-hazard to high-hazard use areas. Administrative areas in laboratory buildings should always be positive with respect to corridors and laboratories.[19]

Table 1: HVAC for Hospital Laboratory

Temp.	Humidity	Air- changes / Hrs, Fresh Air-F, Recirculated-R	Pressure Relation Ship to Adjacent Areas	Bio. Med. Eqpt. Load
22°±2°C	Up to 60%	6-8/h – R	Histology, Microbiology, Virology, Mycology Mobid Anatomy- N	20000 W

Gas Cylinders

If gas cylinders are to be placed in the lab, they should be properly secured to a vertical surface or counter out of the way of traffic in the space. Appropriate space for such cylinders should be provided within the laboratory to minimize potential hazards associated with the use of these cylinders and to maximize usable laboratory space.

Flammable Chemicals and Waste Storage

Flammable-chemical storage cabinets should be placed in each laboratory and meet applicable fire safety requirements. Flammable storage cabinets should not be located near exit doorways, stairways, or in a location that would impede egress. Space should be allocated in each laboratory for storage of chemical waste.[20]

Biosafety levels in laboratory[21]

Biosafety levels are more important today with the expanding usage of DNA Amplification. The Center for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH) have categorized the requirements of the four levels.

Biosafety Levels

- **BSL 1** - Infectious agents not known to cause disease in healthy adults
- **BSL 2** - Infectious agents associated with human disease. Ability to infect through autoinoculation, ingestion, and mucous membrane exposure
- **BSL 3** - Infectious agents with potential for aerosol transmission. Effects may be serious or lethal
- **BSL 4** - Infectious agents which pose high risk of life-threatening disease, aerosol transmitted lab infections, or agents with unknown risk of transmission

Fire Extinguishers

The distribution of fire extinguishers is specified by fire code. For example, a fire extinguisher must be within 30 feet of a flammable liquid storage area. Extinguishers should be conspicuously located where they will be readily accessible in the event of fire. They should be located close to the exits from an area and along normal paths of travel. Fire protection and fire detection equipment should not be obstructed.

Hazard Communication Signage

Each laboratory should have a signage holder for prominently displaying hazard communication information at the entrance door. Individual labs should have signage holders that are consistent with the type used by other laboratories within each department or building.

Alarm and Monitoring Systems

The increasing sophistication and fine control of laboratory instruments and the unique quality of many experiments demand closely monitored and alarmed systems that can be connected to individual pieces of equipment or temperature-controlled rooms. Several excellent monitoring systems are available for this purpose. They can be connected to a central monitoring facility at several levels of observation or can be used internally within a laboratory setting.

TABLE NO 2 : SCHEDULE OF ACCOMMODATION WITH ELECTRICITY LAOD

AREA		SQ MTR	Scale of lighting Watts / Sq mtr	Lighting load in watts	Fan Load @14Sqm / Fan (80 W)	TOTAL LOAD OF FAN(W/FAN)	Total Load in Watt
General							
1.	Reception & Registration	10.50	4.6	48.3	1.00	80	128
2.	Specimen collection and distribution	21.00	4.6	96.6	2.00	160	257
3.	Waiting Rooms	28.00	9.2	130	2,00	160	288
4.	Toilet for male and female (2X3.5)	7.00	4.6	32.2			32
5.	Office, record & computer room	21.00	4.6	96.6	2.00	160	257
6.	Stores Chemical	17.50	4.6	80.5	1.00	80	161
7.	Stores Acid	3.50	4.6	16.1	1.00	80	96
8.	Stores General	7.00	4.6	32.2	1.00	80	112
9.	Stores-in-charge	10.50	4.6	48.3	1.00	80	128
10.	Staff changing	7.00	4.6	32.2	1.00	80	112
11.	Staff toilets for doctors	3.50	4.6	16.1	1.00	80	96
12.	Staff toilets for staffs	3.50	4.6	16.1	1.00	80	96
13.	LPG Bank (if no piped gas (PNG) avlb)	10.50	4.6	48.3			48
Deptt of Morbid Anatomy, Histology & cytology							
14.	Histology Laboratory						
	(a) Grossing and processing	21.00	9.2	193.2	2.00	160	353
	(b) Section cutting and staining	21.00	9.2	193.2	2.00	160	353
15.	Specimen store (for storage of specimen, blocks & slides)	10.50	4.6	48.3			48
16.	Microphotography Room	10.50	4.6	48.3	1.00	80	128
17.	FNAC Room	14.00	9.2	128.8	1.00	80	209
Dept. of Microbiology & Bacteriology							
18.	Bacteriologist with laboratory	14.00	9.2	128.8	1.00	80	209
19.	Bacteriology laboratory	14.00	9.2	128.8	1.00	80	209
20.	Mycology lab	10.50	9.2	96.6	1.00	80	177
21.	Media Rooms						
	(a) Media Kitchen	10.50	9.2	96.6	1.00	80	177
	(b) Media storage and plate pouring	10.50	9.2	96.6	1.00	80	177
	(c) Sterilizing room	10.50	9.2	96.6	1.00	80	177
22.	Incubator Room	3.50	9.2	32.2	1.00	80	112
23.	Cold Storage	3.50	4.6	16.1			16
Department of Immunology							
24.	S.T.S laboratory	14.00	9.2	128.8	1.00	80	209
25.	Laboratory for Other Serological Work	10.50	9.2	96.6	1.00	80	177
Department of Haematology							
26.	Haematology laboratory	17.50	9.2	161.0	1.00	80	241
27.	Stool, Urine examination with	10.50	9.2	96.6	1.00	80	177
28.	Specimen Cubicle	10.50	9.2	96.6	1.00	80	177
Department of Chemical Pathology							
29.	Chemical laboratory No. 1	21.00	9.2	193.2	2.00	160	353
30.	Photometry, Chromatography & Electrophoresis and other electronic equipment room.	14.00	9.2	128.8	1.00	80	209

Equipment Cleaning Section							
31.	Wash up and preparation Room	17.50	4.6	80.5	1.00	80	161
32.	HP sterilizer Room	10.50	9.2	96.6	1.00	80	177
33.	Sterile Storage	7.00	4.6	32.2	1.00	80	112
34.	Janitor's Closet	3.50	4.6	16.1			16
Photography & Illustration, Pathology Museum & Training of Laboratory Technician Section							
35.	Pathology Museum	10.50	9.2	96.6	1.00	80	177
36.	Library & common Room	21.00	9.2	193.2	2.00	160	353
37.	Classroom for trainees	21.00	9.2	193.2	2.00	160	353
TOTAL		**514.5**					**6808 W**
AREA OF FUTURE EXPANSION 10%		**51.45**					
Plinth Area for Circulation Factor 30%		**169.78**					
Plinth Area required		**735.73**					

TABLE NO 2 : Total electricity requirement

Electricity load	Watt consumption
1. Electricity load in different dept	6808 W
2. Refrigerator 286 Ltr's cap (500 w)	4500 W (Min 9 Required)
3. Deep freezer300 Ltr's (750w)	1500 W
4. Exhaust fan 300 mm sweep(100 w)	500 W
5. Geyser 25 Ltr cap	1500 W
6. Solar water heater 100 Ltr cap	2000 W
7. Walk in cooler's 1 Ton cap	1500 W
8. Water cooler 40/50 Ltr's cap. with water purifier	1500 W
9. AC (60 % of plinth area = 441 sq mtr)	20000 W
Total load in watt	39808 W = 39.8 KW

CONCLUSION

Laboratories are process intensive centers and are vital service in patient care delivery. It is thus essential that the complex task of planning laboratories should receive due consideration on all facets. The laboratory building is a complicated system, in the modern laboratory, advanced scientific instruments and superior sound lab is to enhance the level of modern technology, a prerequisite for the growth of scientific research. Laboratories are expensive buildings and must be designed to evolve with the continual shifts in scientific discovery and advances in technology.

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