TAYLOR'S UNIVERSITY

Wisdom • Integrity • Excellence

SCHOOL OF ARCHITECTURE, BUILDING & DESIGN

BACHELOR OF SCIENCE (HONOURS) IN ARCHITECTURE

BUILDING SERVICES (BLD 61403)

PROJECT 2:

CASE STUDY AND DOCUMENTATION OF BUILDING SERVICES SYSTEMS

LIM SHU TING	0320102
SIM JIA HUI	0320386
ANGOLINE BOO LEE ZHUANG	0316144
ONG KER SIN	0321719
NG MING HWEE	0319511
LAI CHI MUN	0319463

TUTOR : MR. SIVA

Table of Content

1.0 Abstract

This report is to record the analyzing and observation results about building services system in KLPAC (Kuala Lumpur Performing Arts Centre), which included the mechanical ventilation, fire protection system, air-conditioning system and mechanical transportation system. After all, this project is to give students a clear image of what the students have learnt from the lecture and evaluate the students' understanding on the systems they have studied from KLPAC.

At KLPAC, the students were guided by a building facilities staff throughout the whole investigation of the services system on site. The places that students visited including the refrigeration plant room, fire protection system panel in the security room, AHU room and assembly point. Students would only understand and be able to analyzed these systems by the guide of the professional building services staff.

For every system that was analyzed and investigated, these systems are divided into 4 main chapters. Each system will be introduced and then further explained according to its location in KLPAC, functions, types of components, and UBBL by-laws. Students would also comment whether each system in KLPAC fulfil the safety policy or if it fulfilled the requirements in UBBL by-laws and MS1525.

2.0 Introduction

2.1 Building History

The Kuala Lumpur Performing Arts Centre (KLPAC) or Pentas Seni Kuala Lumpur located in Sentul West is a non-profit company which aims to "cultivate and sustain the performing arts for the betterment and enrichment of communities within the Klang Valley and for the Nation." Founded by Joe Hasham and Dato' Faridah Merican in 1995 at Plaza Putra, The Actor's Studio was formed as the first privately owned and operated theatre in Malaysia. In 2003, the underground complex of was destroyed due to flash floods. It was then in 2004 that Yayasan Budi Penyayang Malaysia, YTL Corporation Berhad and The Actor's Studio Malaysia created a newly formed platform, which is KLPAC today, to develop the performing arts in Malaysia.

However, the building where KLPAC is today has a long and interesting history. It was originally a railway warehouse which owned by YTL Corporation Berhad. This warehouse had about 200 years of history. In the 1800s, this building was a used to be a wood-crafting workshop and sawmill. Later during World War II, it was partly damaged but then soon rebuilt. After it was abandoned, YTL taken over this building around 1990s, and then renovated this place. The surrounding park's landscape was also later designed and beautified. It's only in 2004 YTL rented this place for KLPAC without charging a cent.

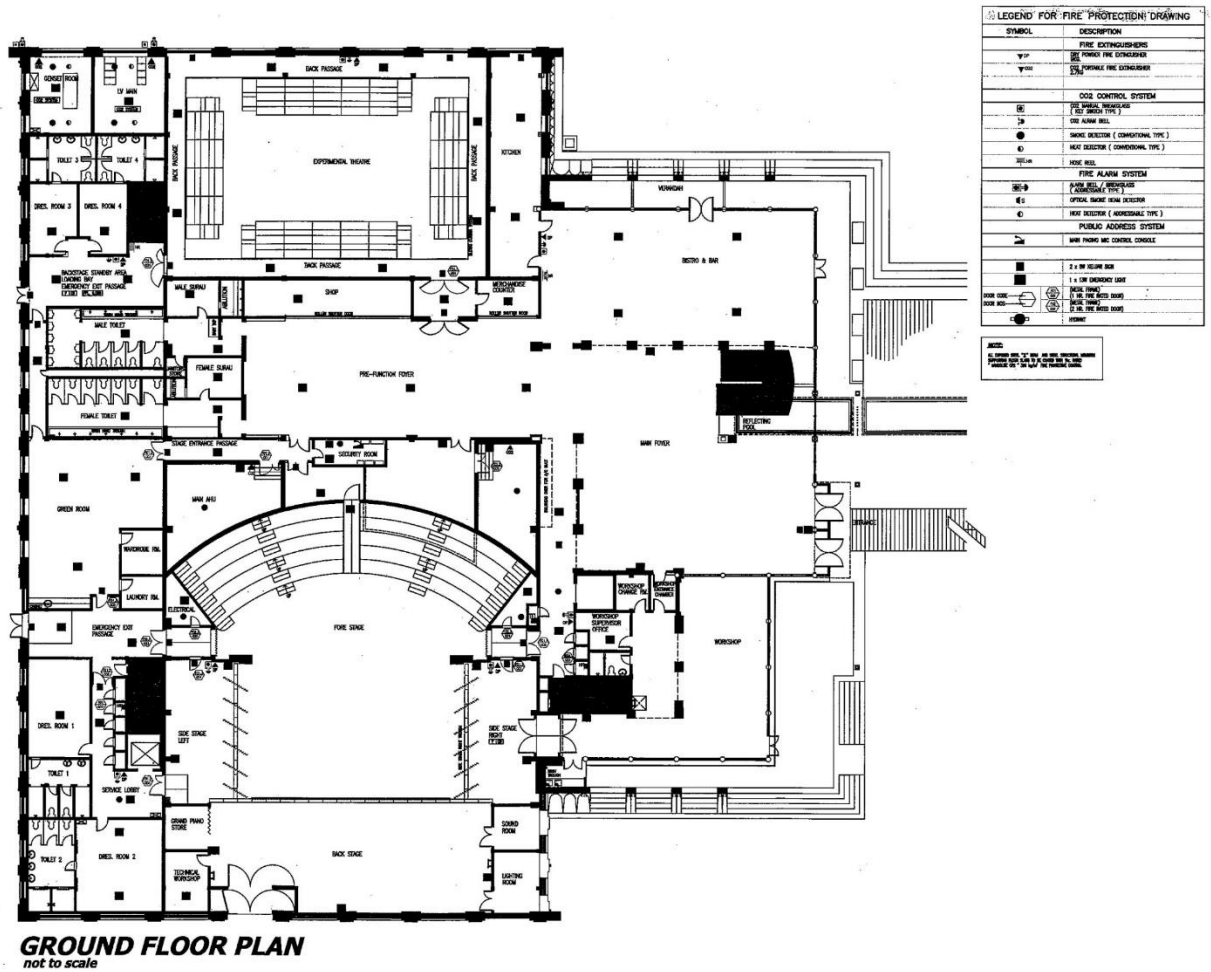
Figure 2.1: Kuala Lumpur Performing Arts Centre.

Source: KLPAC management, (2016).

Figure 2.2: Right frontal view of KLPAC.

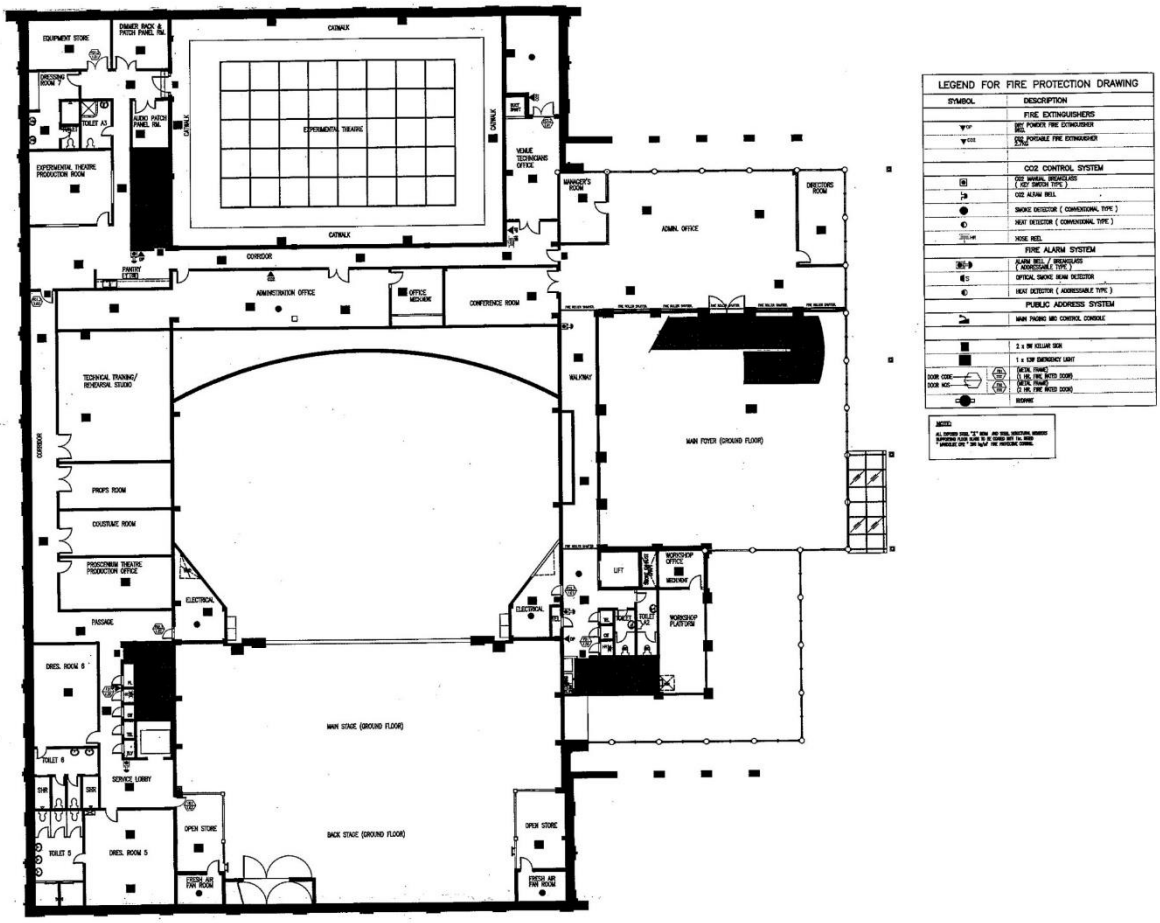
Source: KLPAC management, (2016).

2.2 BUILDING FLOOR PLANS

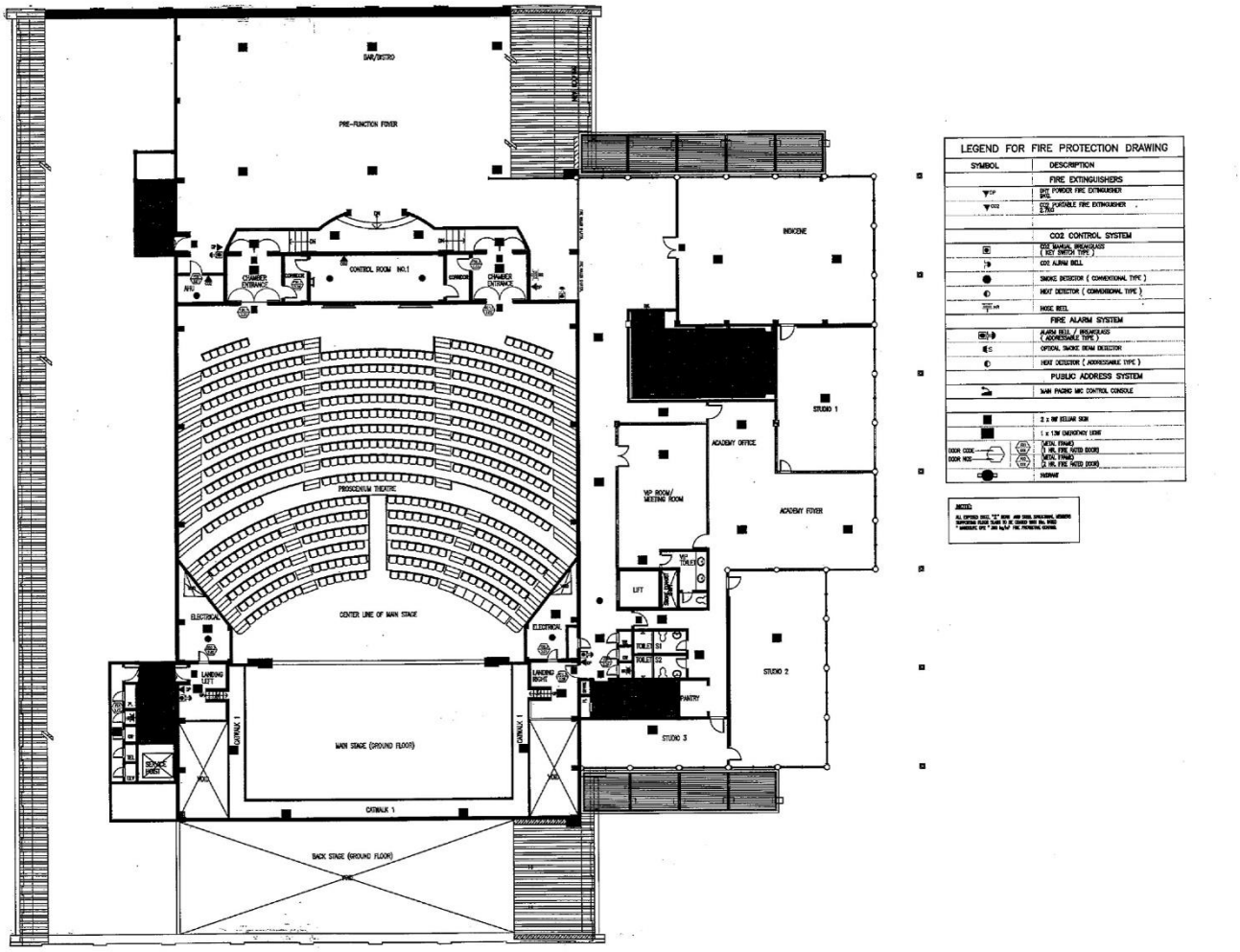


GROUND FLOOR PLAN
not to scale

Source: KLPAC. (2016).

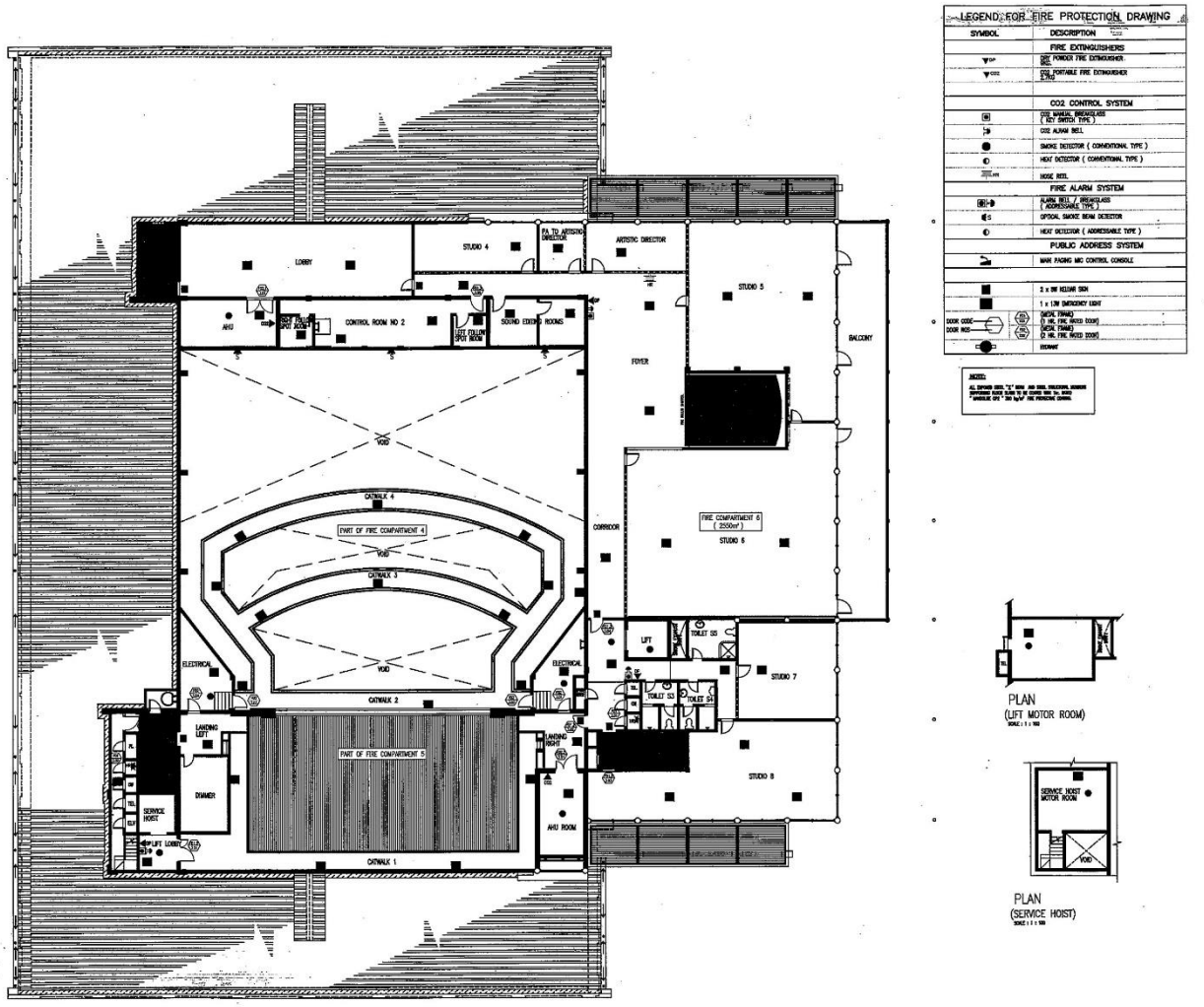


Source: KLPAC. (2016).



2nd FLOOR PLAN
not to scale

Source: KLPAC. (2016).



3rd FLOOR PLAN
not to scale

Source: KLPAC. (2016).

3.0 Mechanical Ventilation

3.1 Introduction

Ventilation is a process of exchanging air, includes both replacing air from outside or circulating air within a space. It is important in obtaining healthy and comfort condition. Ventilation helps to prevent heat concentration and air humidity. Ventilation is also used to remove carbon dioxide, unpleasant smells, excessive moisture and contaminants such as airbome bacteria, smoke to replenish the indoor space with oxygen to maintain the percentage of oxygen at 21%. The disposal of gas plays a crucial role in fire prevention. Therefore, a building should ensure a good air circulation for comfort and safety purpose. Ventilation is divided into natural ventilation and mechanical ventilation. Natural ventilation occurs when there's air difference. It can be achieved via operable windows. Warm air in the building rises to the upper openings and cool air is forced in to ventilate the building. Although natural ventilation is energy saving, it is very climatic based and varies due to different location. That's when mechanical ventilation is introduced to reach the standard required of air in a building.

Mechanical Ventilation is used for application where natural ventilation is not appropriate. Without mechanical ventilation brings in fresh air, contaminants, heat, moisture, odors may be left in the building and caused health problem as well as fire. Mechanical ventilation circulates fresh air by using fans, ductwork rather than relying on openings. Air is being pushed inward or outward by motorized fan, resulting in different air pressure state, and thus allowing the air to circulate around the building in a mechanical way. This is more efficient than natural ventilation when the building is built below ground level and has a huge coverage area.

The purpose of having mechanical ventilation primarily goes to the importance of fresh outdoor air. Sometimes, indoor air is much more polluted than outdoor air. Mechanical ventilation can thus provide a good air quality condition. Besides, mechanical ventilation is much more controllable compare to the natural ventilation. Relying on airflow via openings through walls, windows or roof, there's no control of the source and the amount of airflow. In fact, air leaking in the house may from undesirable area like garage or crawl space and thus increase the level of pollutant in the air. The system is planned before-handed on the sources of airflow and is filtered before entering the building. Air is brought in and pollutant is extracted out consistently and thus provides a comfort living condition.

3.2 Literature Review

Mechanical ventilation can be found in various systems according to the function of the space. There are three type of system, which are supply ventilation system, exhaust ventilation system and balanced ventilation system.

3.2.1 Supply Ventilation System

Supply ventilation system is system where fresh air is brought in mechanically, and extract naturally through the openings from the building. It creates over pressure condition. Air is then drawn out due to lower pressure at the outside. This system is usually used in boiler plants and factories.

The air supply is located in high place and the air inlet must have the possibility of regulated. It should not be located near the outlet location to prevent air from escaping from the building. An air filter is connected to the inlet inside the ductwork to clean the coming air.

A fan or a set of ductwork is used to distribute the fresh air from outside or it can be connecting with the returning air duct, allowing the heating and cooling system's fan and ducts to process the outdoor air before being distributed.

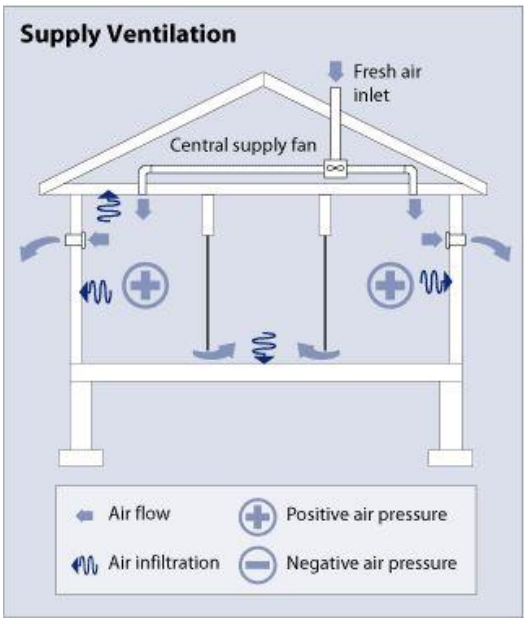


Figure 3.1 supply ventilation air flow diagram

Source: http://energy.gov/energysaver/whole-house-ventilation

3.2.2 Exhaust Ventilation System

Exhaust ventilation system is a system where mechanically exhaust air to the outside. This creates under pressured in the building. The under pressure creates a pressure differences over the ventilation openings, so air is suck in naturally. A controllable exhaust controls the ventilation capacity. In residential area, such system is applied in kitchen (suck out smoke) and toilets. Suction duct is required in non-residential building, such system is applied in places like basement, corridor, food court and etc. The extraction of air processes a loud noise. Thus, baffle filters can be used.

Single fan is installed in the duct connect to the central exhaust point to be expel to outside. Passive vents are installed for the air to flow in. Passive vents however needed a large pressure difference compare to those induced by mechanical supply system. One concern of the exhaust ventilation system is that the possibilities of pollutants existence, including Radon and molds from a crawlspace.

- Dust from an attic
- Fumes from an attached garage
- Flue gases from a fireplace or fossil- fuel- fired water heater and furnace

Exhaust ventilation contributes to higher operation energy and cost in heating or cooling the air because the air supply is brought in naturally with contaminants and moisture.

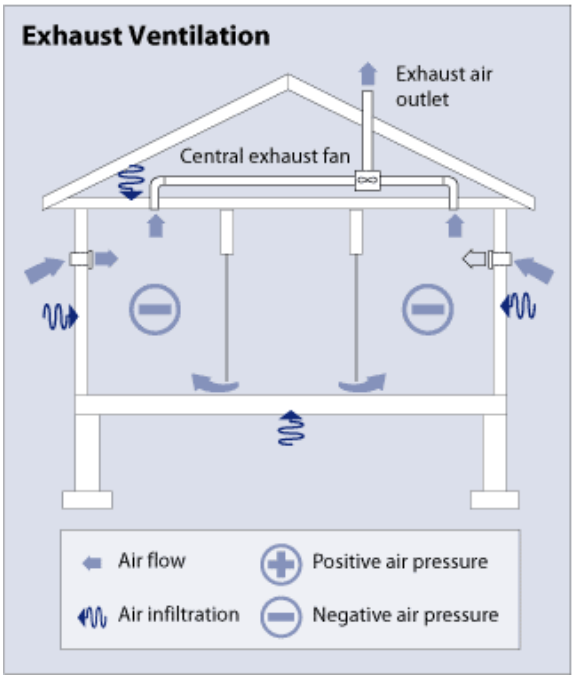


Figure 3.2 Exhaust ventilation air flow diagram

Source: http://energy.gov/energysaver/whole-house-ventilation

3.2.3 Balanced Ventilation System

In a balanced ventilation system (also known as combined ventilation), both the supply air and the exhaust air is done mechanically. The air pressure of the room is in neutral state. As the pressure created by the supply air is then depressurized by the exhaustion of air.

This system is known as the most efficient way in ventilating the air as it is independence of outdoor weather despite of noisy environment and high installation cost. The combination of system requires two ducts and fan system. This system usually applied in the area where natural ventilation hardly accesses or hard to control such as basement and suitable for all climates.

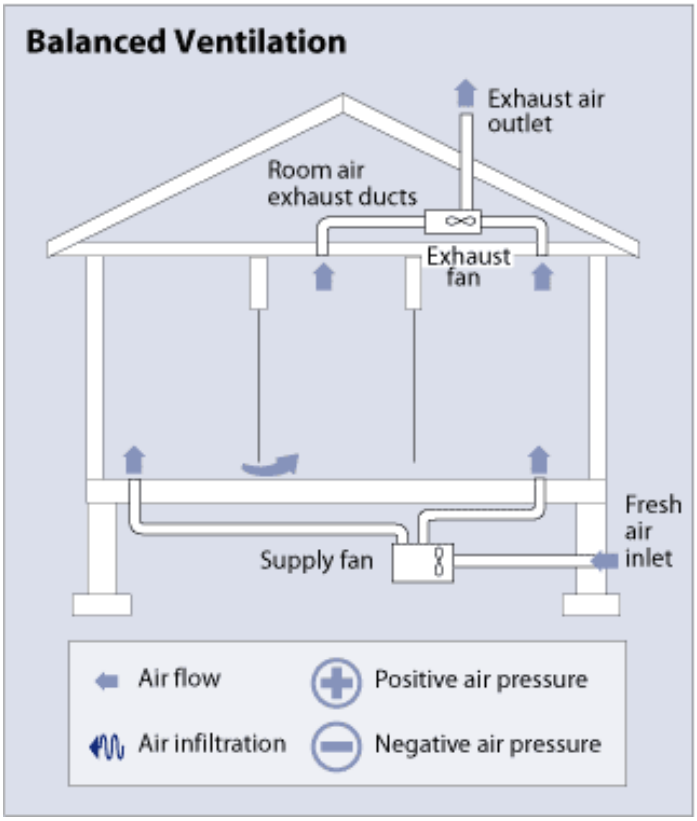


Figure 3.3 Combined ventilation air flow diagram

Source: http://energy.gov/energysaver/whole-house-ventilation

3.2.4 Comparison Between the Three Systems

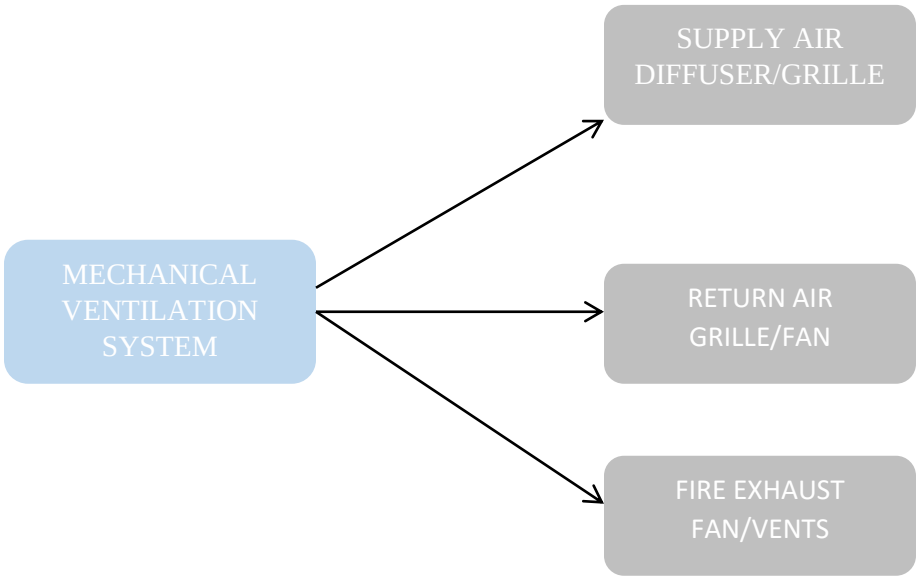
Ventilation system	Pros	Cons
Supply Ventilation	• Relatively inexpensive and simple to install • Allow better control than exhaust system • Minimize pollutants from outside • Prevent back drafting of combustion gases from fire places and appliances • Allow filtering of pollen and dust in outdoor air • Allow dehumidification of air • Work well in hot and humid climate	• Can cause moisture problem in cold climate • Will not temper or remove moisture from outside air • Can increase heating and cooling costs • May require mixing of outdoor and indoor air to avoid crafts in cold weather
Exhaust Ventilation	• Relatively inexpensive and simple to install • Work weak in cold climates	• Can draw pollutants into living space • Not appropriate for hot and humid climates • Rely in part on random air leakage • Can increase heating and cooling cost • May require mixing of outdoor and indoor air to avoid drafts in cold weather
Combined Ventilation	• Appropriate for all climate	• Can cost more to install and operate than exhaust or supply system • Will not temper or remove moisture from incoming air

Table 3.4 Comparison of Ventilation System

Source: http://energy.gov/energysaver/whole-house-ventilation

3.3 Case Study

KLPAC uses combined system of both supply and exhaust ventilation for the whole building by using large amount of grilles and diffusers hidden behind the ceilings to ensure ventilation throughout the building. Although there is large glass window at the front façade allowing natural sunlight to penetrate through the building to light up the interior, but it is enclose thus not allowing natural ventilation to happen. To compensate for the lack of passive design for ventilation, the whole building is filled with mechanical ventilation system to ventilate the air in the building. This results in high maintenance cost for the building, which explains why during our visit to the building, most of the air conditioning systems are closed.



3.4 Components of System

3.4.1 Supply Air Diffuser/ Grille

Figure 3.5: Vertical Supply Air Diffuser located in the Main Foyer of KLPAC

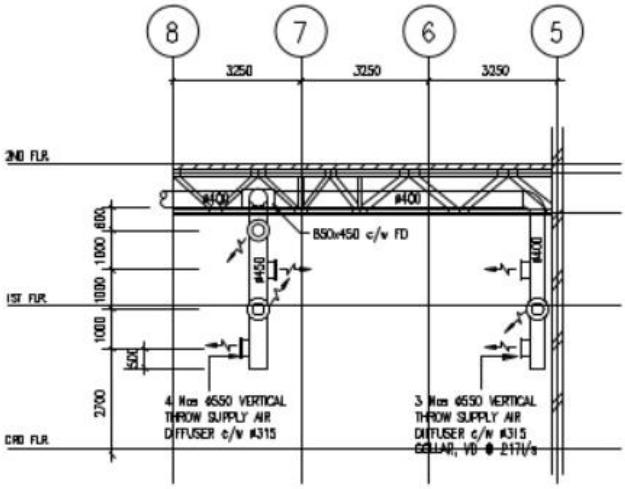


Figure 3.6: Section Drawing of Vertical Supply Air Diffuser located in the main foyer of KLPAC

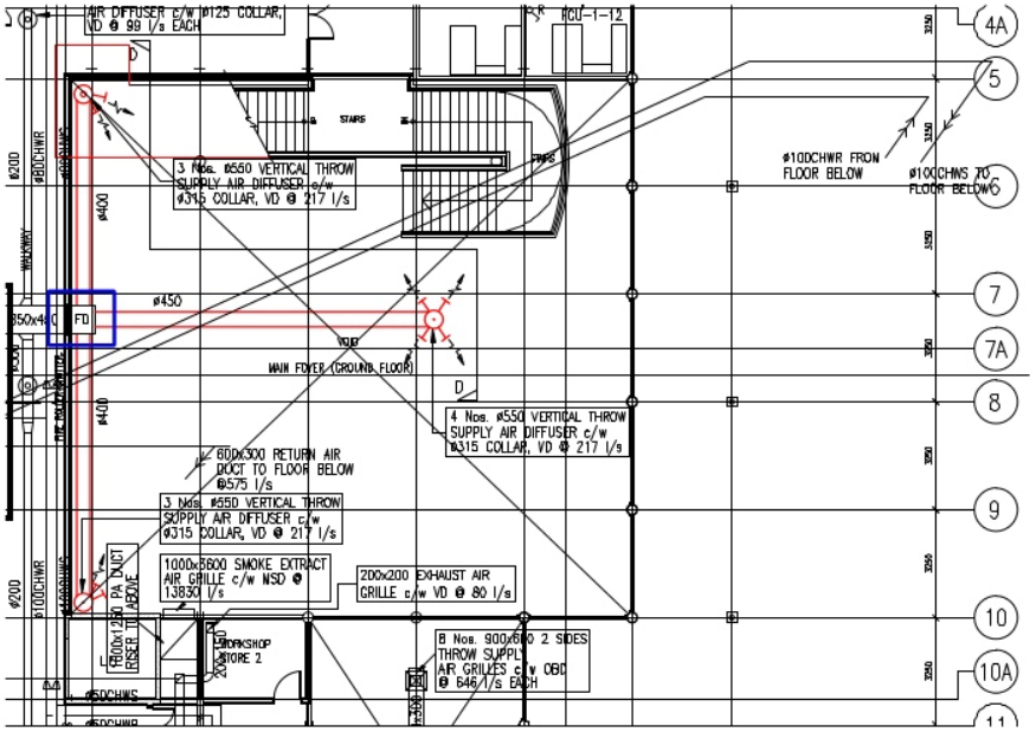


Figure 3.7: Plan Drawing for Vertical Supply Air Diffuser in the Main Foyer

There are at least three connected vertical supply air diffuser in the main lobby. These diffusers are located in this area due to the coverage area of the main lobby is larger scale than normal.

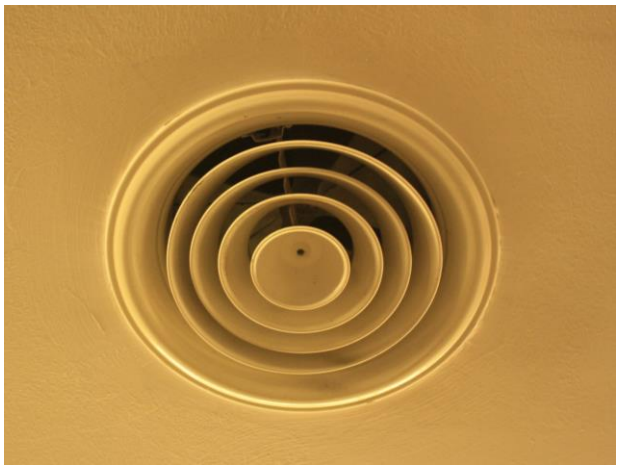


Figure 3.8 Diffuser concealed by the ceiling

MS 1525 8.3.1 Separate Air Distribution System

Zones that are expected to operate non-simultaneously for more than 750 hours per year should be served by separate air distribution system. As an alternative off-hour controls should be provided in accordance.

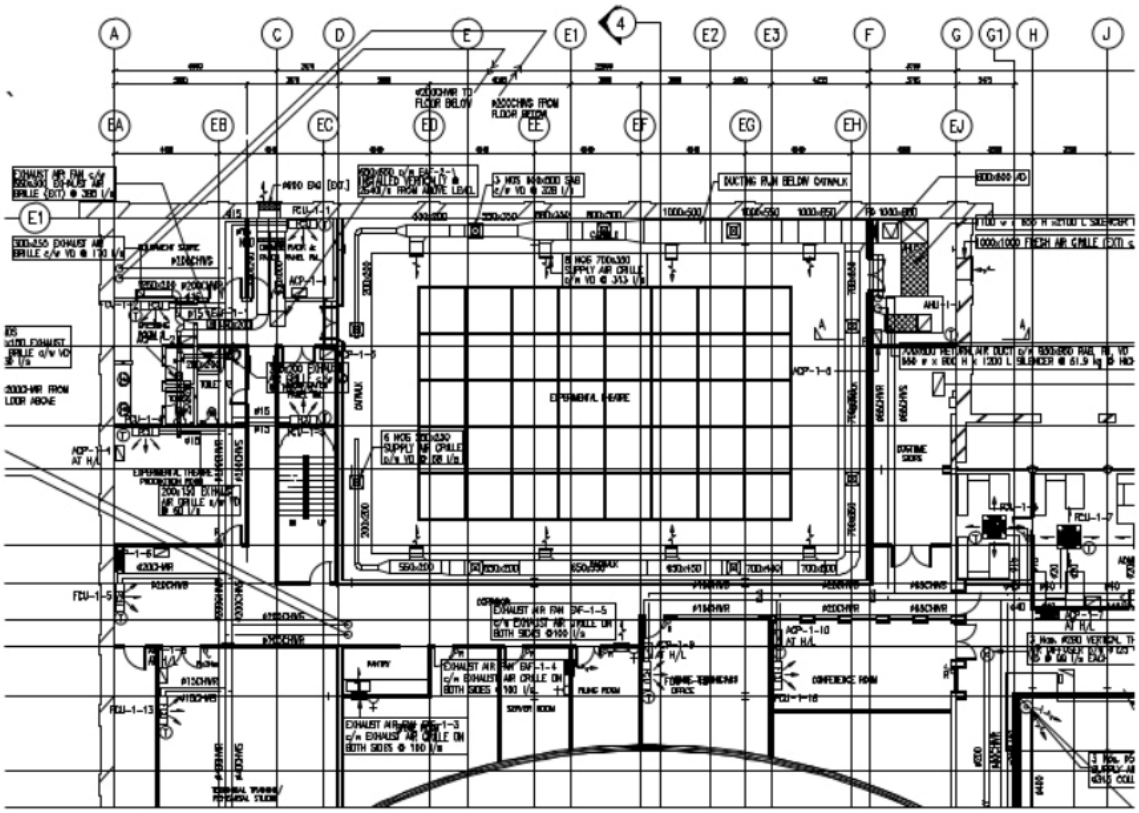


Figure 3.9: Plan drawing of how Air Diffuser are connected through ductwork

Analysis

In KLPAC, different spaces are equipped with more than one ventilation system to regulate the air in the spaces respectively according to the space, usage and operating hours.

Figure 3.10: Grille located behind seating of the Main performance stage

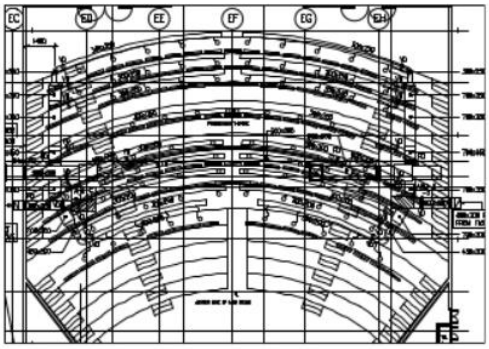


Figure 3.11: Detailed Plan Drawing for Supply Air Grille Location

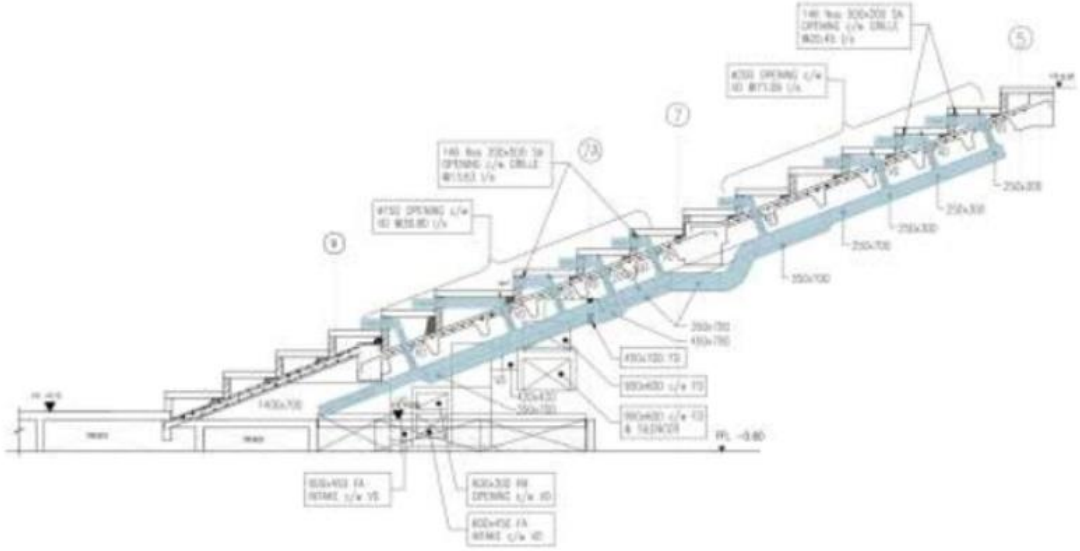


Figure 3.12: Detailed sectional drawing of the supply air grille behind the seating of the main performance stage

Diffusers are located at the edge of the ductwork where the supply air is released into the room. They do not require any generation of power and create low-velocity air movement in occupied rooms in any desired directions while producing the minimum amount of noise. Most of the air diffusers in KLPAC are rectangular or circular air diffusers and are either exposed or concealed in ceilings. However, in the main performance stage, supply air grilles were installed behind the seats to evenly distribute air inside the large area.

3.4.2 Return Air Grille

Figure 3.13: Exhaust Air Grille located at Ground Floor Corridor

Figure 3.14: Exhaust Air Grille located on the ceiling in the toilet

Figure 3.15: Exhaust air grille at fire pump room

A return air grille is a connection to a chain of ductwork that draws air from the spaces back to the heating or cooling system. They usually use grillwork to cover the duct behind it to avoid big objects from entering the duct and damaging the AHU. Filters are also installed to trap pollutants and allow better airflow in the building. In KLPAC, it is installed in warm spaces containing equipment that generates heat such as the fire pump room and the lift control room. These air grilles or fans are placed under timer to suck out warm air every few hours to prevent overheating.

MS 1525 code 8.4.5 Mechanical Ventilation Control

"Each mechanical ventilation system (supply/exhaust) should be equipped with a readily accessible switch or other means for shut down or volume reduction when ventilation is not required. Example of such devices would include timer switch control, thermostat control, duty cycle programming and CO/CO2 sensor control"

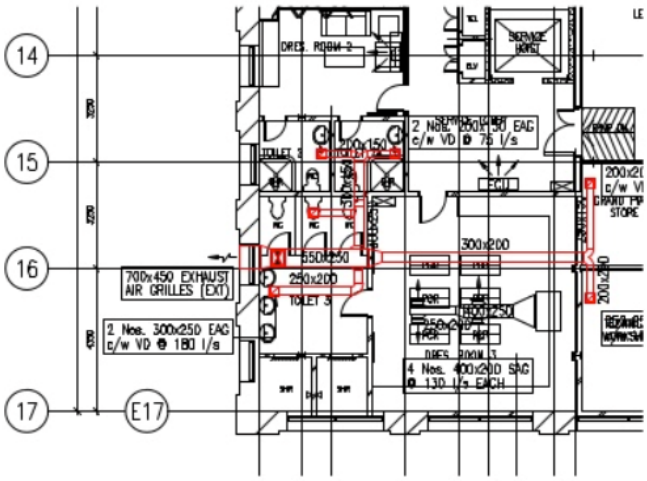


Figure 3.16: Plan drawing of exhaust air grille used in the toilet beside the main stage

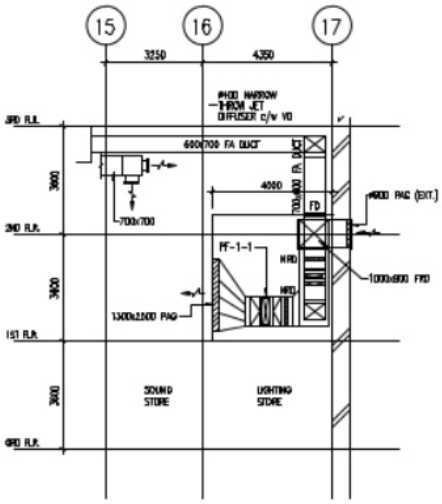


Figure 3.17: Sectional drawing of the exhaust air grille used in the toilet beside the main stage

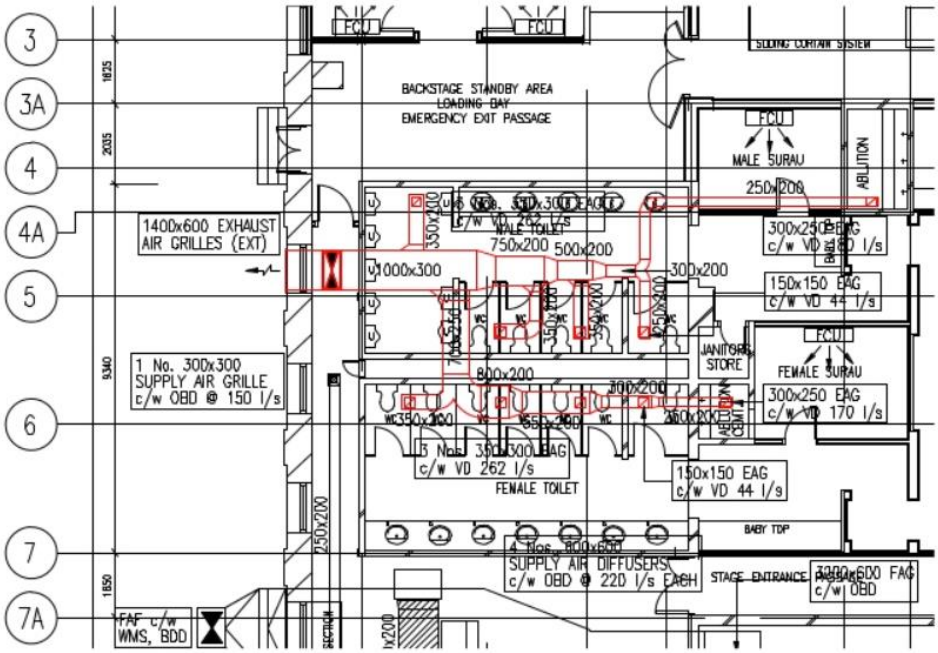


Figure 3.18: Plan drawing of exhaust air grille used in the public toilet of KLPac

Analysis

The toilets are located at different parts in KLPAC, ensuring the building is well-ventilated and foul air expelling out from the building. As shown in Figure 3.4.2.5, the amount of exhaust air grille is enough to cover the whole area in the toilet.

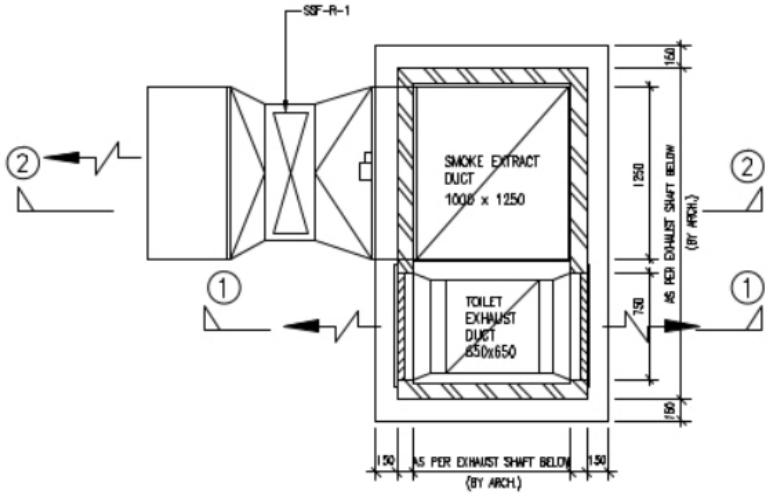


Figure 3.19: Detailed drawing of exhaust ventilation system in KLPAC

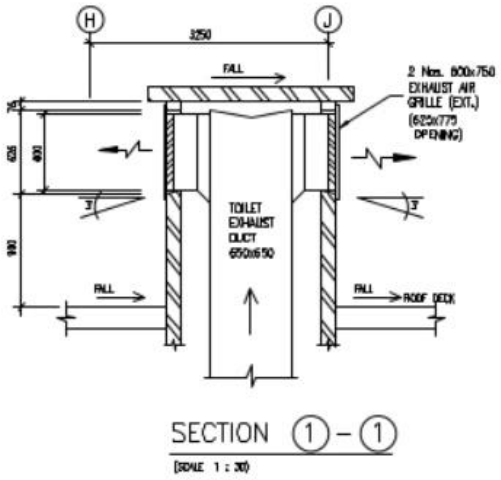


Figure 3.20: Sectional drawing for toilet exhaust duct in KLPAC

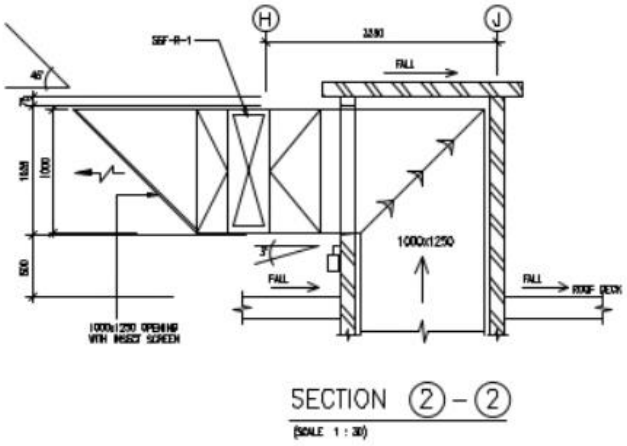


Figure 3.21: Sectional drawing for smoke Extract Duct in KLPAC

UBBL By Law-41

Law Section 10- Water Closets and toilets

Water closets, toilets, lavatories, bathroom, latrines, urinals or similar rooms or enclosures used for ablutions which are situated in the internal portions of the building and in respect of which no such external walls or those overlooking verandahs, pavements or walkways are present, shall be provided with

3.4.3 Fire Exhaust Fan/ Vents

Figure 3.22 Fire exhaust fan located outside of KLPAC

In KLPAC, automatic fire exhaust vent is installed at the main performance stage so that it will expel smoke, heat and gas automatically in case of fire emergency. Exhaust fans connecting to smoke exhaust ductwork are used to remove air from building to allow more

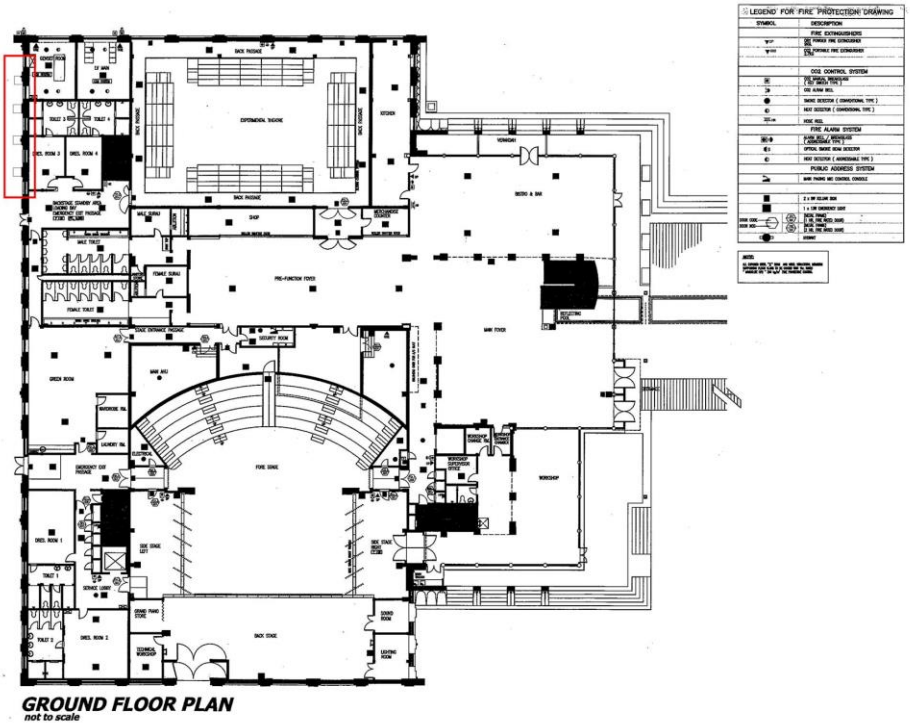


Figure 3.23 Ground floor plan of KLPAC showing the location of fire exhaust fan

3.4.4 Fire Damper

Figure 3.24 Example of fire damper

Source: **http://firedamper.com/product_category/fire-dampers-static**

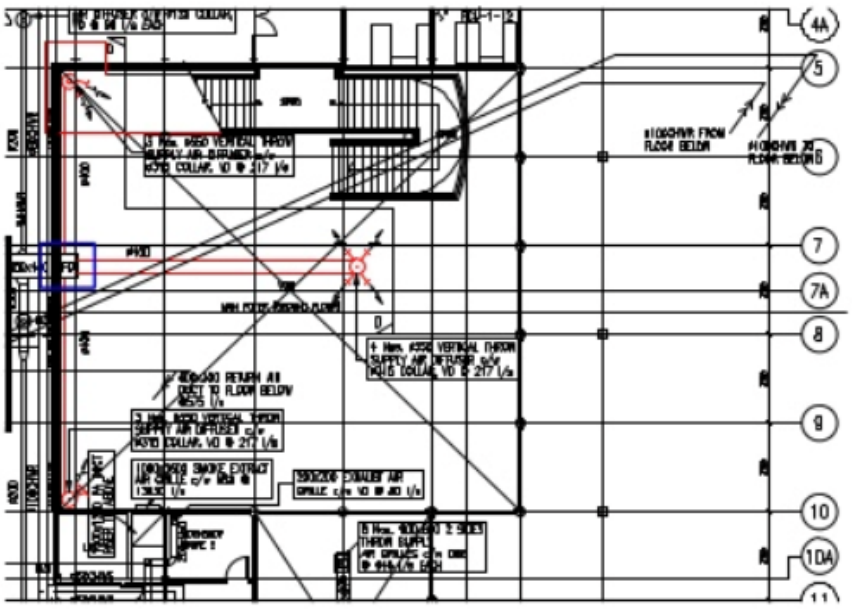


Figure 3.25 Fire damper is installed in between the three diffusers

UBBL By Law

Law Section 156- Protected Shaft as Ventilating Duct

(1) If a protected shaft serves as, or contains, a ventilating duct

(a) The duct shall be fitted with automatic fire dampers together with or without subducts as Australian Standard 1668: Pt. 1:1974, so constructed at such intervals and in such positions as may be necessary to reduce, so far as practical, the risk of fire spreading from a compartment to any other compartment, or such other provision shall be made as will reduce such risk so far as practicable

Fire dampers have an important role in controlling the ratio of fresh air and recycled air while exhausting part of the recycled air. When the air sensor detects more than 500pm of carbon dioxide in the return air of the space, the system will automatically activate, allowing the damper to open and receive more fresh air from the outside and allow the fresh air to flow into the building.

Analysis

Based on the UBBL, it is a must to install fire damper in between ductwork that is connected to both mechanical ventilation and also air conditioning system. With the installation of air damper, fire wont be able to spread throughout the building during a fire emergency, thus avoiding fast pace of fire spreading throughout the whole building.

3.5 Passive Ventilation

Figure 3.26: glass facade at the front lobby

UBBL Section 41- Mechanical Ventilation & Air conditioning

Windows and openings allowing uninterrupted air passage is not necessary if the room is equipped with mechanical ventilation or air-condition

As shown in Figure 3.26, KLPAC is designed with a large glass façade at the front part of building. It allows natural sunlight to penetrate through the building and lit up the interior, but it doesn't allow natural ventilation to occur as the glass window is closed all the time. Building is well regulated even without natural ventilation occurring in the building.

3.6 Conclusion

In conclusion, as KLPAC is almost entirely sealed, it is difficult to allow external air to be naturally flow into the building. Hence, due to the poor air circulation, mechanical ventilation system is installed accordingly to facilitate the air circulation in the building. As KLPAC comprises of different spaces for different function for example, auditorium, studio and offices, by increasing the component of mechanical ventilation in the building, it would bring burden to the maintenance cost of the whole building. Different spaces of the building require ventilation at different hours, resulting in separated air distribution systems equipped with accessible switches to control the air flow. In my opinion, KLPAC is well ventilated with separated ventilation system and controlling system. It is scheduled to be open during events and working hours only.

4.0 Air-Conditioning System

4.1 Introduction

Most buildings and homes in Malaysia have installed air-conditioning system. Always referred to as air-con or AC, air-conditioning system is device used to provide an acceptable level of occupancy comfort by controlling the temperature, humidity, air distribution and indoor air quality(IAQ) in order to maintain a cool and comfortable atmosphere. Air-conditioning system is group of components working together to remove heat from a particular space, such as compressors, condensers, ductwork etc.

4.2 Literature Review

4.2.1 Air Cooling Principle

When gas is being compressed, it will be liquefied and release a large amount of latent heat from within the gas. When the pressure of the liquid is lowered, the liquid will vaporize back to gas, and when it boils through the vaporizing process, it will absorb a large amount of latent heat into the liquid.

4.2.2 Compressive Refrigerant Cycle

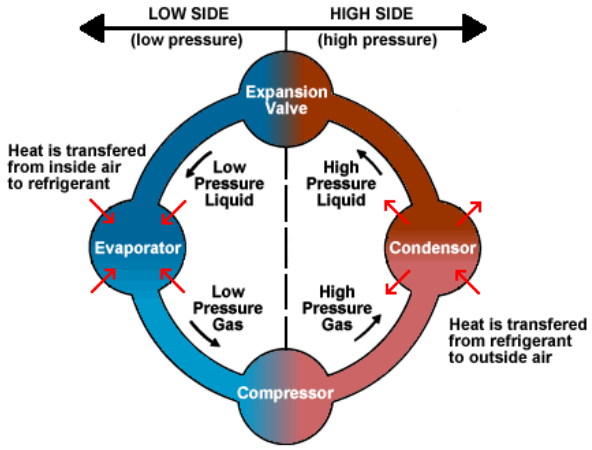


Figure 4.1: Compressive Refrigerant Cycle. Source: Hoffman.P (2006).

Refrigerant cycle serves the purpose of discharging unwanted heat from the inside of a building space to the outside. The type of refrigerant cycle in KLPAC's air-conditioning system is compressive refrigerant cycle, which is a fully enclosed system consisting 4 stages: expansion, evaporation, compression and condensation. Within this enclosed system there is a chemical compound named a refrigerant. The refrigerant will be liquefied and evaporated repeatedly during the process of it releases and absorbs heat in the cycle to help remove heat from the supply air and discharge it to the outside air. Thus, refrigerant can be used over and over again.

4.2.3 Air-Conditioning System

There are 4 main types of air-conditioning system which each serves different types of building depending on the building sizes. Thus, it is important to choose the most suitable system in order to maintain thermal comfort inside a building.

4.2.3.1 Window Unit Air-Conditioner

This is the most basic and smallest size of air-conditioners, usually installed at a window. It is a simple air-conditioning system and suitable for small room or small houses.

Figure 4.2: Room air-conditioner installed at a window.

Source: Home Depot. (2016).

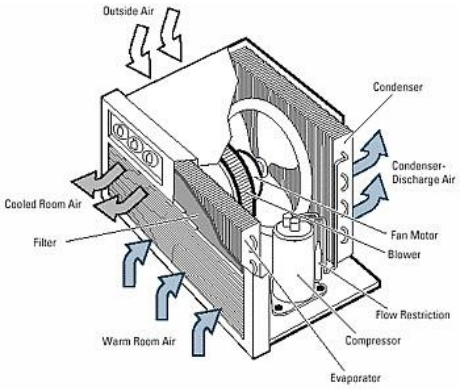


Figure 4.3: Diagram showing the components of a room air-conditioner.

Source: Window Parts. (2015)

4.2.3.2 Split Unit Air-Conditioning System

Split unit air-conditioning system is the most common type of air-conditioners used in residential housings and small scale buildings, because of the elegance look and silent, simple operation. This system mainly consists of two units, which is the outdoor and indoor unit. From figure 4.5 it can be seen that the outdoor and indoor unit is connected by a copper tubing.

Figure 4.4: Split air-conditioner with an indoor unit, outdoor unit, and the control switch.

Source: Home Depot. (2016)

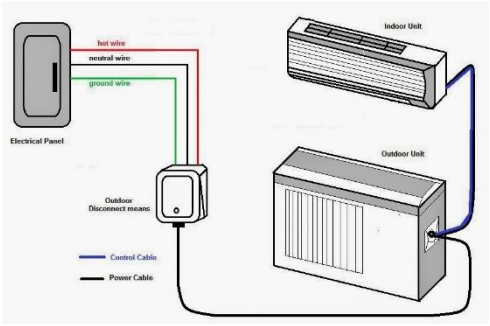


Figure 4.5: Diagram of a split air-conditioners system.

Source: Electrical Know How. (2013)

4.2.3.3 Packaged Unit Air-Conditioning System

Packaged unit air-conditioning system is very similar to room air-conditioner but it serves larger scaled buildings then houses. It is commonly used for medium sized buildings such as multipurpose halls, restaurant, and etc. It consists of a large casing that keeps all the important components inside, such as the compressor, condenser and fan.

Figure 4.6: Packaged unit air-conditioner.

Source: DIY Doctor Ltd. (2016).

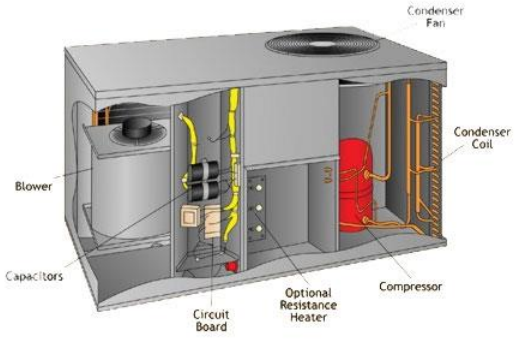


Figure 4.7: Components inside a packaged unit air-conditioner.

Source: Bright Hub INC. (2012).

4.2.3.4 Centralized Air-Conditioning System

Centralized air-conditioning system is mainly for large and complex buildings such as hospital, library, shopping malls, airports and etc. that can be wholly or partly centralized air-conditioned. It consists of a few main components which are the refrigerant plant, AHU and cooling tower. This system works by cooling the refrigerant in the plant room and distribute it to the AHU room that located inside the buildings, normally located at each floors. Then, the cooled air will be transferred from AHU to different rooms via the supply ducts. In the refrigerant room, its main components include the chiller, compressor and condenser.

Figure 4.8: Air-cooled chiller located outside of the building.

Source: Kiran Group. (2015).

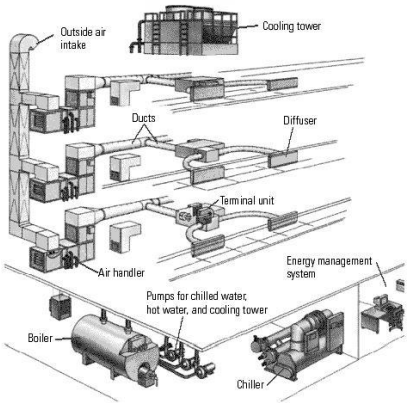


Figure 4.9: Diagram showing how the AHU, chiller and cooling tower are connected.

Source: Khemani. H. (2009).

4.3 Case Study

The air-conditioning system used in KLPAC is centralized air-conditioning system and split air-conditioning system. The centralized air-conditioning system is mainly used for the larger spaces such as the auditorium. KLPAC has 2 chillers and one plant room located outside of the building, and 5 AHU room located inside the building. Due to its medium sized scale, KLPAC does not have cooling tower. 4 of the AHUs are working for the auditorium due to the huge volume and large amount of people that it contains, and the last AHU is serving the smallest auditorium. The air temperature inside KLPAC is fixed, thus, for larger space, air-conditioner shall be switched on 2 hours earlier to cool the spaces. Besides that, KLPAC also has fan coil units serving the smaller spaces such as the double volume lobby, office, studio and conference rooms. The fan coil units are located inside one of the AHU rooms located near to the lobby.

Figure 4.10: One of the largest auditorium of KLPAC.

Figure 4.11: Indicine space of KLPAC.

Figure 4.12: Studio.

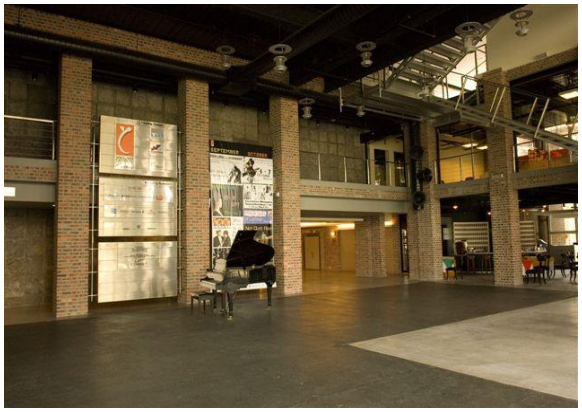


Figure 4.13: Double-volume lobby.

Images Source: KLPAC Management. (2016).

4.4 SPLIT UNIT AIR CONTIONING SYSTEM

Figure 4.14: Image of box office at KL PAC

Source: Pua,(2015)

In the main building of KL PAC, centralised air conditioning system is applied to enhance the ventilation and maintain the comfortable temperature in the building. Apart from the main building, two box offices are located separated with the main building and split unit air conditioning system is installed.

Split unit air conditioning system consist two parts: indoor and outdoor unit. The outdoor unit is fitted outside the room, comprising compressor condenser and expanding valve etc. Meanwhile the indoor unit is fitted in the room and usually hang on the wall, the evaporator or cooling coil and cooling fan are inside the indoor unit.

Two box office own its split unit air conditioning system. The occupants are able to control the temperature by using the temperature control switch according to their preferences. In the next paragraphs, the components of both units, the location consideration and the flow of the function of split unit system will be discussed.

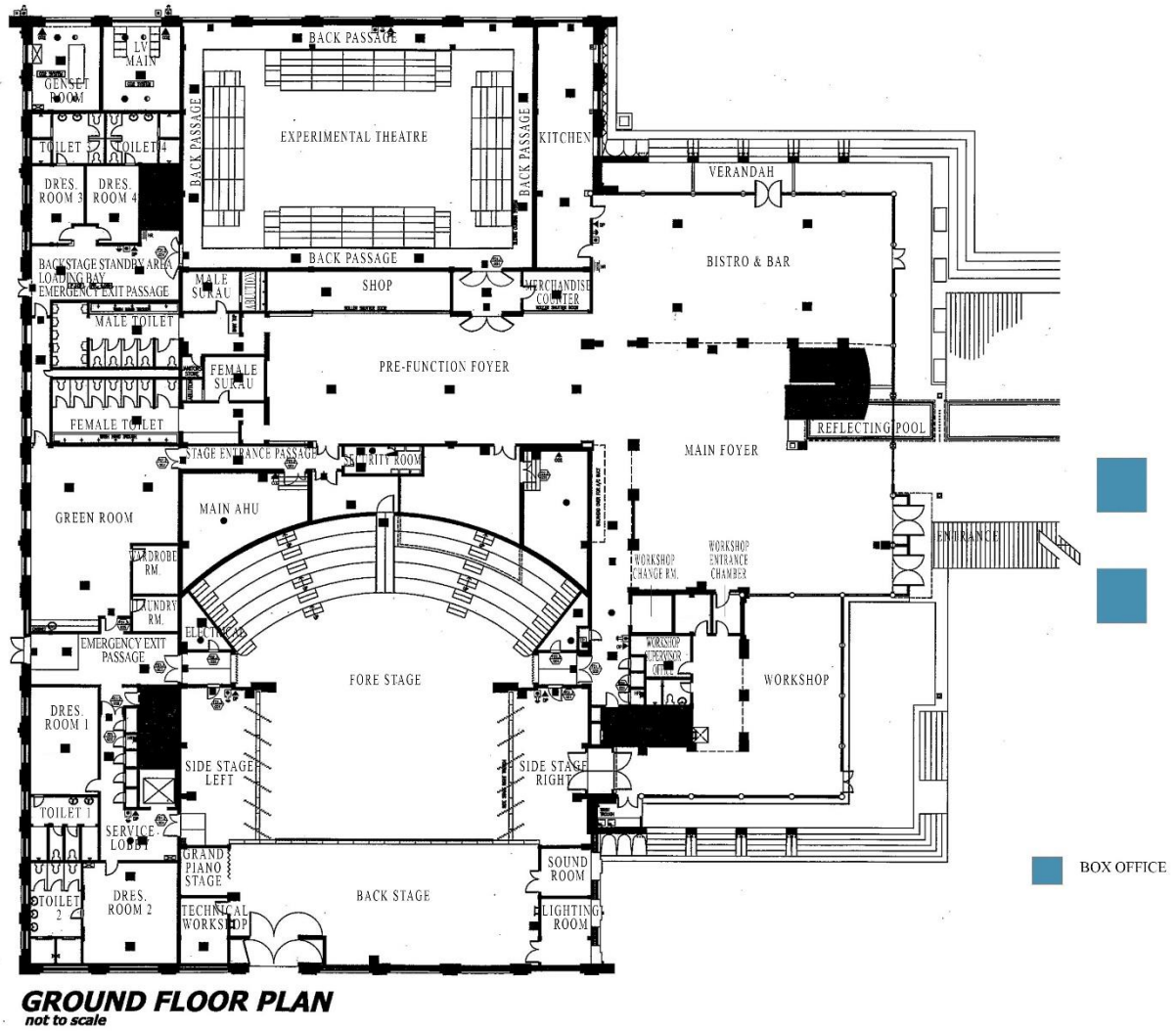
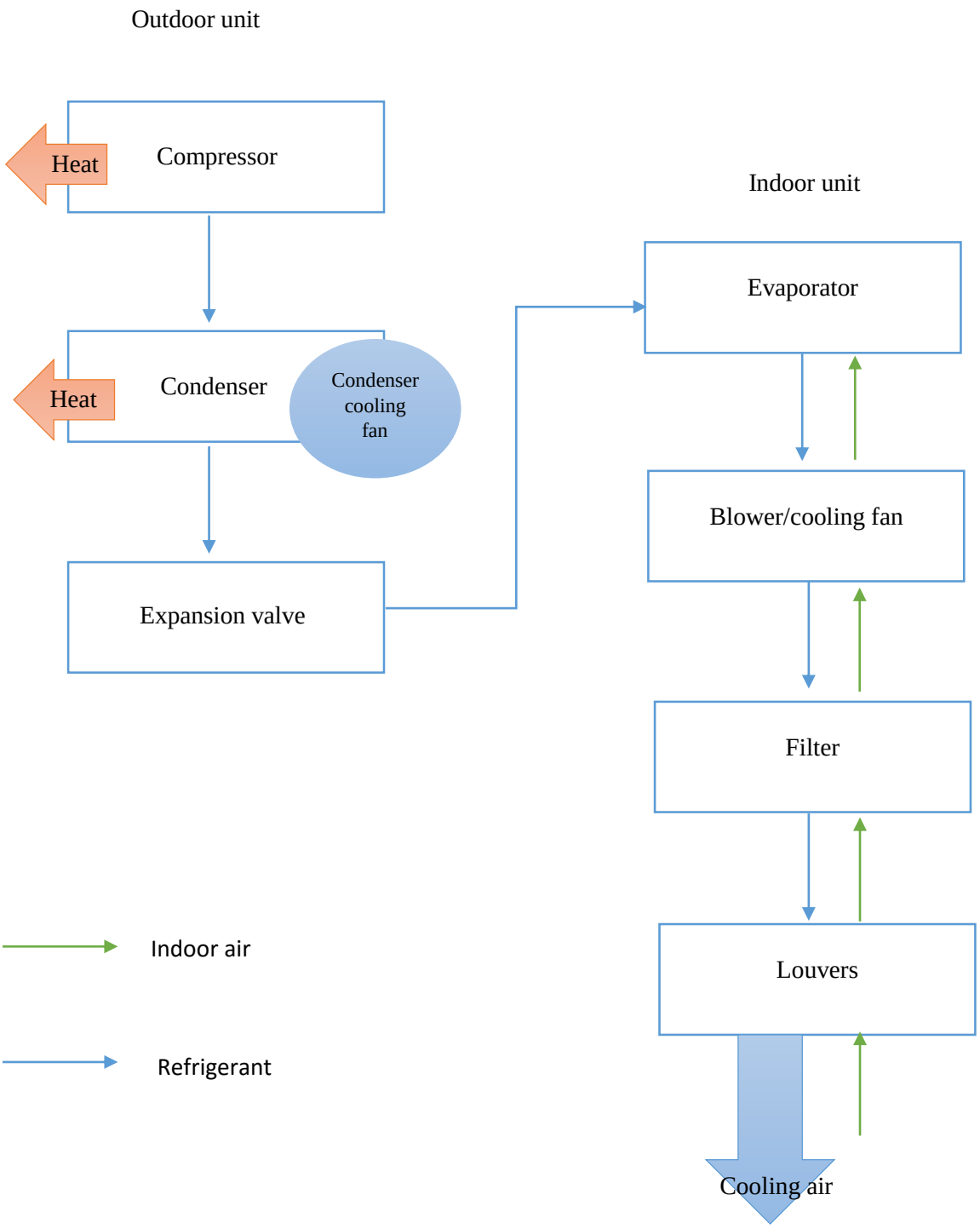


Figure 4.15: Ground floor plan showing location of box office

4.4.1 Flow Chart of Split Unit Air Conditioning System.



4.4.3 OUTDOOR UNIT

Figure 4.16: Image of Outdoor Unit of KL PAC

Source: Sylva, (2016)

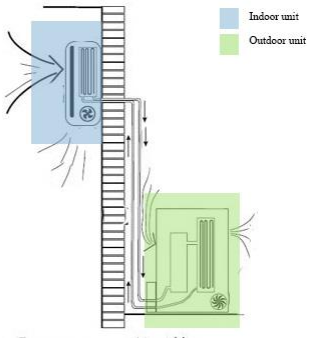


Figure 4.17: Showing position of outdoor unit.

Source: Source: Ramesh Trading (2016)

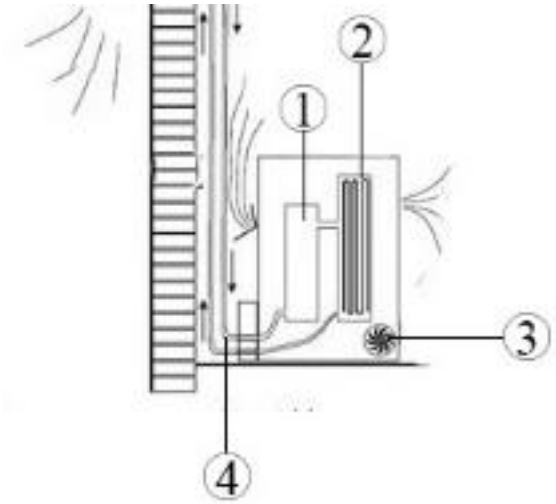


Figure 4.18: Illustrated outdoor unit showing components.

Source: Ramesh Trading (2016)

The outdoor unit is more like a smaller size of chiller. It comprises the most important components such as compressor and condenser. The unit run at a minimum level of noise to provide acoustic comfort to the working environment.

Components of outdoor unit

As mentioned before, outdoor unit comprises important components (Figure4.4.8) of the air conditioning system such as compressor and condenser. While conditioning the indoor air, lots of heat is generated in this two parts.

1. Compressor: It becomes the most important part ever in the whole system. The refrigerant is compressed and pressurised before sending to the condenser. In this kind of domestic used of AC, the compressor and the motor to drive the shaft are sealed so it cannot be seen externally. To compress the refrigerant external power is supplied and lot of heat is produced, which means that it has to be removed by fan or other means.

2. Condenser: It is the coiled cooper tube in one or more than one row. The number of the rows is depending on the size of AC unit and the compressor. The high pressured and high temperature refrigerant form the compressor will be releasing its heat in it. Aluminium fins are covered on it in order to promote the rate of remove heat from the refrigerant.

3. Condenser cooling fan: It is located in front the condenser and compressor. In the long run process of pressurised and heating the refrigerant in the compressor, heats produced could be burnt the motor coils and eventually breakdown the compressor to the whole AC system. Moreover, refrigerant within the condenser coil need to be cooled in order to make it cool enough to produce cooling effect after expansion.

4. Expansion valve: It is where medium temperature refrigerant enter and temperature to be dropped down after the condenser. It is normally a copper capillary tubing with several rounds of coils.

MS 1525Code 8.4.4.2

Outdoor air supply and exhaust systems should be provided with motorised or gravity dampers or other means of automatic volume shut-off or reduction during period of non-use or alternate use of the spaces served by the systems.

Consideration of the placement of outdoor unit

Figure 4.19: Outdoor unit is placed at the back of the box office Source: Heat Patrick, (2015)

In KLPAC, outdoor unit are install at the back façade of the box office on a rigid and flat wall (figure 4.4.6) it can sustain its heavy weight. The area is ensured with the sufficient air flow to remove the heat produced. The work of maintenance is easily can be done as the outdoor unit has been placed at a place that easy to access. We can see that the outdoor unit in KL PAC is placed at the back of the box office. Thus, it has avoided to spoil the aesthetic value of KL PAC in overall. From figure 4.4.6, it can only be seen when we come to the opposite side of lake. Besides, as we can see that they are closed to the ground but with anchored to wall by using steel rod, risk of contact to the water is decreased.

4.4.3 Indoor Unit

Figure 4.20: Image of indoor unit of KL PAC.

Source: Pua, (2015)

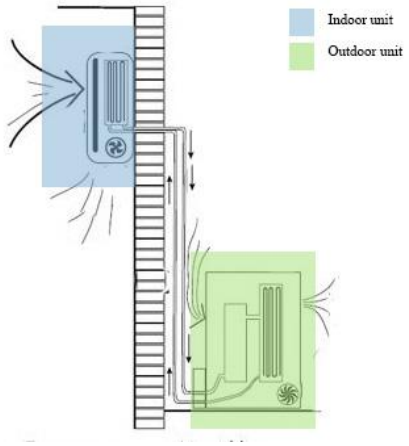


Figure 4.21: showing the position of indoor unit.

Source: Ramesh Trading (2016)

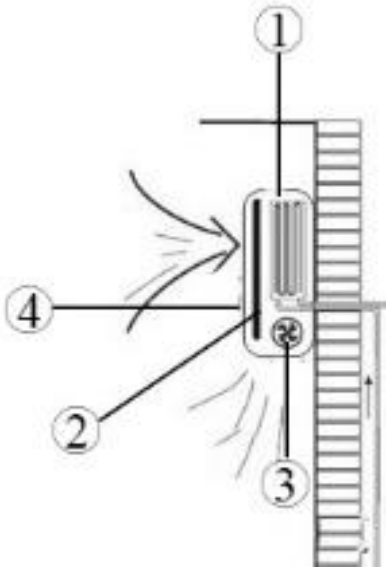


Figure 4.22: Illustrated indoor unit showing components

Source: Ramesh Trading (2016)

Indoor unit serves as the same purpose as AHU. However, the air is not distributed to different spaces. The cooling air is directly transfer to the spaces where indoor unit is and the flow of air is controlled by the horizontal louvers. It run at an extremely low level of noise. Hence, people has considered it as white noise which could enhance the sleeping quality or working performance.

Components of indoor unit:

1. Evaporator: The cooling coil is made of number of turns of the tubing. The cooling coil is covered with aluminium fins so that the heat can be transmit from the coil to air at maximum level. The low temperature and low pressure refrigerant enter to cooling coil. While the blower absorb the hot indoor air passes to the cooling coil, the air is being cooled and later on disperse back to the space. After absorbing the heat in the room, high temperature refrigerant flows back to the compressor through the return tubing.

2. Filter: It is important to remove the dirty articles in the room in assisting providing clean air to the room. The filter is placed before the cooling coil in the indoor unit. When the blower sucks the hot indoor air to the indoor unit, it will pass through the filter thus after the air being cooled down it is fresher and cleaner.

3. Blower or cooling fan: It is an induced type of blower. It sucks the unclean and hot air in and passes through the filter then the cooling coil to remove the heat and dust, then later only disperse to the room to complete the functional flow. The shaft of the blower rotates inside the bushes and it is connected to a small multiple speed motor, thus the speed of the blower can be changed. When the fan speed is changed with the remote it is the speed of the blower that changes.

4. Louvers: The cool air is supply pass through the fins or louvers. The angle of the louvers can be adjusted in different direction by using the remote. In the indoor unit of KL PAC, the horizontal louvers is used and it controls the direction of conditioned air in the

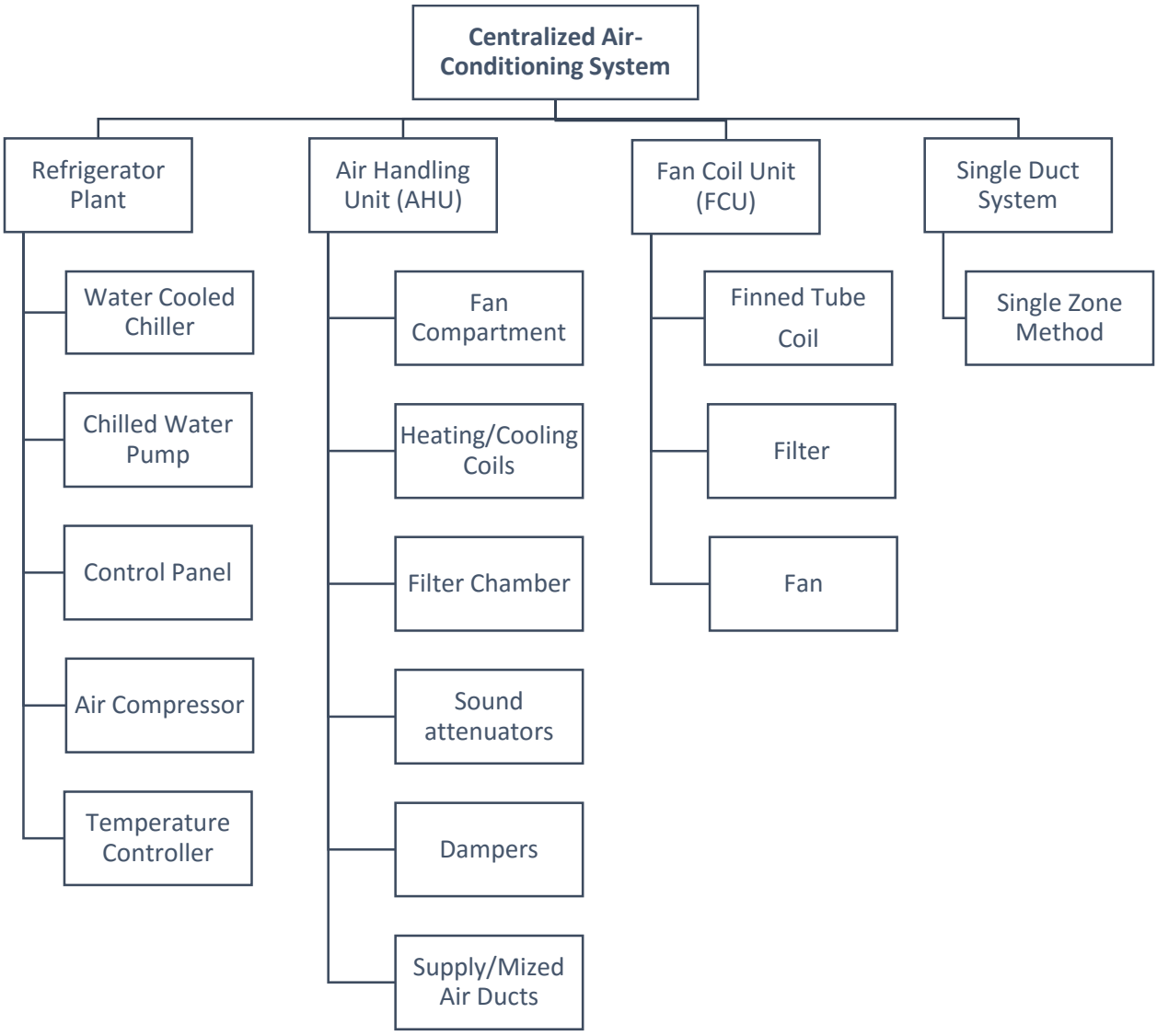
Consideration of placement of indoor unit

Figure 4.23: Indoor unit mounted on wall at box office
Source: Sylva , (2016)

In KL PAC, outdoor unit are install at the back façade of the box office on a rigid and flat wall (figure 4.4.7) it can sustain its heavy weight. The area is ensured with the sufficient air flow to remove the heat produced. The work of maintenance is easily can be done as the outdoor unit has been placed at a place that easy to access. However, the outdoor unit should keep away from the possibility in contact with the water. Moreover, it is anchored on the wall and supported by the steel rod. We can see that the outdoor unit in KL PAC is placed at the back of the box office. It has avoided to spoilt the aesthetic value of KL PAC but it is much close to the ground. Thus it is anchored on steel rod to the wall to prevent from water to corrode it results in breakdown of system.

4.5 Centralized Air-Conditioning System

In KLPAC, the main building body is conditioned by centralized air-conditioning system, which it has a plant room and 2 chillers located outside of the building, and then the chilled water will be transferred to the AHU room, then cooled air will be distributed from AHU to different spaces through the ducts.



Flowchart 4.24: A basic information of Centralized air-conditioning system of KLPAC.

4.5.1 Chilled Water Air-Conditioning System

To produce cool environment for large spaces in KLPAC, chilled water air-conditioning system is used to produce the cooling needed to reduce the interior temperature. In this case, the chiller used in KLPAC is the air-cooled chiller, and the refrigerant used in the machine is water.

First, the water is supplied to the chiller to reduce its temperature, then the chilled water will flow to the coils in the Fan Coil Unit(FCU) and Air Handling Unit(AHU) to cool down air and distribute to the space needed to be conditioned. Pumps are normally used to move water between the chiller and FCU/AHU. The chilled water will absorb the heat from the room air at the FCU/AHU and then pump back to the chiller. At the chiller, the heated water will be chilled again by the machine removing the absorbed heat. Once chilled, the water will be pumped back to the FCU/AHU system. This process of recirculation is repeated as needed to reduce the temperature of the space being conditioned in KLPAC. A cooling tower is not need by KLPAC because it is using air-cooled chiller.

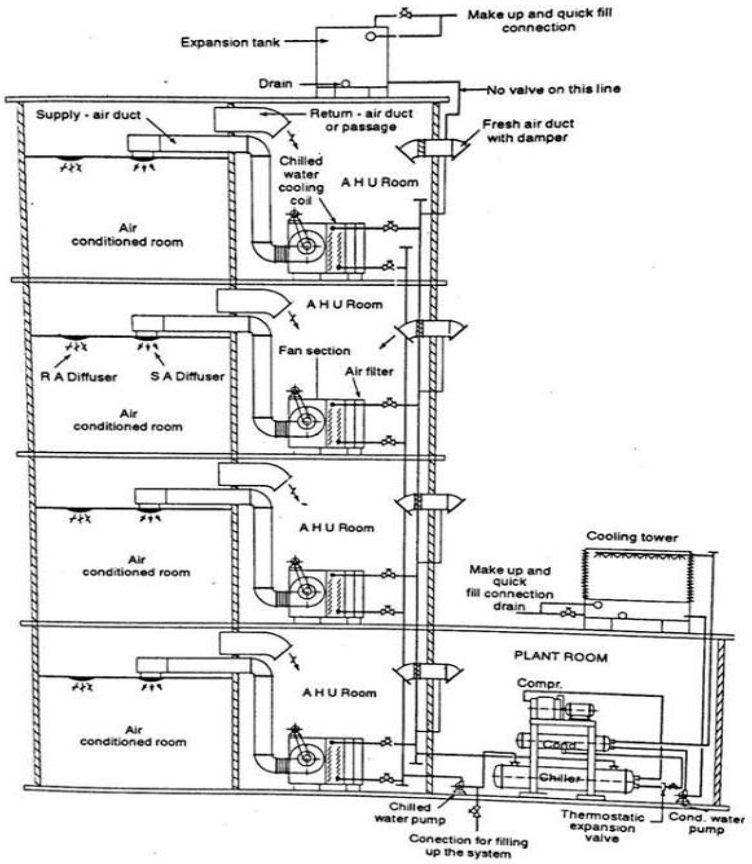


Figure 4.25: Chilled water air-conditioning system with a cooling tower to remove heat to surrounding.

Source: Khemani. H. (2009).

4.5.1.1 Air-Cooled Chiller

Air-cooled chiller is consisted in the chilled water air-conditioning system of KLPAC to cool down the water. For air-cooled chillers, cooling tower is not needed because it uses the evaporation and condensation process and let heat escape from the refrigerant. The air-cooled chiller mainly contains evaporator, condenser, compressor, and an expansion valve that run the system. The chiller is located outside of the building due to it releases heat and make loud noises when operating.

Figure 4.26: 2 air-cooled chillers used by KLPAC located beside plant room.

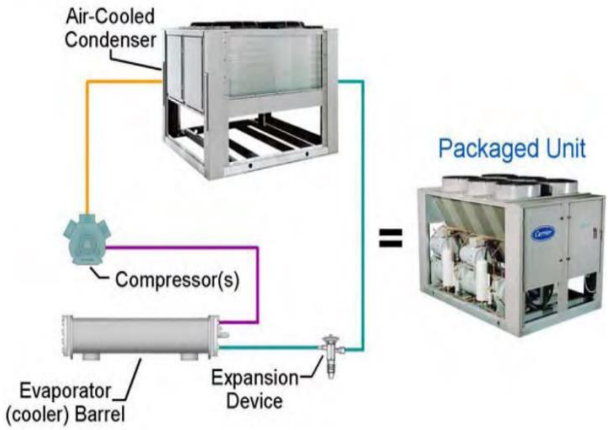


Figure 4.27: Main components inside an air-cooled chiller.

Source: Electrical Know How. (2013).

MS 1525:2007 code 8.2 System and Equipment Sizing

8.2.2 Where chillers are used and when the design load is greater than 1000 kWr, a minimum of two chillers or a single multi-compressor chiller should be provided to meet the required load.

8.2.3 Multiple units of the same equipment type, such as multiple chillers, with combined capacities exceeding the design load may be specified to operate concurrently only if controls are provided which sequence or otherwise optimally control the operation of each unit based on the required cooling load.

Analysis

KLPAC has 2 chillers located outside. Most of the time only one chiller will be running. But sometimes when all the 4 auditoriums are in use and the energy load becomes very high, the other chiller will be operating too.

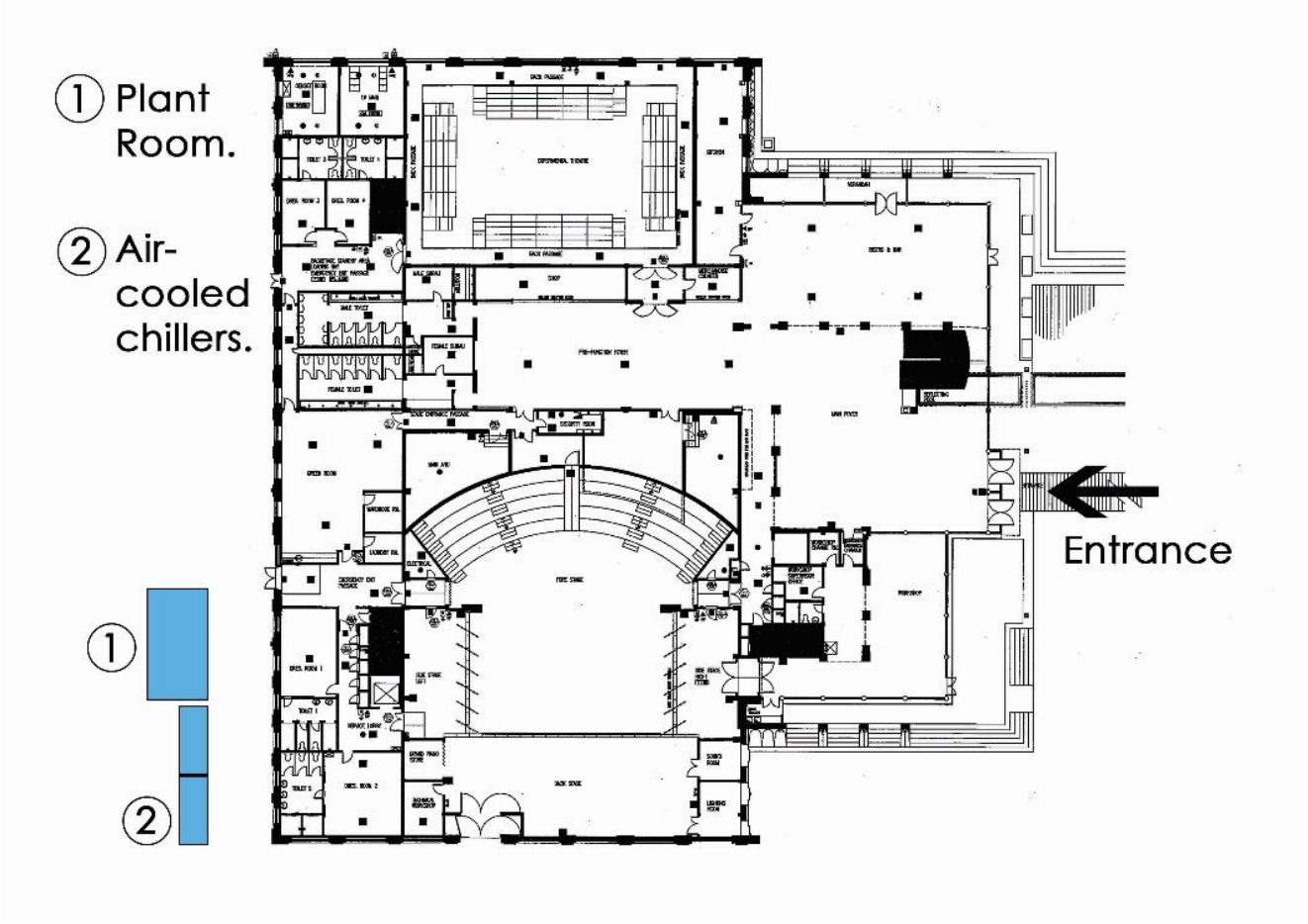


Figure 4.28: Floor plan of KLPAC showing the location of Plant room and air-cooled chillers.

Source: KLPAC Management. (2016)

4.5.1.2 Components of Air-Cooled Chiller

The four most important components in an air-cooled chiller is the compressor, condenser, evaporator and expansion valve. In the air-cooled chiller refrigeration cycle, the refrigerant in evaporators will absorb heat of the warmer water entered to it, and exits the evaporator in vapor form. The refrigerant vapor then will be taken away by the compressor which will heat and pressurize the vapor, then transfer to the condenser. In the air-cooled condenser, the vapor condenses and changed to liquid form while it releases heat to the outside atmosphere, drawn out by condenser fans. When the cooled and condensed liquid refrigerant leaves the condenser, it passes an expansion device that will further reduce its pressure and temperature. Finally, after leaving the expansion device, the refrigerant will enter the evaporator and repeat the process of removing heat.

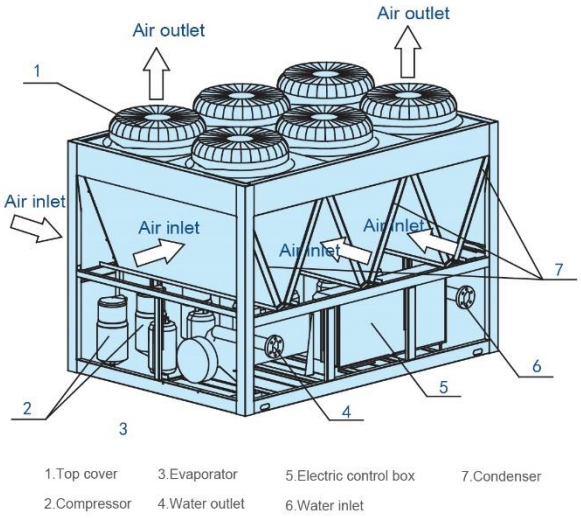


Figure 4.29: Components and parts of a air-cooled chiller.

Figure 4.30: Air-cooled chiller of KLPAC.

4.5.2 Air Handling Unit (AHU)

The air handling unit (or air handler) is a central air-conditioner system that helps to treat the air that will be supplied to the building spaces. It is a blue large metal casing of double skin insulated panels that containing fan compartment, heating/cooling coils, filter racks, sound attenuators, dampers and ductworks. AHU is a device that used to condition and circulate air of the auditorium. The untreated outside air will be treated by filtering, cooling and dehumidifying before delivered to the auditorium heaters of KLPAC via duct system. There is a control panel to switch on/off the air handling units near to the AHU room.

Figure 4.31: 1 of the 5 AHU rooms serving the auditoriums.

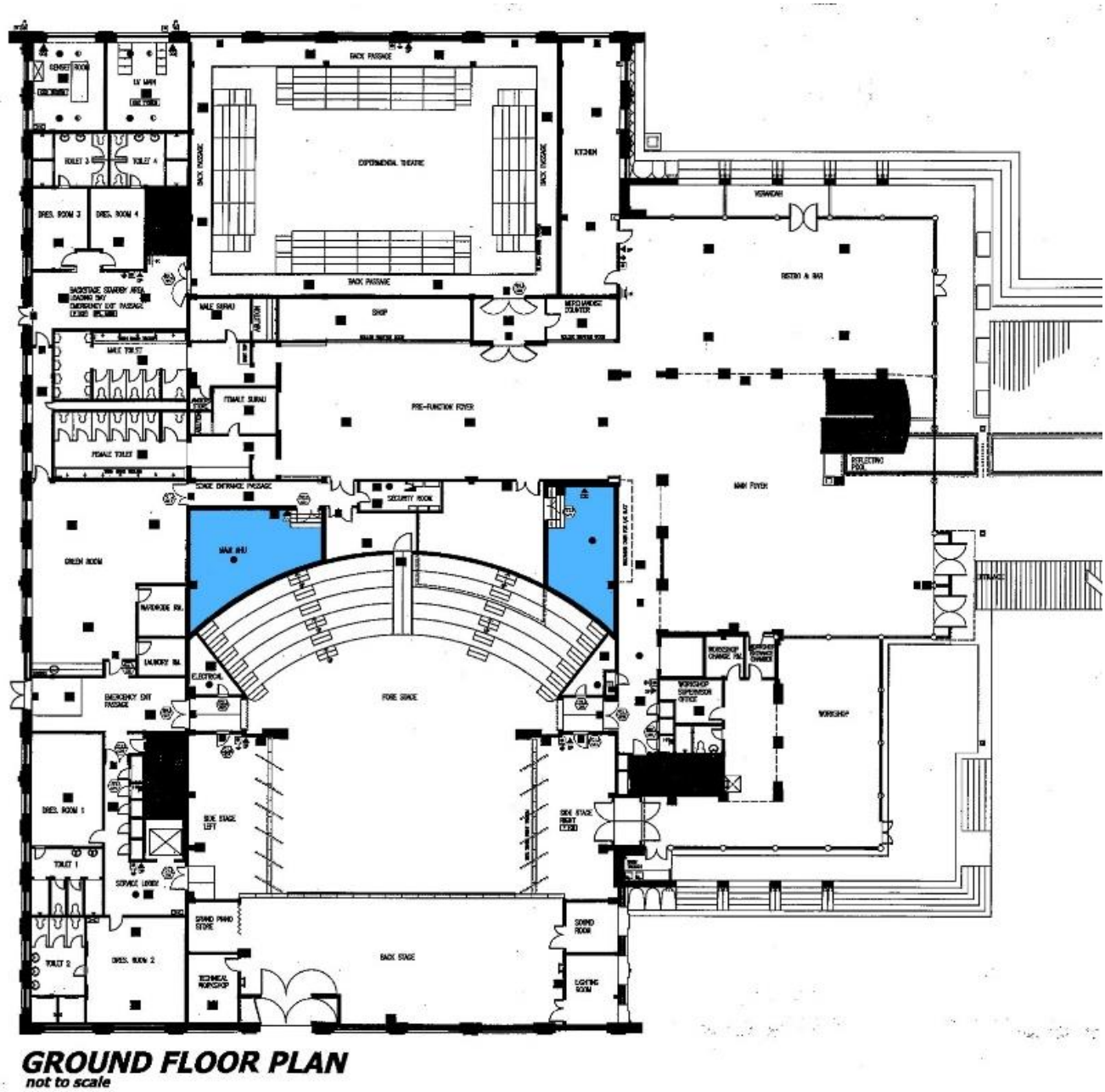
Figure 4.32: Control panel for AHU in the security room.

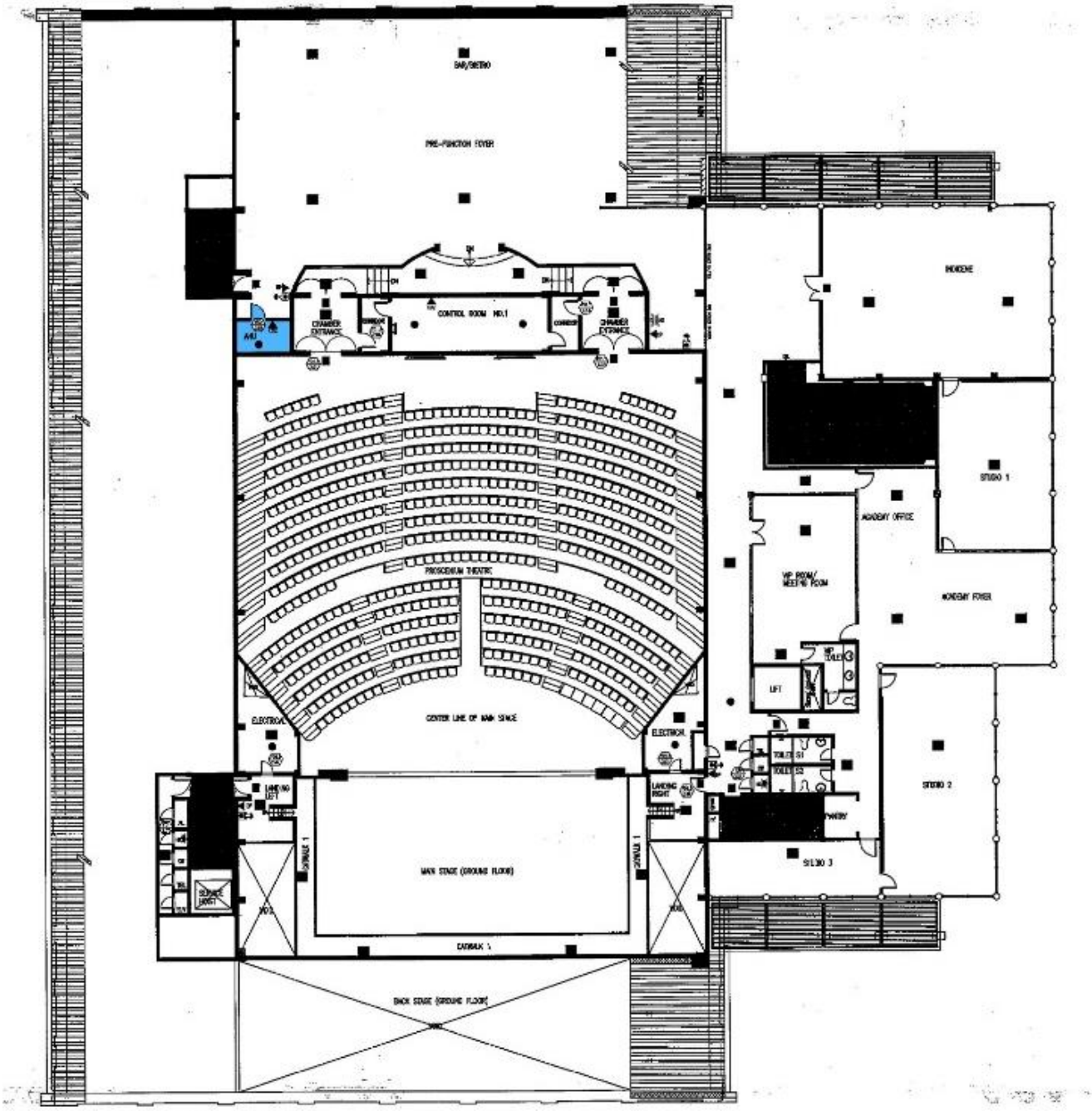
MS 1525:2007 code 8.4.1.2.1 Control setback and shut-off

Each system should be equipped with a readily accessible means of shutting off or reducing the energy used during periods of non-use or alternate uses of the building spaces or zones served by the system. The following are examples that meet these requirements:

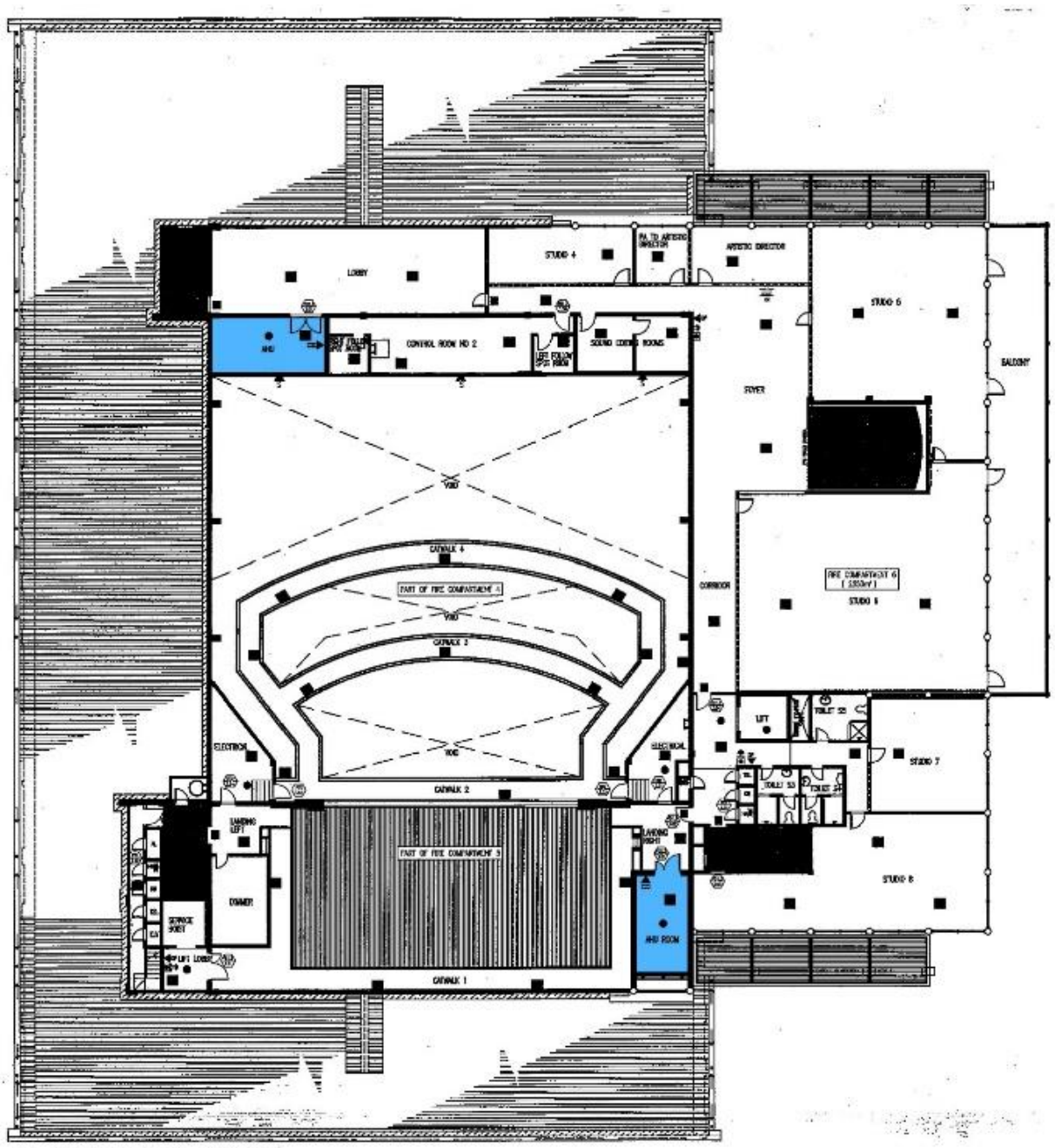
a) Manually adjustable automatic timing devices;
b) Manual devices for use by operating personnel; and
c) Automatic control system.

KLPAC has a total of 5 AHU rooms. 2 located at the Ground Floor, 1 located at the 2nd floor and 2 located at the 3rd floor.





2nd FLOOR PLAN
not to scale



3rd FLOOR PLAN
not to scale

4.5.2.1 Components of Air Handling Unit

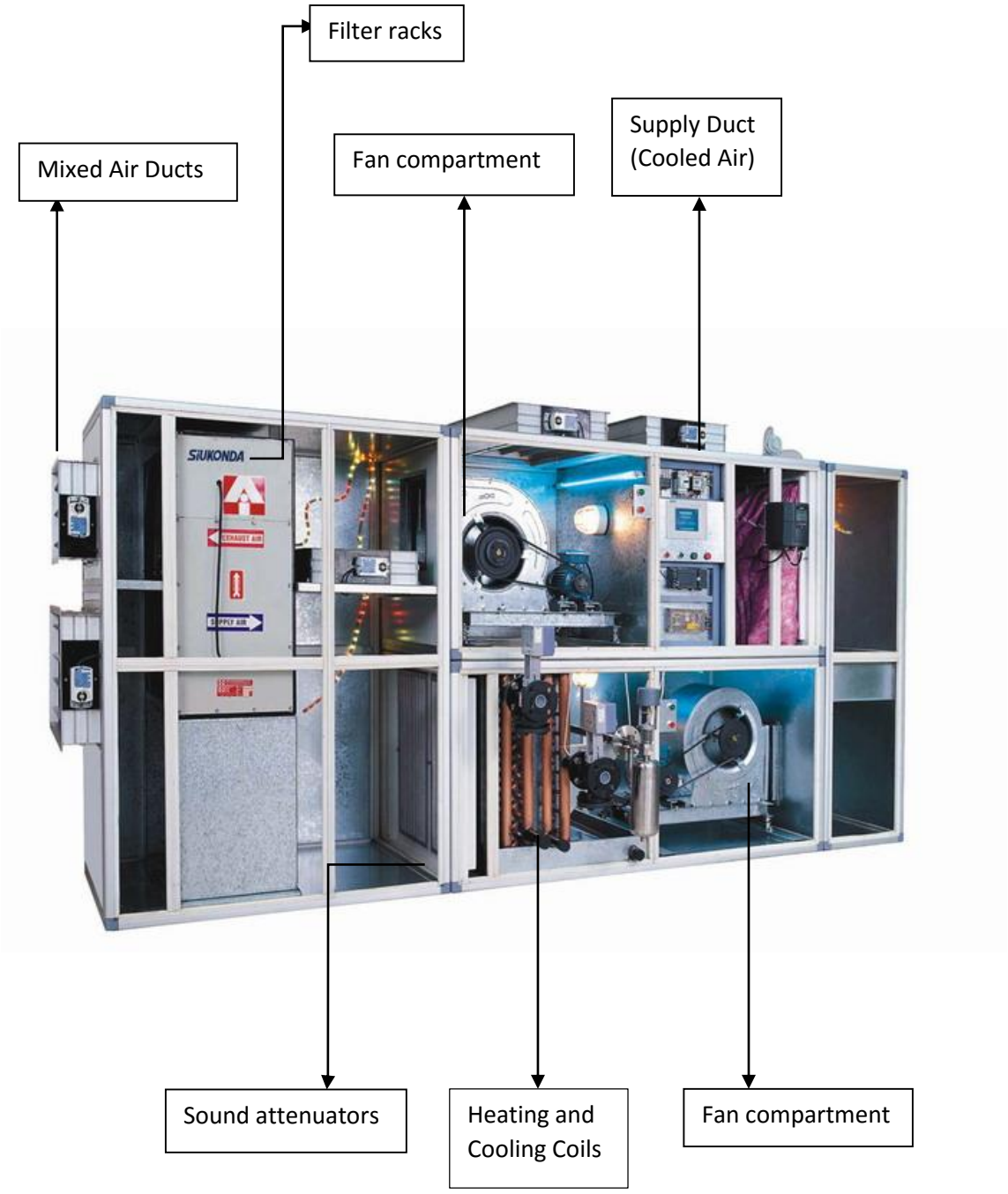


Figure 4.33: Components inside an AHU.

Source: Electrical Know How. (2013).

4.5.2.2 Fan Compartment

There are 2 fans in 1 AHU that serves different functions. One is to draw in the mixed air into the AHU while the other one is to push out the cooled air through the supply duct and deliver the cooled air into the building space. The fan used in AHU of KLPAC is running at a constant rate due to its single zone method system, which the temperature and pressure will be maintained the same all the time.

Figure 4.34: Fan compartment inside an AHU.

Source: Dynamic Engineering. (2015).

4.5.2.3 Heating and Cooling Coils

The AHU need to have heating and cooling coils to change the temperature of the supply air drawn in from the auditorium. These coils are made of copper tubes with aluminum fins to aid heat faster. KLPAC's AHU system is single zone method (Constant air volume), thus the temperature of the auditorium is all the same. The coils will vary the temperature to keep the auditorium temperature constantly cooled.

Figure 4.35: Heating and cooling coils.

Source: Dynamic Engineering. (2015).

4.5.2.4 Filter Racks

Air filter is needed in an AHU system to ensure the air are clean and dust-free before sending out to the auditorium. Clean filtered air contributes to reliable air conditioner operation and better human health.

Figure 4.36: Air filter compartment inside an AHU system.

Source: Dynamic Engineering. (2015).

4.5.2.5 Sound Attenuators

Also known as silencer or sound traps, its function is to prevent noise generated by fans from being transmitted into the distributed space. The sound attenuator is made up of sound-absorbing material faced with perforated metal. It does not need any electrical or mechanical means to function because it just needs to insulate the noise made by the inside compartments.

Figure 4.37: Sound Attenuator.

Source: Dynamic Engineering. (2015).

Figure 4.38: The blue casing is the sound attenuator of AHU system in KLPAC.

4.5.2.6 Dampers

Dampers are acting as a valve to proportion the inlet, outlet and mixed air in the AHU system. It also helps to maintain constant air flow by adjusting the horizontal blades of the dampers. For dampers installed in AHU of KLPAC, it is automatically controlled inside.

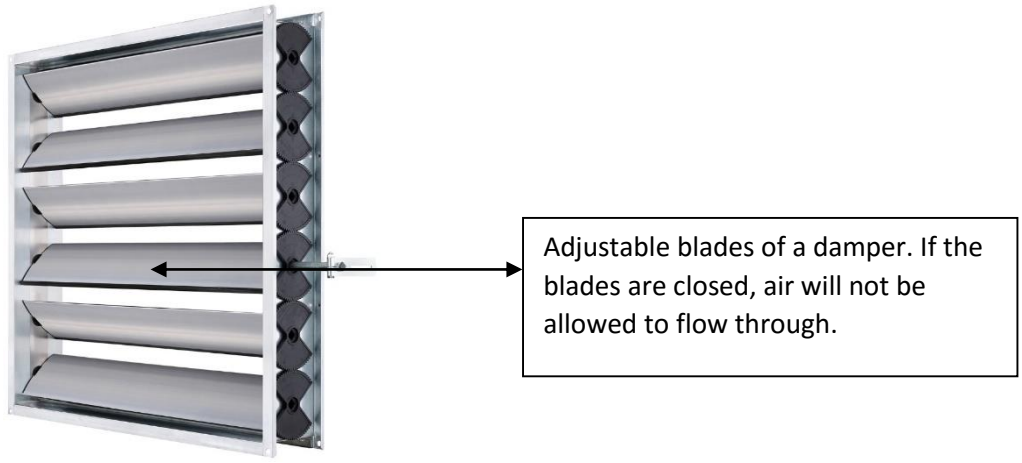


Figure 4.39: Dampers inside AHU system.

Source: Dynamic Engineering. (2015).

4.5.2.7 Supply and Mixed Air Duct

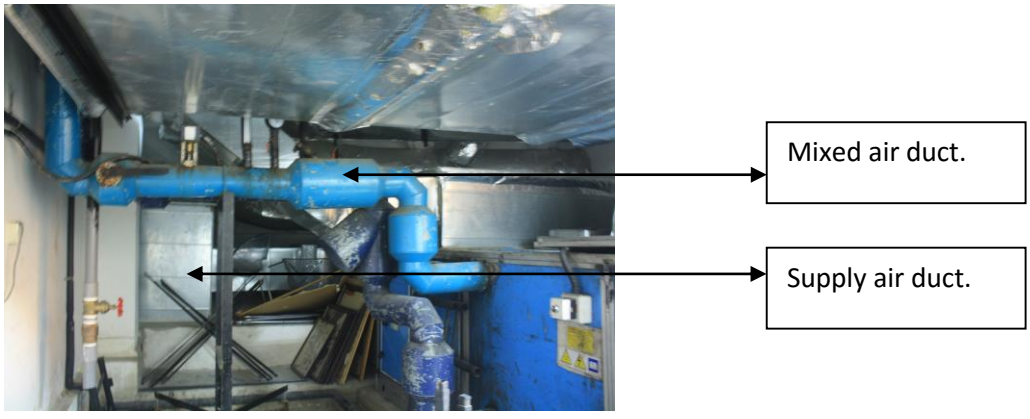


Figure 4.40: Air ducts of AHU in KLPAC.

Two different air ducts used to separate the inlet and outlet air. The air drawn in from the auditorium will go inside the AHU via mixed air duct. After the air being cooled down, it will be transferred back to the auditorium through supply air duct.

4.5.3 Fan Coil Unit

Figure 4.41: Fan coil unit at studio.

Source: Pua, (2015)

Figure 4.42: Control panel at Security room.

Source: Pua, (2015)

Fan coil units are mostly applied in the bigger spaces such as shopping complex. In KL PAC, fan coil units are mainly used in the spacious area such as lobby, cafeteria and studios upstairs. The fan coil unit in KL PAC are controlled by the control panel nearby or using remote control. So it can be manually turn off whenever the area is not occupied in order to save energy.

FCU can mainly be divided into two types: cassette and ceiling mounted type. In KL PAC, both types of FCU can be found. There is one special type in KL PAC which is a duct like of FCU.

Figure4.43: Duct-like FCU in the lobby

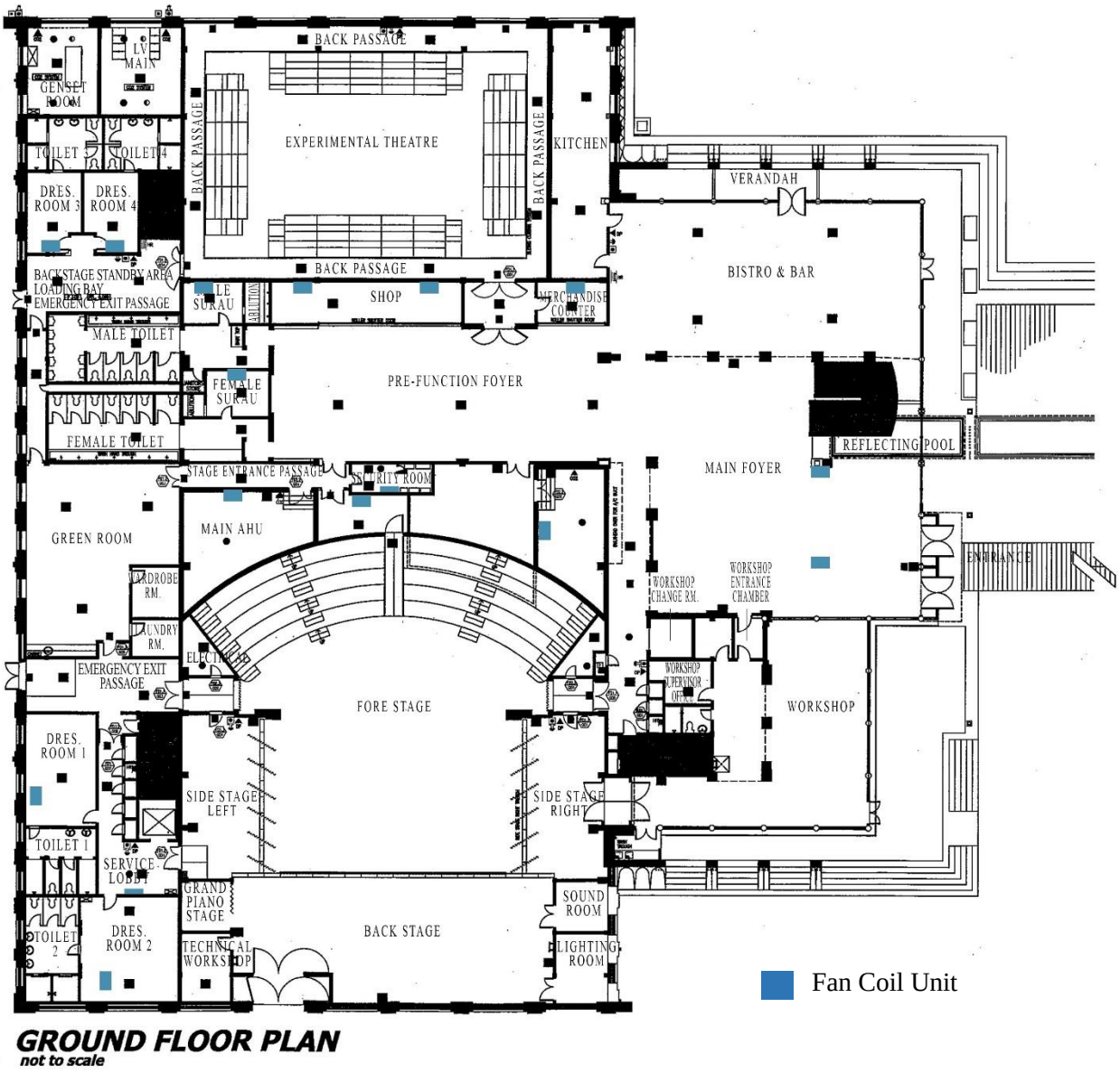


Figure 4.44: Ground Floor Plan showing location of FCU

Source: KL PAC Management (2016)

Wall mounted FCU and Suspended ceiling FCU

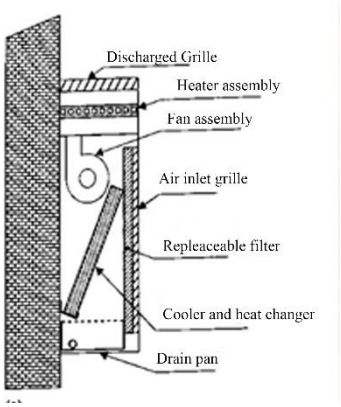


Figure 4.45: Wall mounted FCU

Source: Annanthanarayanan. (1982)

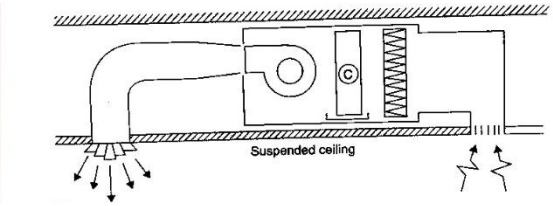


Figure 4.46: Ceiling mounted FCU

Source: Annanthanarayanan. (1982)

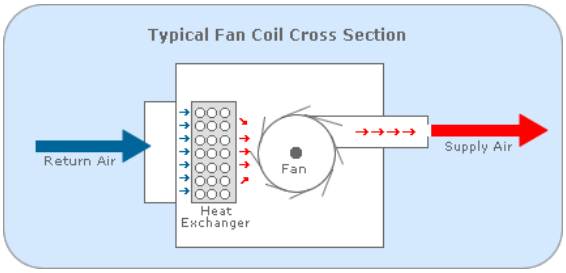


Figure 4.47: typical fan coil cross section

Source: homeair (2016)

FCU is which a system that similar to AHU but smaller in size. It is made up with a fan, a heating or cooling coil connected to the cold water system. It can be manually controlled the temperature of the spaces.

A fan coil unit comprises a heat exchanger in which water of circulated and a fan assembly, incorporating a filter and simple controls. The fan coil unit is installed as a part of the ducted air system. Air is drawn through a fan with a motor. While the air is passing through the evaporator coil or heat exchanger, the air is cooled or heated.

Wall mounted FCU is designed to fit on the perimeter wall or a ceiling mounted FCU within the ceiling voids. It can be configured as a cassette. It is considered as pleasing looking types of AC system as the duct can be hidden in the ceiling.

FCU system gives the individually control for zones (Figure 4.5.7) and it is lower in cost compared to others. But, it is limited in the flexibility in the units as the manufacturers fixed the operating parameters.

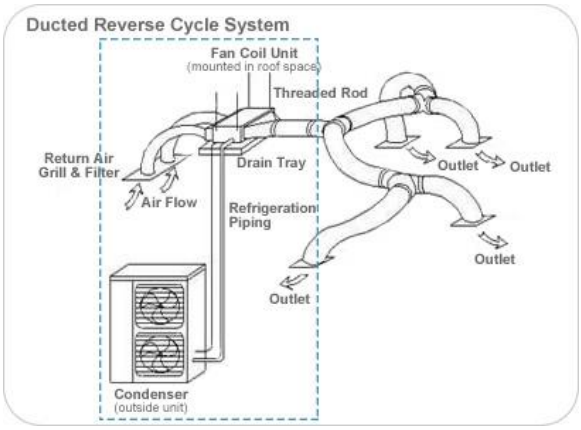


Figure 4.48: Ducted Cycle System

Such as in KL PAC, the FCU in lobby is customized into another form to match with the aesthetic value of the environment and ensure sufficient cool air is distributed to the double volume space.

The ACMV in KL PAC has achieved the requirement according to the MS 1525. Certain area in KL PAC are occupied with FCU in order to have a better control wise in the temperature of spaces. In general speaking, FCU in KL PAC is designed and placed well to ventilate the areas.

MS 1525 CODE 8.4.4.1 off -hour Control

ACMV system should be equipped with automatic controls capable of accomplishing a reduction of energy use for example through equipment shutdown during periods of non –use or alternatives use of the spaces served by the system.

← Within AHU Room

4.5.4 Single Duct System

Single Duct System is the simplest form of systems used to maintain air flow at a constant rate and temperature to the distribution space through a low velocity duct system. The heating and cooling coils in AHU will help vary the temperature of the air in response to a control thermostat, while the function of double duct system is just to keep the air that was transferred out from AHU are at the constant rate and temperature.

Figure 4.49: A single duct terminal unit.

Source: All Biz Ltd. (2016)

MS 1525:2007 code 8.4.1 Temperature Control

Each system should be provided with at least one thermostat for the regulation of temperature. Each thermostat should be capable of being set by adjustment or selection of sensors over a minimum range of between 22’C to 27’C.

4.5.4.1 Constant Air Volume System

In the AHU system, the fans are required to run continuously to provide ventilation and cooling effect to the auditoriums, which in this case it is called – constant air volume system. When the temperature of the auditorium changed, the dampers will either close or open to adjust the air flow through the AHU system, as long as to maintain the auditorium temperature the same all the time.

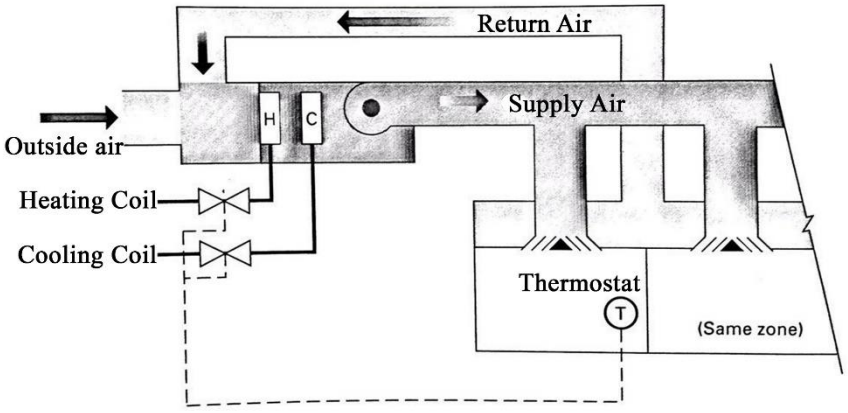


Figure 4.50: Diagram showing how does a single duct system works.

Analysis

For spaces that are composed of rooms and areas with different load characteristics, in this case the different sizes of auditoriums and other rooms in KLPAC, constant air volume system is not preferable. This is due to the temperature of air can be controlled at the thermostat, but the temperature of different rooms cannot be altered. Thus, in KLPAC, the authorized personnel will need to switch on the air-conditioners in auditorium at least 2 hours before show starts, which caused a huge waste on electricity and energy.

4.6 Conclusion

For conclusion, KLPAC can said to have fulfilled most of the MS1525 and Uniform Building By-Laws requirements for air-conditioners system, as it is a medium sized building and using an air-cool chilled water air-conditioning system to run its air-conditioners for auditoriums and split-unit air conditioners for the smaller scaled box office. It would be better if KLPAC uses variable air volume system in the building so that the temperature can be alternated in each space, and save time and electrical energy instead of letting the air-conditioners run longer for cooler temperature. Variable air volume air-conditioner system also more suitable for KLPAC that has rooms of different sizes.

5.0 Fire Protection System

5.1 Introduction

The main analysis of this chapter is about the fire protection systems being used and introduced in Kuala Lumpur Performing Arts Centre (KLPAC). Fire plays a very crucial role in our daily life, yet fire could be extremely dangerous if we do not have the knowledge of the protection of fire. So, it is very important to design a building with well-performed fire protection system that is capable to protect its users from the fire to ensure their safety and security.

The fire protection system in a building has been categorized into two which are the active fire protection system and also the passive fire protection system. Through this chapter, we are going to discuss in detailed about how these systems work to ensure the safety of the users.

5.2 Literature Review

5.2.1 Active Fire Protection System

Both the active fire protection system and passive fire protection system are essential in assuring the safety and security of the occupants in KLPAC. Active fire protection system is about a process or an approach to alert the occupants or users and also the attempts to control or extinguish the fire by using the methods of applying automatic or manually operated fire mechanical system. The methods that are included in this system are the fire detections which include smoke/ heat detection, triggers, alarm bells, pump room and the others. All of these systems especially the fire alarm systems are extremely important to notify the users in the building that evacuation is necessary after detecting the smoke or heat during the fire. Sprinkle systems which are included in the active fire protection system are important to slow down the rate of fire as the glass of the sprinkles will burst to release water when there is excessive heat from the fire is detected. Active fire protection systems are particularly useful in larger buildings where it is more difficult to ventilate the central spaces through natural openings such as the windows, so smoke and heat extraction systems are often used.

5.2.2 Passive Fire Protection System

Another fire protection system being used is the passive fire protection system which is introduced in parts of the building or structure as a barrier to the fire and slow down the rate of fire and smoke from spreading to other areas or parts of the building. One of the most important features in passive fire protection system is the protection of escape routes from the fire and smoke to prolong the escape time by designing and introducing fire-resistant characteristic into the elements of the building. There are two key important components in passive fire protection system. The first one is the compartmentalization of the spaces with fire-rated building components such as the fire-rated walls and doors are taken into consideration to prevent the fire spreading from space to space. This is extremely important in creating an Oxygen barrier and compartmentalize the spaces during a fire. The fire-rated wall not only represent a direct shield which the fire would need to physically burn through to pass, but also a choke point for air during the fire. The second component that is very crucial is the means of escape that determines the procedure and efficiency of escape to outside of the building during the event of fire and emergency. This including the usage of exit signs, emergency staircase design and the others.

5.3 Active Fire Protection System

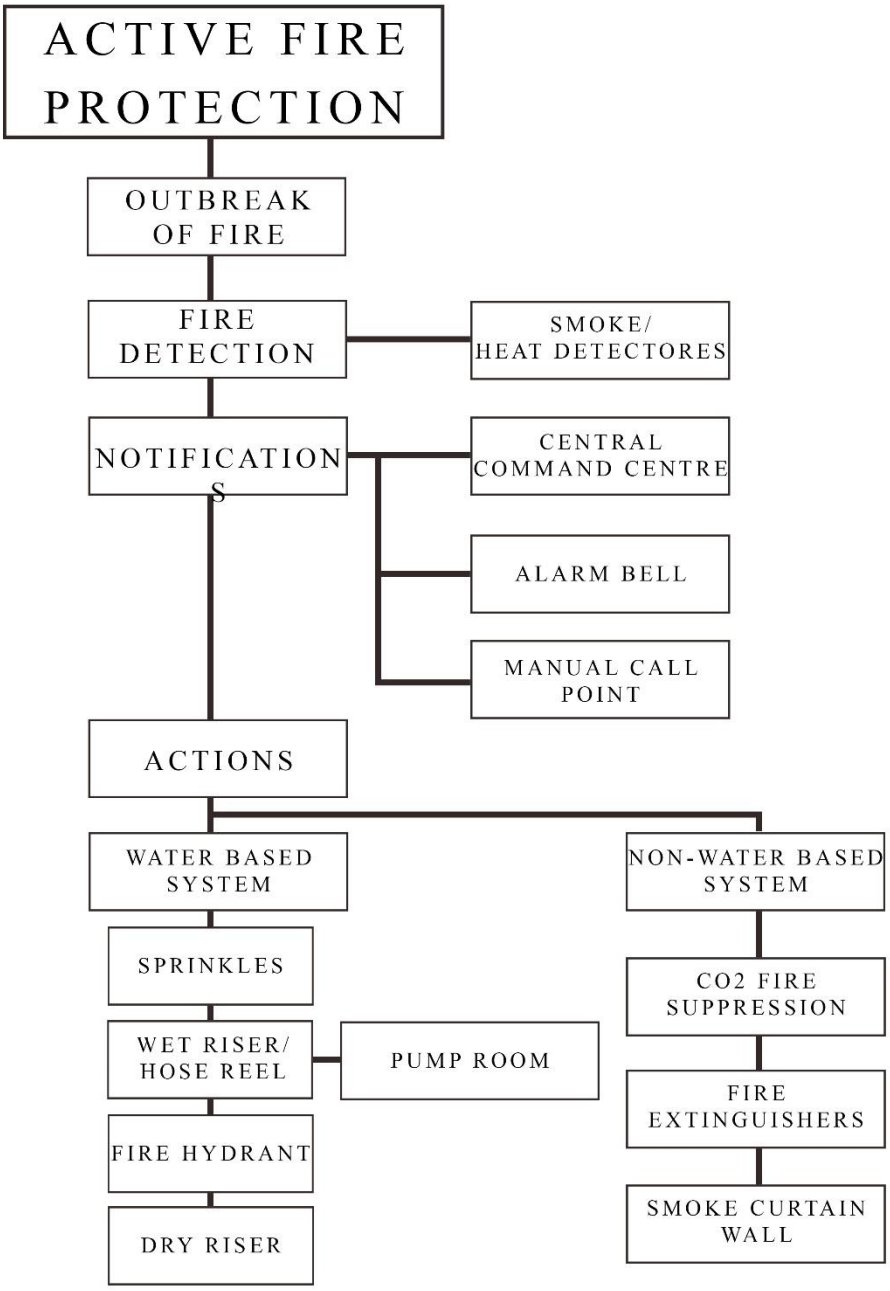


Figure 5.1: Diagram showing the Active Fire Protection System used in KLPAC.

The diagram above shows the schematic diagram of the active fire protection system specifically designed for KLPAC. Active fire protection system plays an important role in extinguishing fire outbreaks during fire emergency by using both mechanical and manually methods. We will be discussing regarding this active fire protection system of KLPAC in detail in this chapter.

5.3.1 Fire Detection

A key aspect of fire protection is to identify a developing fire emergency in a timely manner, and also to alert the building's occupants and fire emergency organizations. This is the role of fire detection and fire alarm system. The main purpose of the fire detection provide a means to identify a developing fire through either mechanical or manual methods. There are several types of fire detector have been used in KLPAC which include the heat detectors and also the smoke detectors.

5.3.1.1 Heat Detector

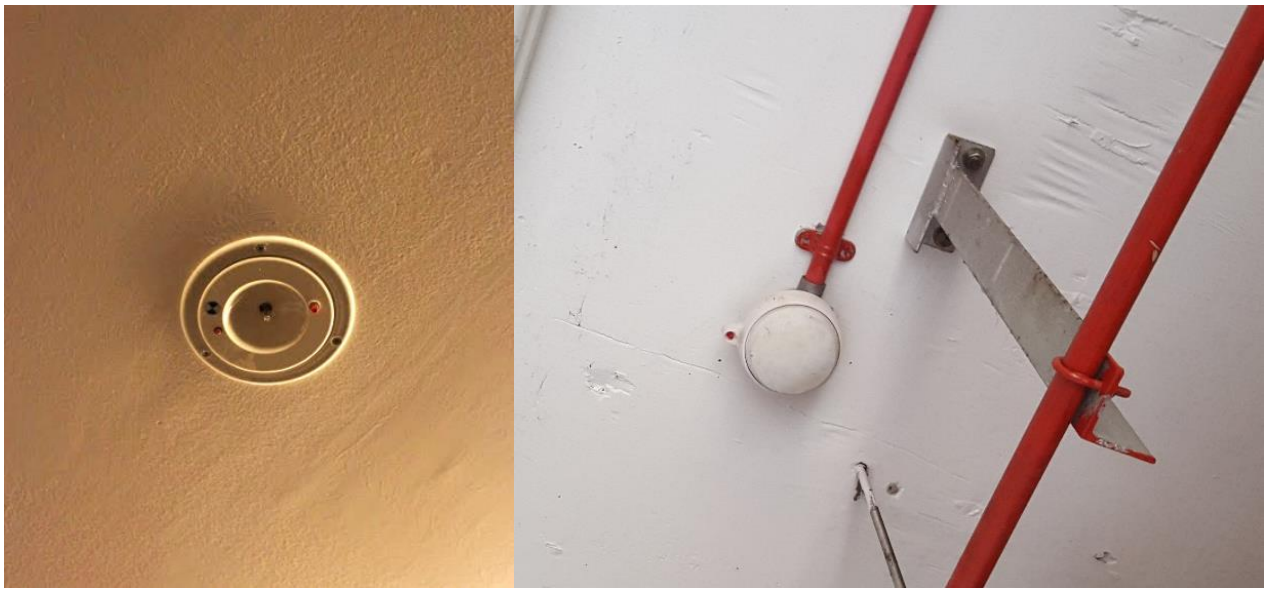


Figure 5.2: Heat detectors that are found in pre-function foyer (left) and LV main (right) at the ground floor.

The heat detectors that are used in KLPAC are the conventional "Fixed Temperature" heat detectors. These detectors will be operated when the ambient temperatures reach a fixed point, usually during the event of fire. This type of heat detectors are highly cost-effective as it is cheaper than the other types and also efficient enough to detect the ambiant temperatures in order to proect the occupants and property of KLPAC. But in the case that rapid response to fire detection is required, the "Rate of rise" detectors will be ideal in this condition to detect both the rapid and slow temperature increases.

UBBL- Section 225. (1)

Every building shall be provided with means of detecting and extinguishing fire and alarms together with illuminated exit signs in accordance with the requirements as specified in the Tenth Schedule to these By-Laws.

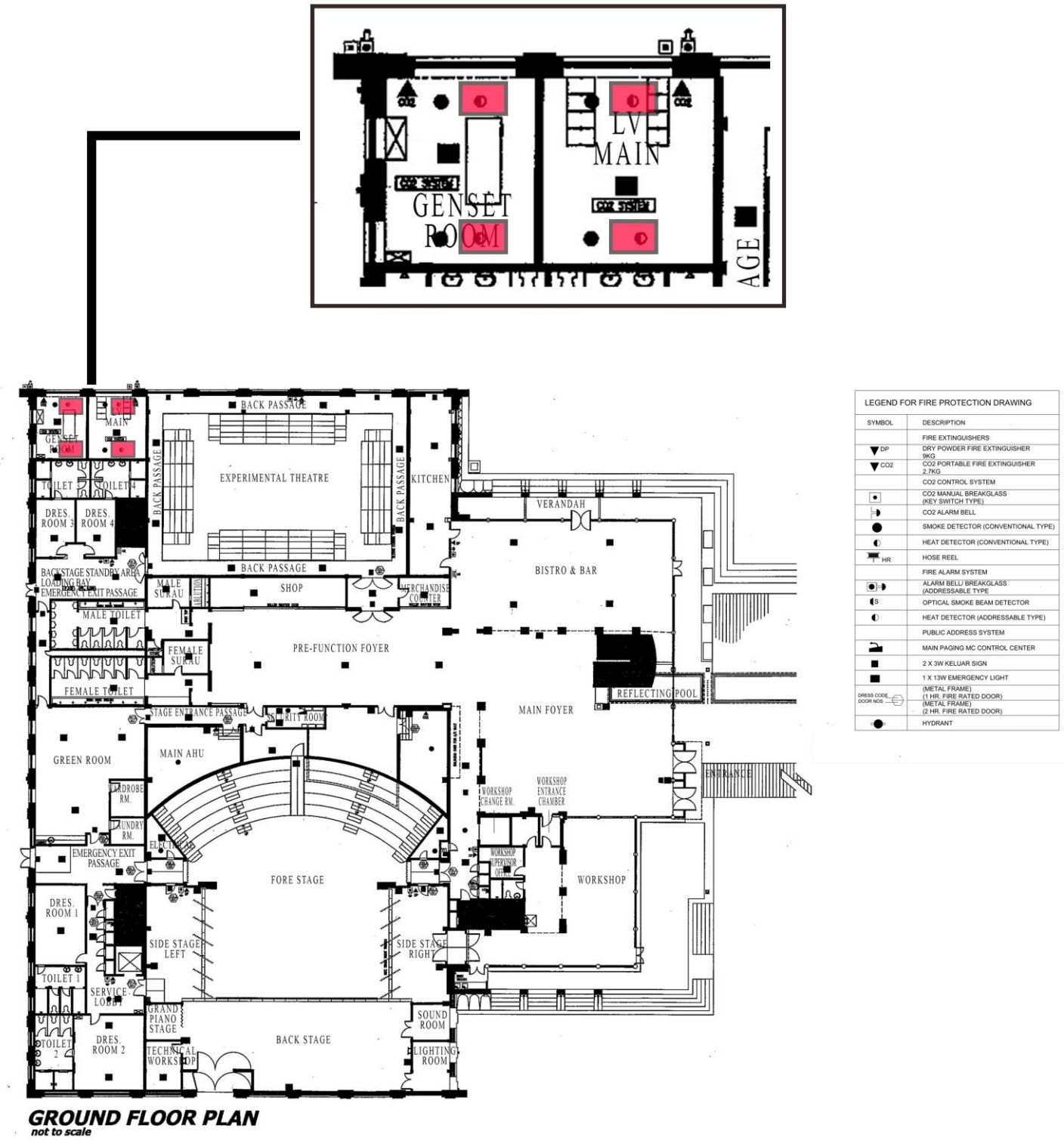
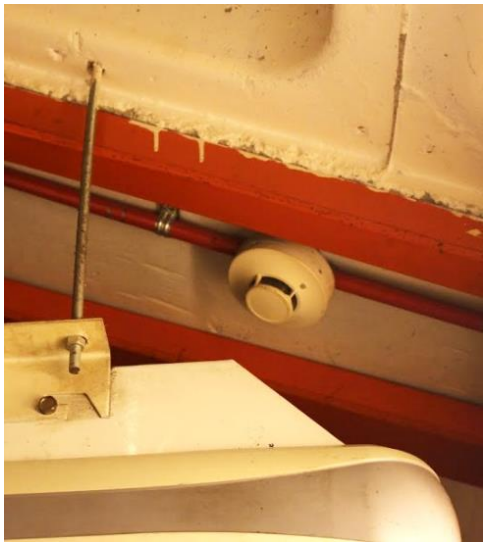


Figure 5.3: Diagram showing the locations of the heat detectors in the "genset room" and "lv main" at the ground floor.

5.3.1.2 Smoke Detector



UBBL- Section 225. (1)

Every building shall be provided with means of detecting and extinguishing fire and alarms together with illuminated exit signs in accordance with the requirements as specified in the Tenth Schedule to these By-Laws.

Figure 5.4: Smoke detector located at the security room at ground floor.

The smoke detectors that have been installed on most of the ceilings of each floors are photoelectric smoke detectors which are the most suitable and recommended smoke detectors among all. Photoelectric smoke detectors are detectors that contain a light source in a light-sensitive electric sensor. The light source will be positioned 90-degree (as shown in Figure 5.5) that the light from the light source will shoot straight across and misses the sensor, which will then be disturbed and hit the sensor then triggers the alarm when the smoke enters the chamber and scatters the light.

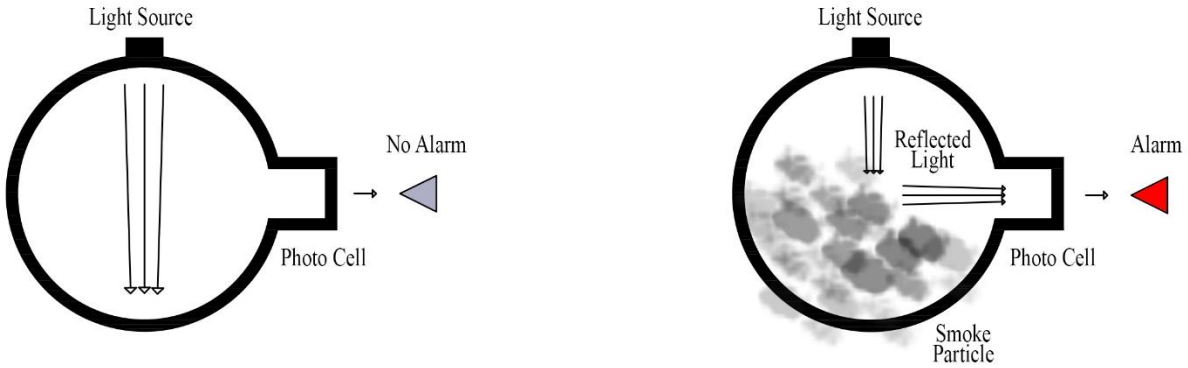


Figure 5.5: Smoke detector located at the security room at ground floor.

Source: (Simplisafe, 2013)

Photoelectric smoke detectors typically respond faster to a fire in its early, smoldering stage which is before the source of the fire bursts into flames. These detectors are more sensitive to the large combustion particles that emanate during slow, smoldering fires, which usually occur at night.

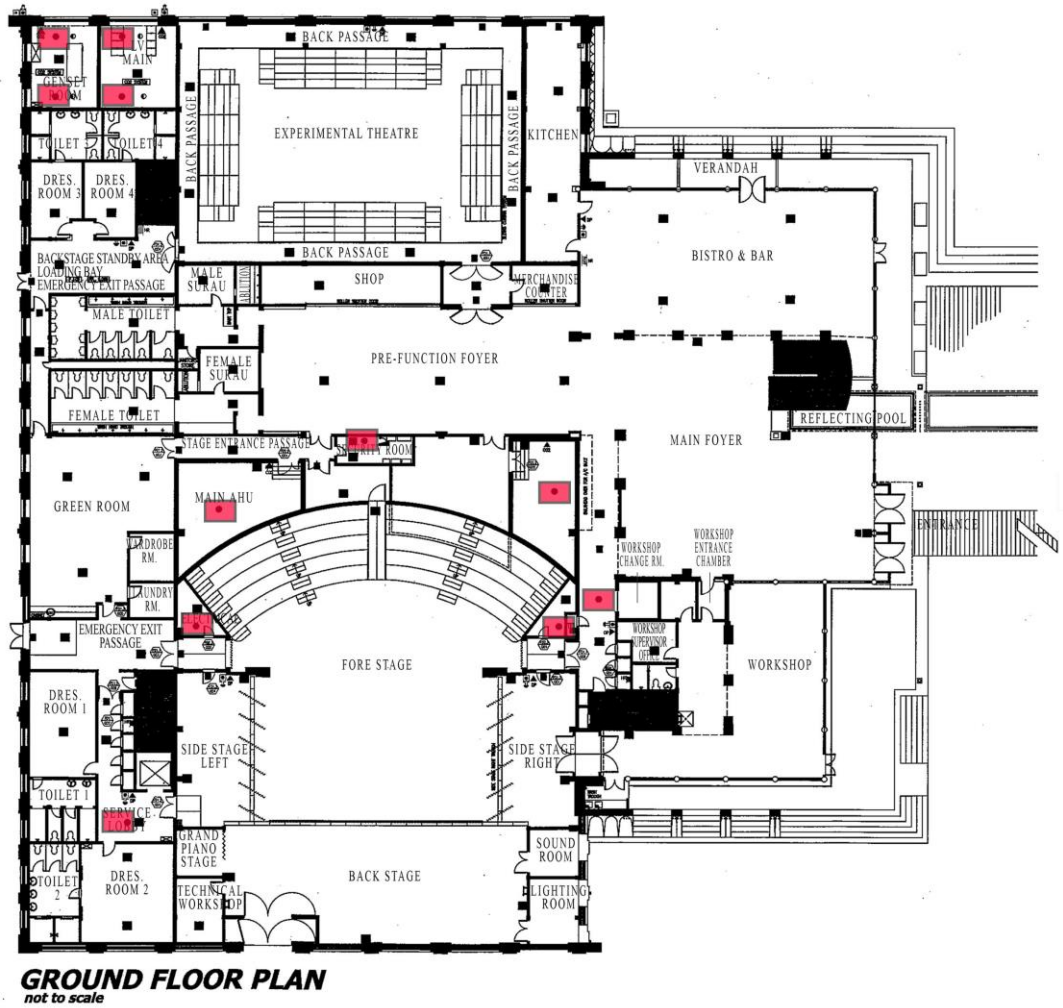


Figure 5.6: Diagram showing the locations of all the smoke detectors at the ground floor.

Analysis

The smoke detector that we have seen in the security room has been blocked by some structures from the roof. This situation will be affecting the effectiveness of the smoke detector during the event of fire.

5.3.1.3 Optical Smoke Beam Detector

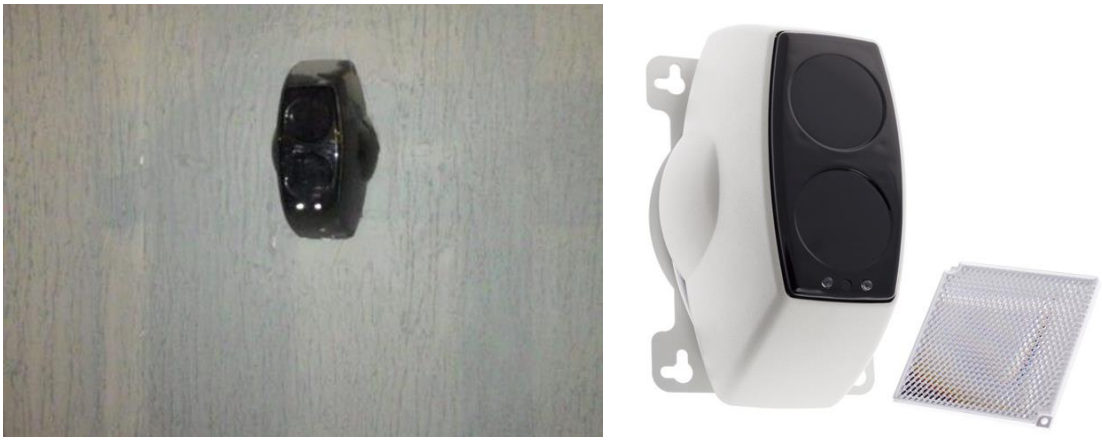


Figure 5.7: Optical smoke beam detector located at third floor and the example of the detector.

Source: (Ffeuk, 2016)

There are some optical smoke beam detectors installed at third floor where the spaces are larger and open with bigger height. An optical beam smoke detector is a device that uses projected beam of light to detect smoke across large areas. The reason that they are used at the third floor is that the standard point smoke detectors are restricted by the height of that floor. The principle of light obscuration (as shown in Figure 5.8) is applied in these detectors where the presence of smoke blocks through either absorbance or light scattering might block the transmission of light from the detectors. A fire will be signalled or notified through the fire alarm system once a certain percentage of the transmitted light has been blocked by the smoke.

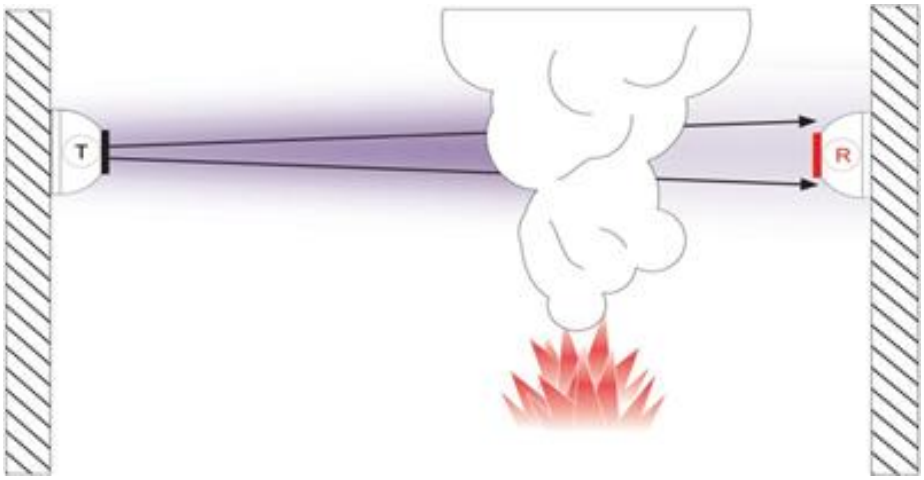


Figure 5.8: Diagram showing how the optical smoke beam functions during the event of fire.

Source: (Simplisafe, 2013)

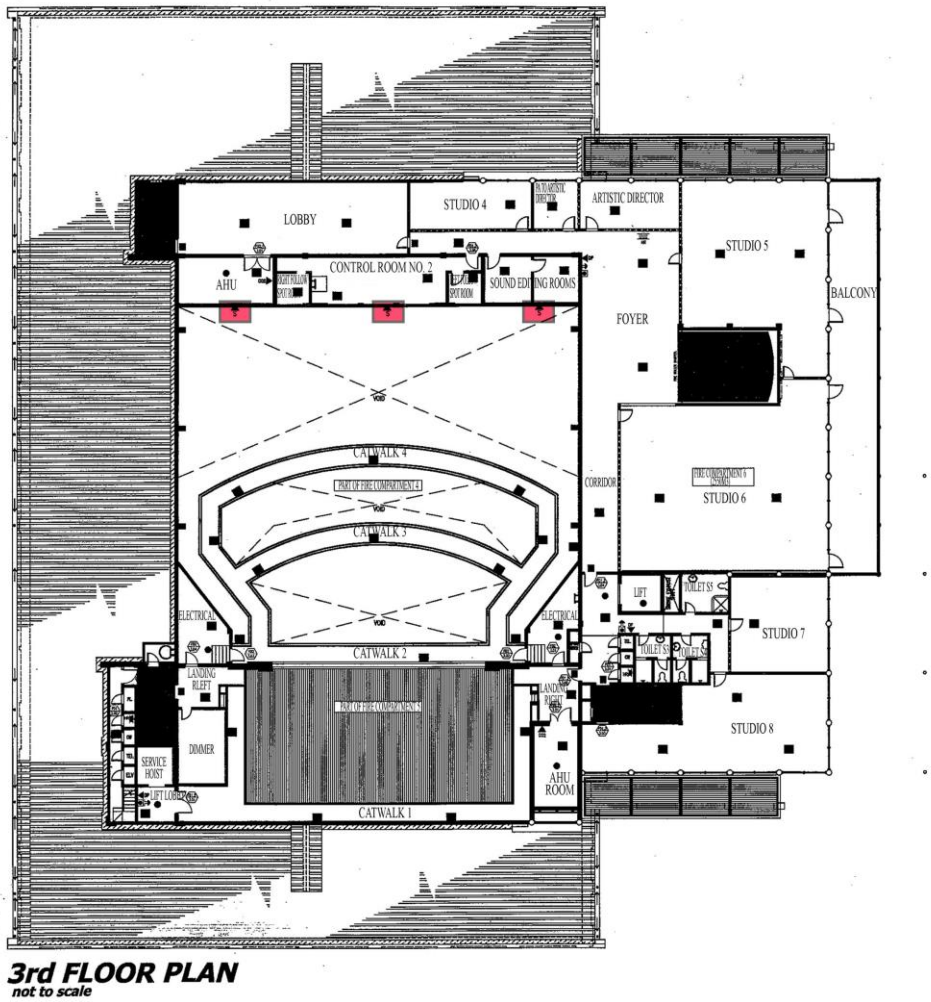


Figure 5.9: Diagram showing the locations of all the optical smoke beam detector at third floor.

UBBL- Section 225. (1)

Every building shall be provided with means of detecting and extinguishing fire and alarms together with illuminated exit signs in accordance with the requirements as specified in the Tenth Schedule to these By-Laws.

5.3.2 Notifications

5.3.2.1 Central Fire Alarm Control Panel (and Communication System)

UBBL- Section 238

Every large premises or building exceeding 30.5 meters in height shall be provided with a command and control center located on the designated floor and shall contain a panel to monitor the public address, fire brigade communication, sprinkle, water flow detectors fire detection and alarm systems and a direct telephone connection to the appropriate fire-station by-passing the switchboard.

Figure 5.10: Fire Alarm Control Panel (FACP) located in the security room at ground floor.

A Fire Alarm Control Panel (FACP), is the main controlling component in a fire alarm system. This panel will be receiving information and monitoring the sensors such as the alarm devices and the detectors (both heat/ smoke and optical smoke beam detectors) that are designed to detect changes, then transmitting the information necessary to the panel in order to sounding and switching off alarms in case where false signal has been detected. Besides, visual status indication for all relevant fire pumps, generators and other required fire safety equipment installed in KLPAC are present in the panel as well to prepare the facilities needed for fire emergency such as activating the alarm bells. The FACP also contains facilities for sounding and switching off alarms in case where false signal has been detected. Besides, visual status indication for all relevant fire pumps, generators and other required fire safety equipment installed in KLPAC are present in the panel as well.

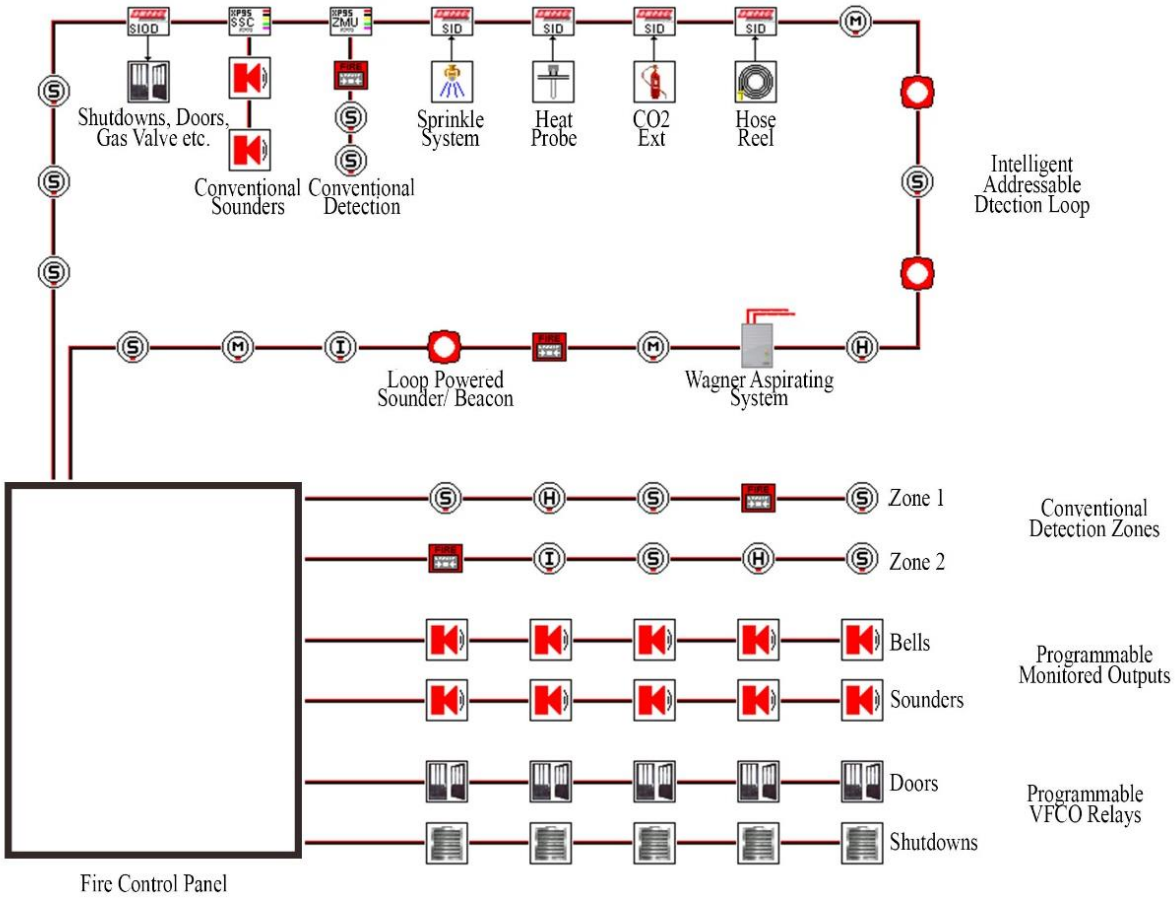


Figure 5.11: Diagram showing the system of the fire control panel and how the systems are linked together.

Source: (Airlight, 2014)

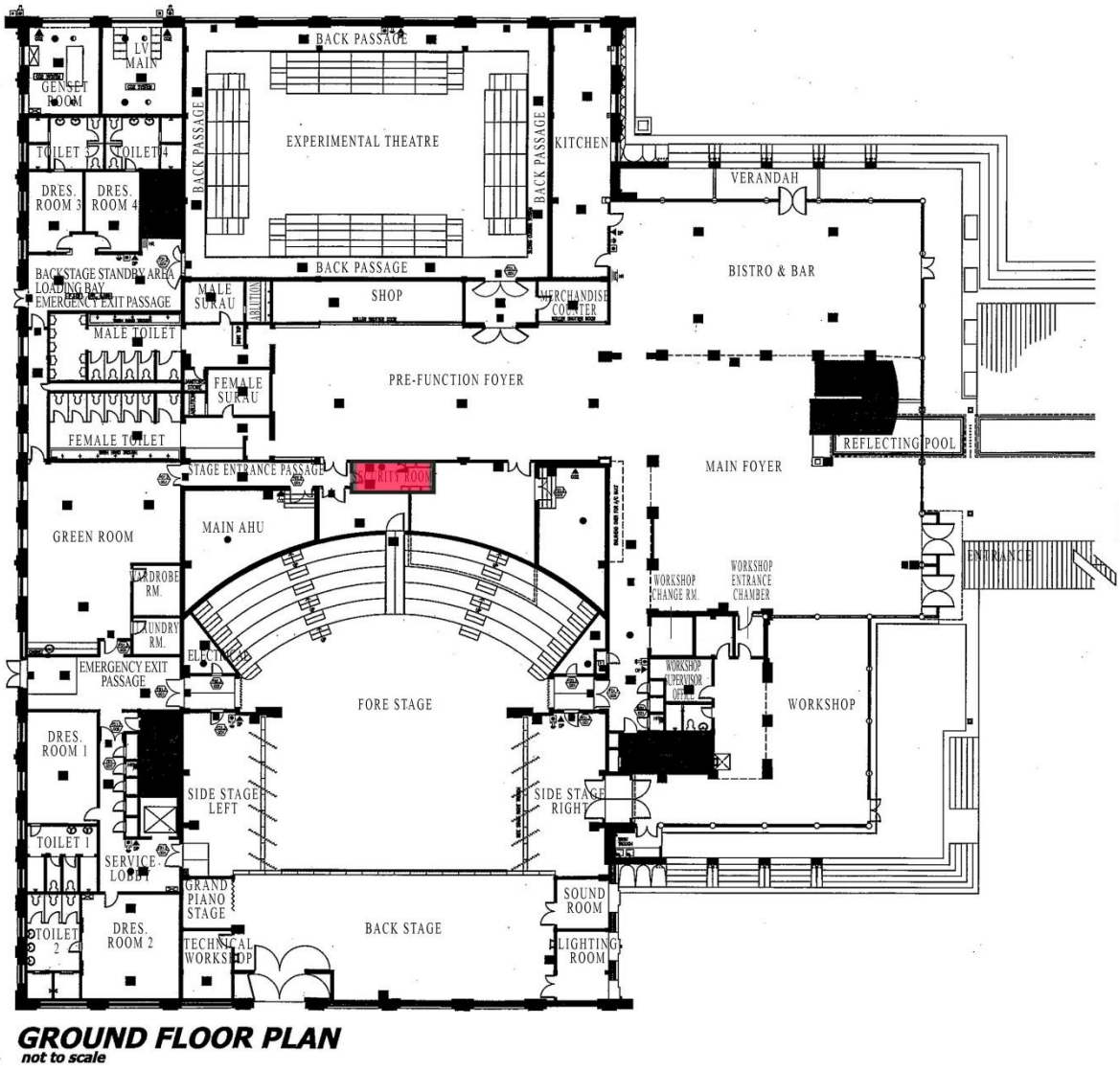


Figure 5.12: Diagram showing the location of all the FACP at ground floor.

Figure 5.13: The Digital Alarm Communicator located above the control panel in the security room at ground floor.

There is a digital alarm communicator that is directly linked to Jabatan Bomba located above the control panel which can be used to report to the fire-station as associated in the event of emergency.

OSHA stated that, when the devices either manually or mechanically are activated, a signal will be sent to the FACP, in accordance to the type of systems and hazards, can be programed to:

1. Activate a pre-discharge alarm.
2. Initiate agent release.
3. Shut down ventilation system.
4. Shut down machinery equipment.
5. Activate visual and audible fire alarms.
6. Notify emergency response personnel.

5.3.2.2 Fire Alarm

Figure 5.14: Fire alarm bells located inside the security room at ground floor.

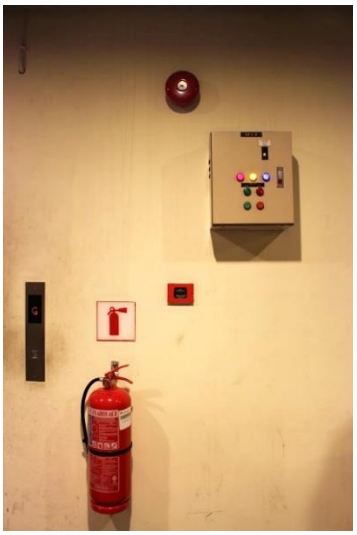


Figure 5.15: Fire alarm bells located next to the lift together with fire extinguisher and manual call point.

The fire alarm system is capable of alerting the users and occupants of KLPAC in the event of fire emergency. These devices that have been installed throughout the building of KLPAC are responsible to trigger the fire alarm system either manually (manual break glass) or mechanically (detectors) whenever the devices are signaled. These fire alarm bells are reponsible to alert the occupants of KLPAC to evacuate immediately during the event of fire emergency. Special circuit is needed for the fire alarm system as an independent power supply will be required. The fire alarm bells will usually be placed about 1200mm above the manual call point and 2700mm from the ground level.

UBBL- Section 155. (1)

The fire mode of operation shall be initiated by a signal from the fire alarm panel which may be activated automatically by one of the alarm devices in the building or manually.

UBBL- Section 237

(1) Fire alarms shall be provided in accordance with the Tenth Schedule to these By-Laws.

(2) All premises and building with gross floor area excluding car park and storage area exceeding 9290 square meters or exceeding 30.5 meters in height shall be provided with a two-stage alarm system with evacuation (continuous signal) to be given immediately in the affected section of the premises while an alert (intermittent signal) be given in adjoining section.

(3) Provision shall be made for the general evacuation of the premises by action of a master control.

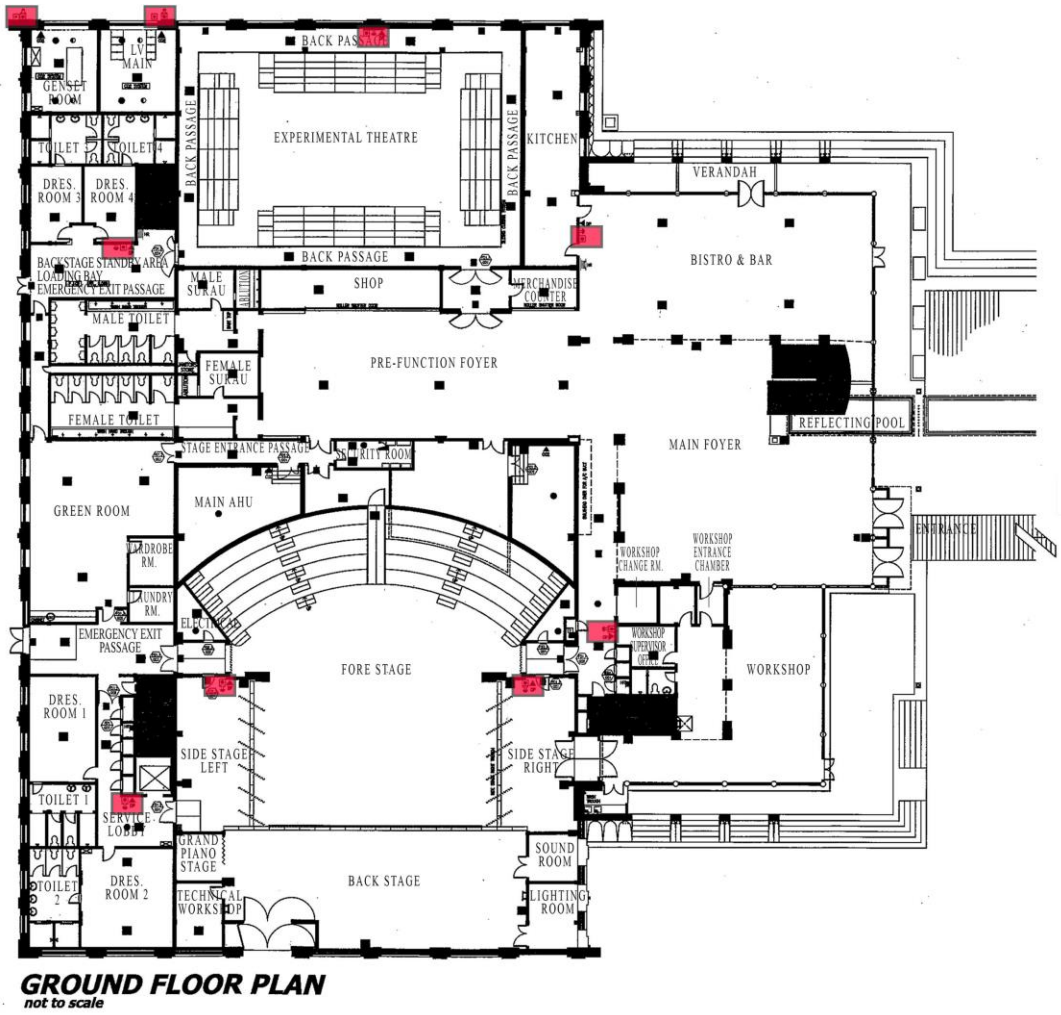


Figure 5.16: Diagram showing the locations of all the fire alarm bells at ground floor.

Analysis

The fire alarm bells are placed at the right places in accordane to the UBBL Section 155, but the amount of the fire alarm bells could be increased as the building KLPAC is huge. Besides, as the KLPAC is a public building in which that visible indicator fire signals shall be incorporated in addition to the normal fire alarm system in accordance with the UBBL Section 241, as the audible alarm system is undesirable for the deaf persons.

5.3.2.3 Manual Call Point

UBBL- Section 237

Alarm bell must provide a minimum sound level of 65db (A) or +5db (A) above any background noises, which is likely to persist for more than 30 seconds.

Figure 5.17: Manual call point that can be found at most of the areas and doorways.

In some cases that some of the fire alarms might not be detected due some reasons, the manual call point can be used to trigger the fire alatms. The manual call points are located nearby the exits and doorways for the occupants of KLPAC to break the glass which a warning signal will be sent to the control panel, then to trigger the fire alarms and cut off the other services such as the ventilation system. The manual call points are placed 1500mm from the groud which is accessible for the disabled.

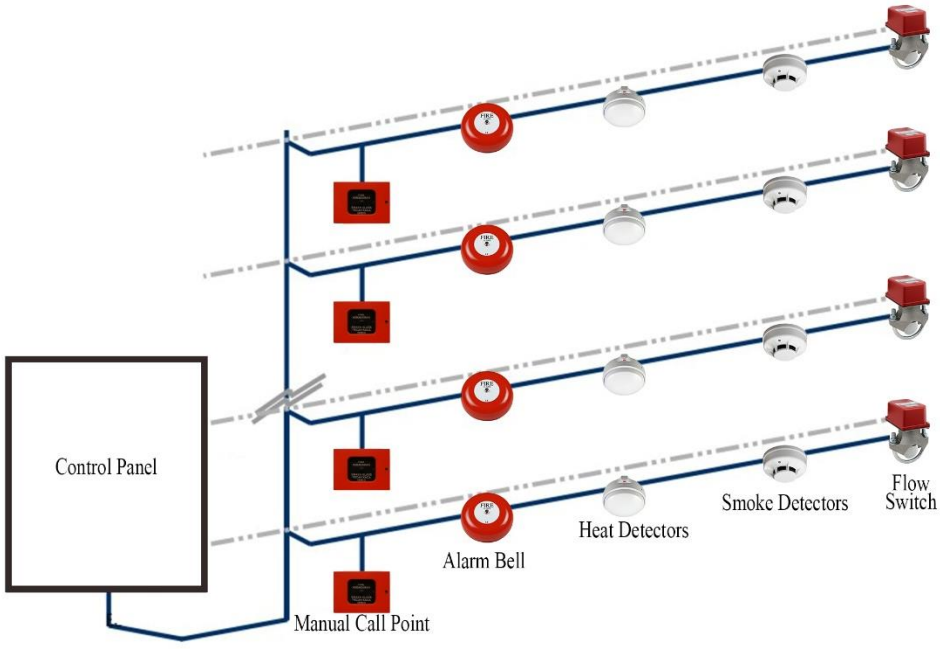


Figure 5.18: Diagram showing how the manual call point are linked to the control panel and the other components in the fire alarm system.

Source: (Airlight, 2014)

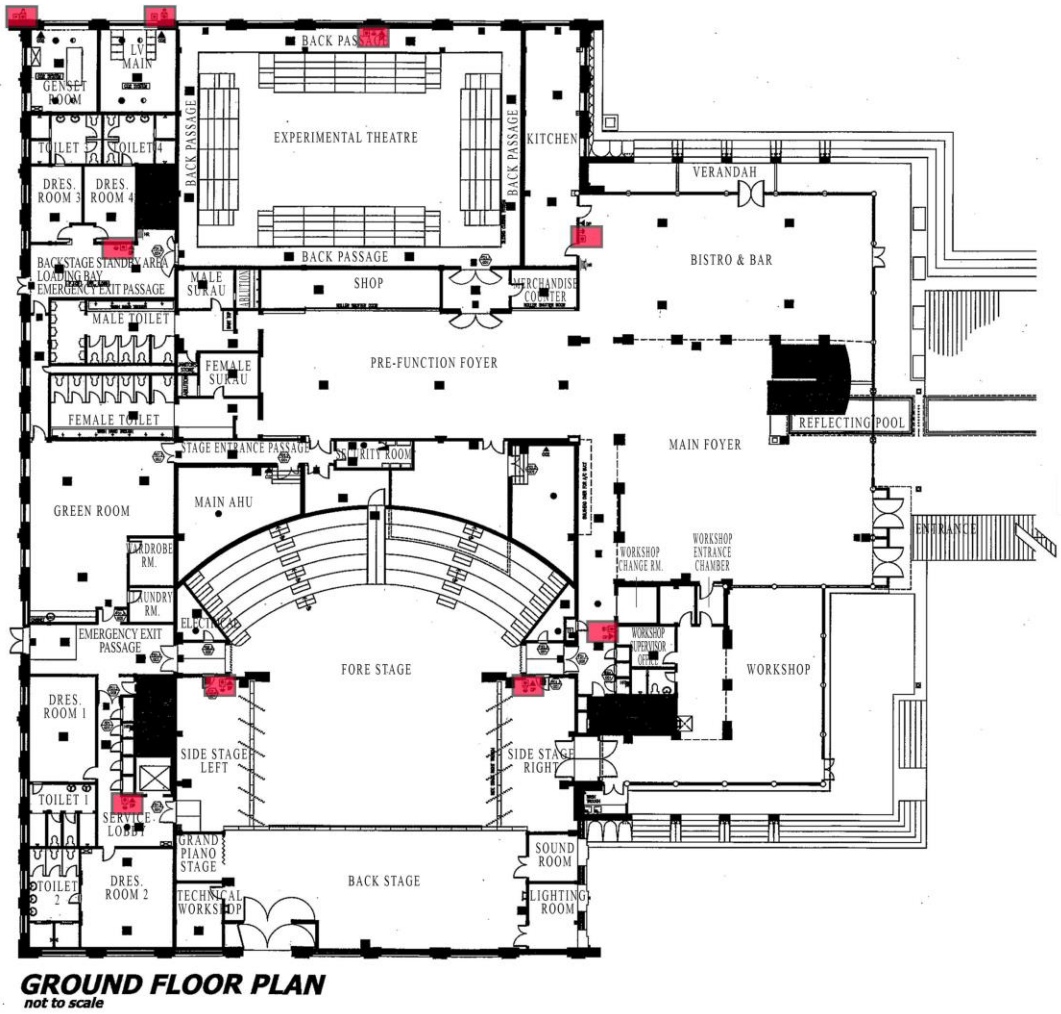


Figure 5.19: Diagram showing the location of all the manual call point at the ground floor.

5.3.3 ACTIONS (WATER-BASED SYSTEM)

5.3.3.1 SPRINKLES

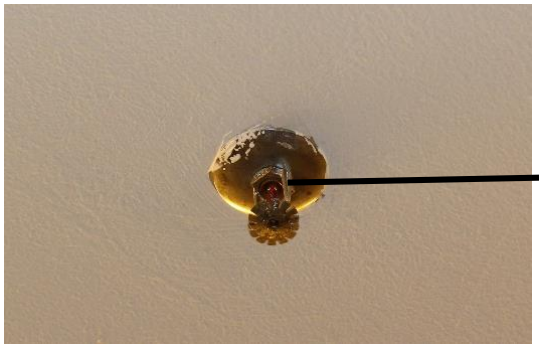


Figure 5.20: Sprinkles that can be found over the ceilings throughout The KLPAC.

Figure 5.21: Red color liquid in the bulb.

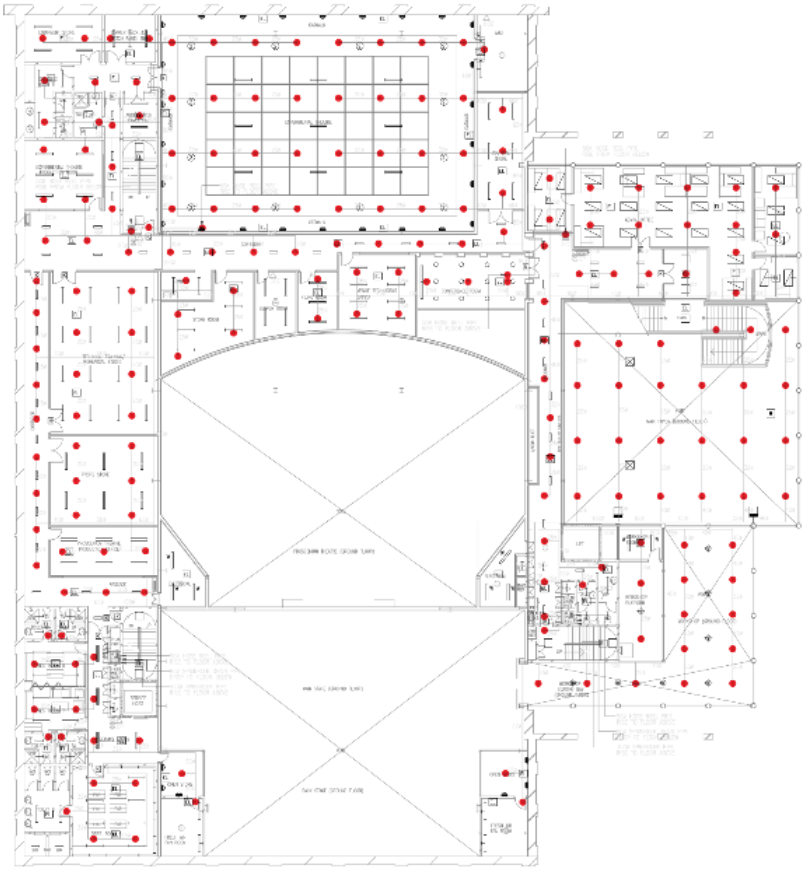


Figure 5.22: Location of Sprinklers at the ground floor.

A sprinkler can be deployed in seconds when fire is detected, possibly before the fire station has been informed of the fire. Therefore, it is very effective at putting out a fire in the early stages, *before it grows into a large fire*. Sprinkler is widely used in all building because it is a proven automatic fire suppresser. A sprinkler is a nozzle attached to a network of pipes, and installed just below or within the ceiling of a room. Water is prevented from emerging by a glass or quartzite bulb containing liquid. The different colors liquid in the bulb denote different operating temperature because the size of the air bubble changes. For KLPAC, it installed red color liquid of sprinkler head within the whole building.

Bulb liquid color	**Rupturing temperature(°C)**
Orange	57
Red	68
Yellow	79
Green	93
Blue	141
Mauve	182
Black	204/260

Figure 5.23: Sprinkler bulb color & rupturing temperature.

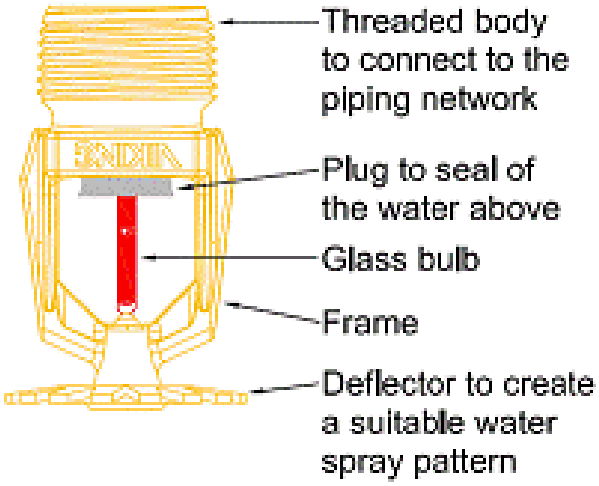


Figure 5.24: Diagram showing the mechanism of a sprinkle.
Source: (http:/5.33/www.derbys-fire.gov.uk/)

Every sprinkler has a small glass bulb with a liquid in it. This bulb normally blocks the flow of water. In a fire, heat causes alcohol inside bulb to expand, shatter bulb and water flows. The water from the sprinkler head will cover the area where the fire is located and will continue to operate until the fire department can fully extinguish the fire.

Wet Pipe System

For KLPAC, it is installed the most popular system which is wet pipe sprinkler system. It has all pipework permanently charged with water. It is suited to building interiors that remain above freezing and do not exceed 70‘C.

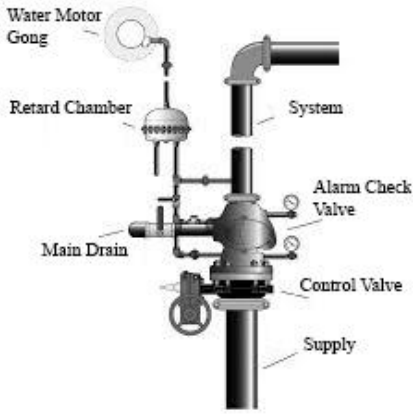


Figure 5.25: Typical Alarm Check Valve Riser.
Source: (http://firewize.com/)

Figure 5.26: Wet pipe sprinkler system located outside of KLPAC, beside the water pump room.

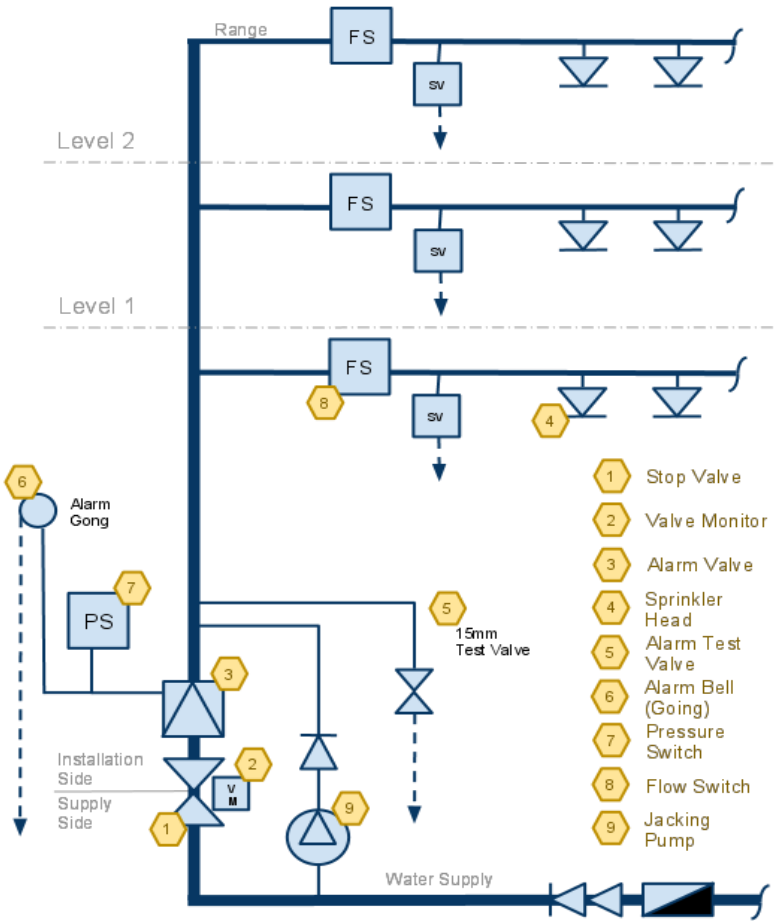


Figure 5.27: An automatic fire sprinkler system.

Source: (http://firewize.com/)

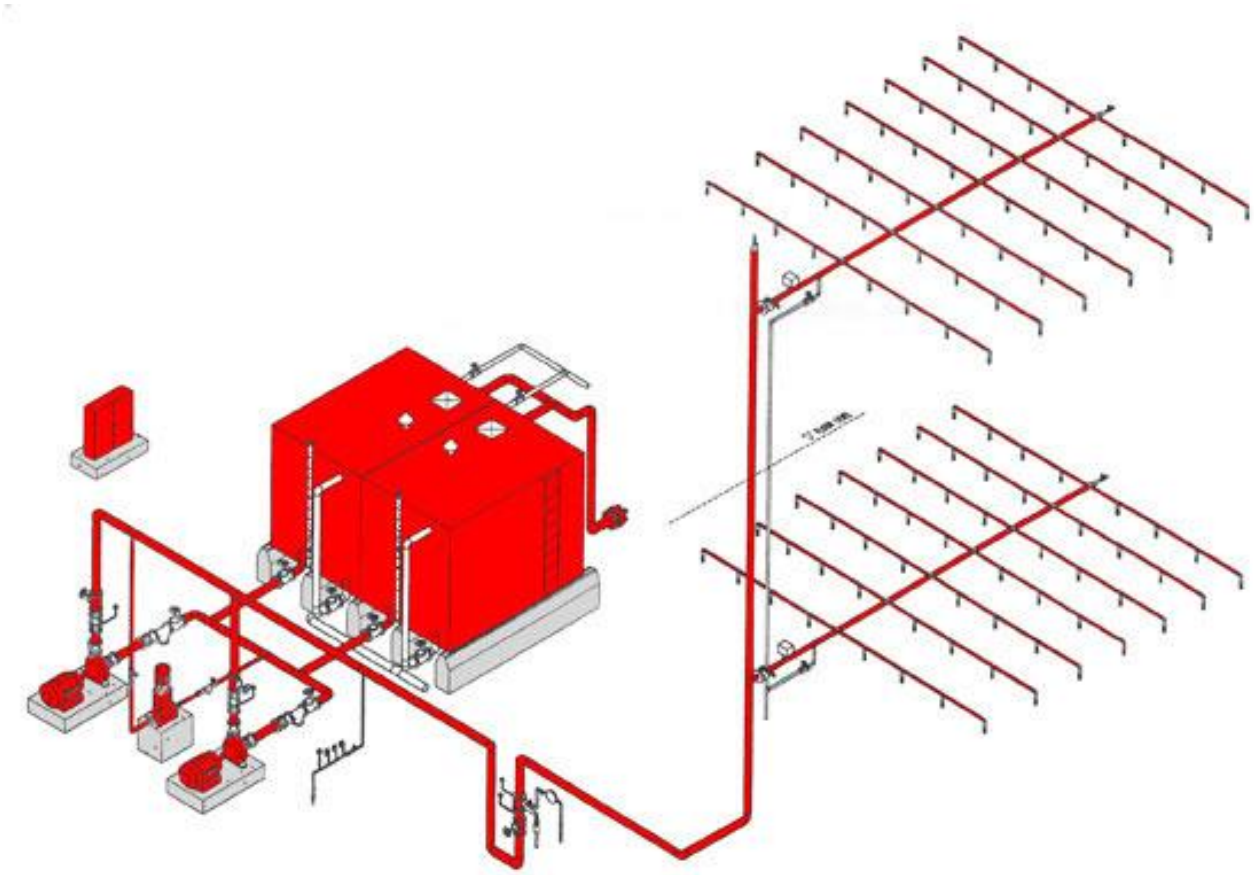


Figure 5.28: Schematic Diagram of Fire Sprinkles

Source: (http://www.rajyogfire.com/)

The starting point for all wet-based sprinkler systems is the water source. The wet pipe system is controlled by an alarm check valve. When a sprinkler activates, the flow of water raises the alarm valve clapper from its seat, thereby lifting the pilot valve disc from the nozzle. This permits water to enter the alarm line. A water motor gong is actuated by the flow. An optional pressure switch may be attached on the alarm line to provide an electric signal to an outdoor alarm bell or to the building's main fire alarm control panel.

Analysis:

The sprinkler system in the building will responds immediately to the automatically once the alarm is activated to effectively extinguish the fire with the wet sprinkler system. KLPAC did well on this sprinkler system and putting the sprinkler heads among the whole building.

UBBL- Section 225. (2)

(1) Sprinkler valves shall be located in a safe and enclosed position on the exterior wall and shall be readily accessible to the Fire Authority.

(2) All sprinkler systems shall be electricity connected to the nearest fire station to provide immediate and automatic relay of the alarm when activated.

5.3.3.2 WET RISER AND HOSE REEL SYSTEM

Figure 5.29: Hose reel that are found at the ground floor of KLPAC

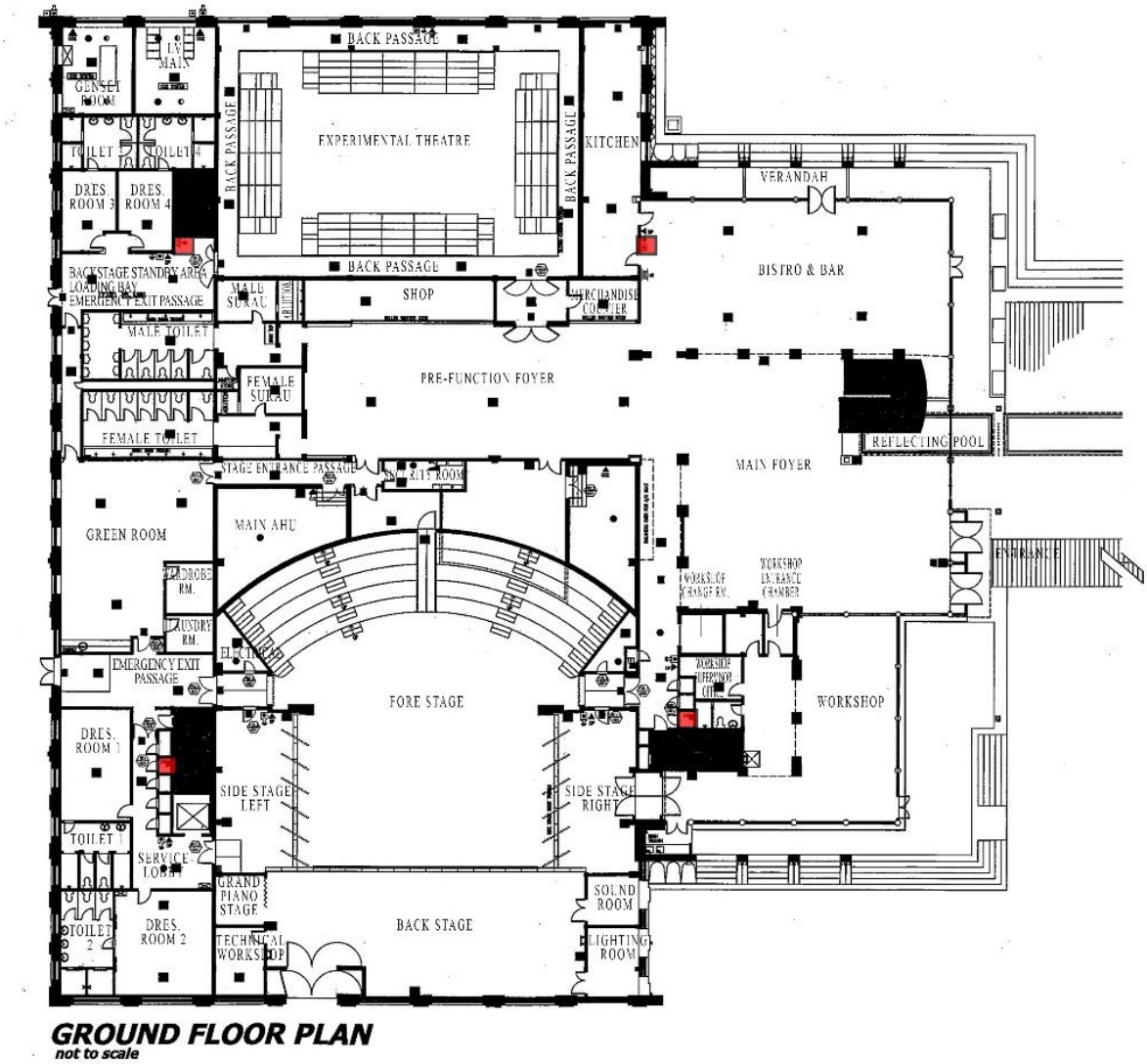


Figure 5.30: Diagram showing the locations of the hose reels at ground floor, KLPAC.

The Hose Reel System is intended for the 3occupant to use during the early stages of a fire. Fire hose reels are located at strategic places in buildings to provide a reasonably accessible and controlled supply of water for fire extinguishing. Fire hose reel systems consist of pumps, pipes, water supply and hose reels located strategically in a building, ensuring proper coverage of water to combat a fire.

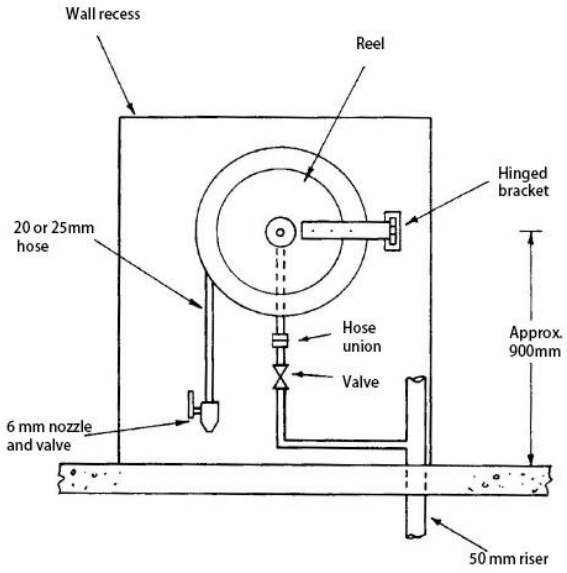


Figure 5.31: Hose Reel Diagram

Source: (http://www.rajyogfire.com/)

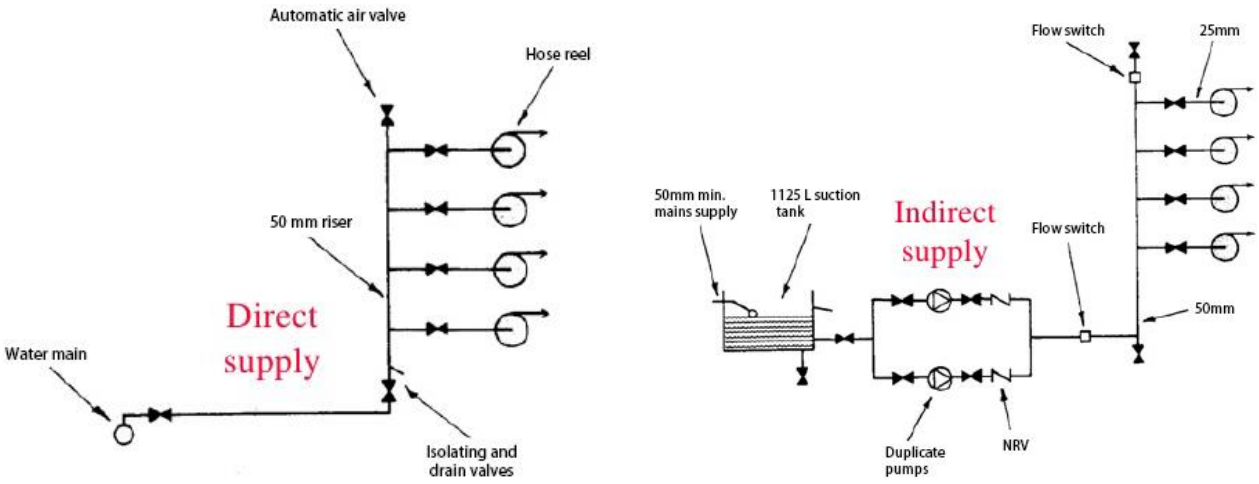


Figure 5.32: Hose Reel Installation

Source: (http://www.rajyogfire.com/)

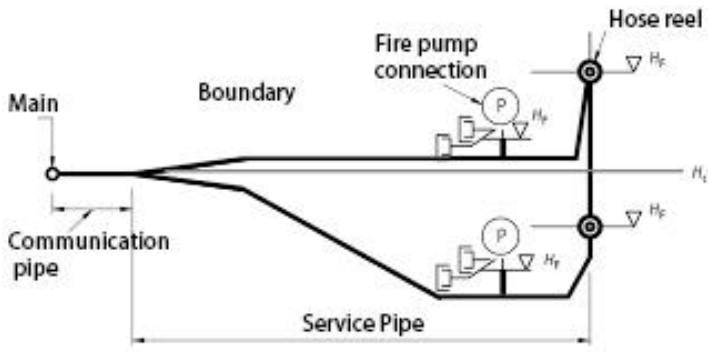


Figure 5.33: Schematic layout of service2 pipes serving a fire pump connection of hose reel.

Source: (http://www.rajyogfire.com/)

The hose reel is connected to the wet riser in which it is always being filled with pressurized water for any emergency usage. The system is manually operated and activated by opening a valve enabling the water to flow into the hose that is typically 30 meters away. The system pressure loss will activate the pump ensuring adequate water flow and pressure to provide a water jet of typically a minimum of 10 meter from the nozzle.

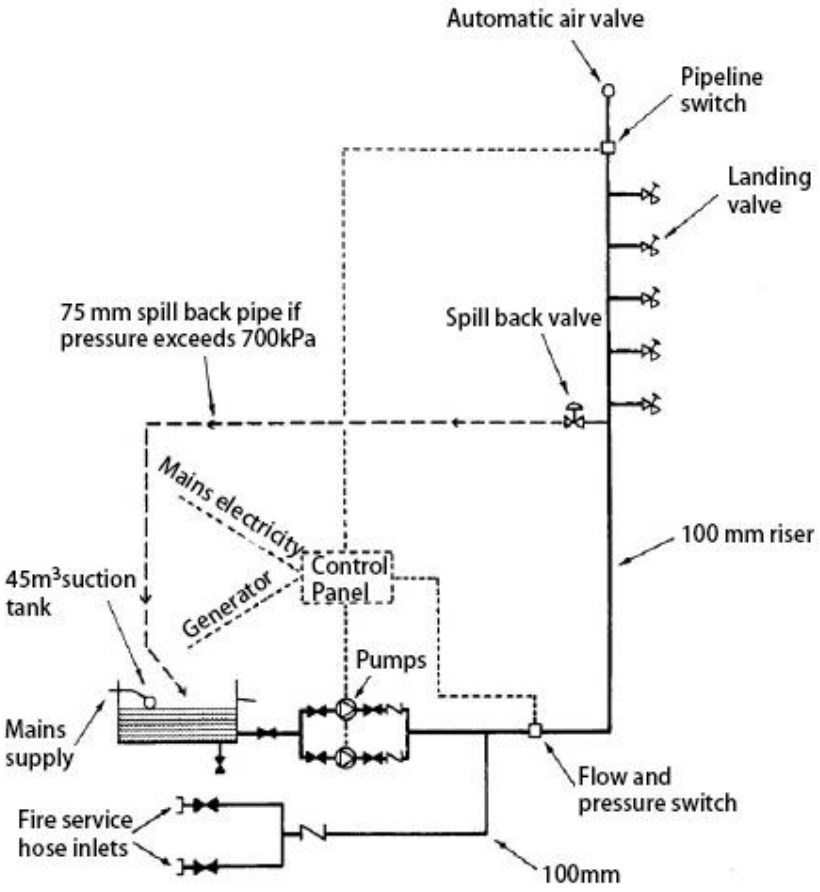


Figure5.34: Internal Hydrant: Wet Riser

Source: (http://www.rajyogfire.com/)

The wet risers are a form of internal hydrant for the fireman to use and are always pressurized with water unlike the dry risers. Wet riser system usually will comprise the duty fire pump with standby pump discharging into a 150mm diameter riser pipe with landing valves at each floor and to which canvas hose with nozzles that can be connected to direct the water jet towards the fire. Besides, a jockey pump is usually provided to maintain system pressure.

Analysis:

KLPAC followed the requirement of UBBL, the position of the hose reel in KLPAC can be enter every spaces with the appropriate lengths. The hose reel can fully extended reach to within 6m of every part of the floor.

UBBL- Section 231

(1) Wet rising system shall be provided in every building in which the top most floor is more than 30.5 meters above the fire appliance access level.

(2) A hose connection shall be provided in each fire-fighting access lobby.

UBBL- Section 248

(1) Wet riser, dry riser, sprinkler and other fire installation pipes and fittings shall be painted red.

(2) All cabinets and areas recessed in walls for location of fire installations and extinguishers shall be clearly identified to the satisfaction of the Fire Authority or otherwise clearly identified.

5.3.3.3 PUMP ROOM

Figure 5.35: Image showing the duty pump and standby pump used for fire emergency.

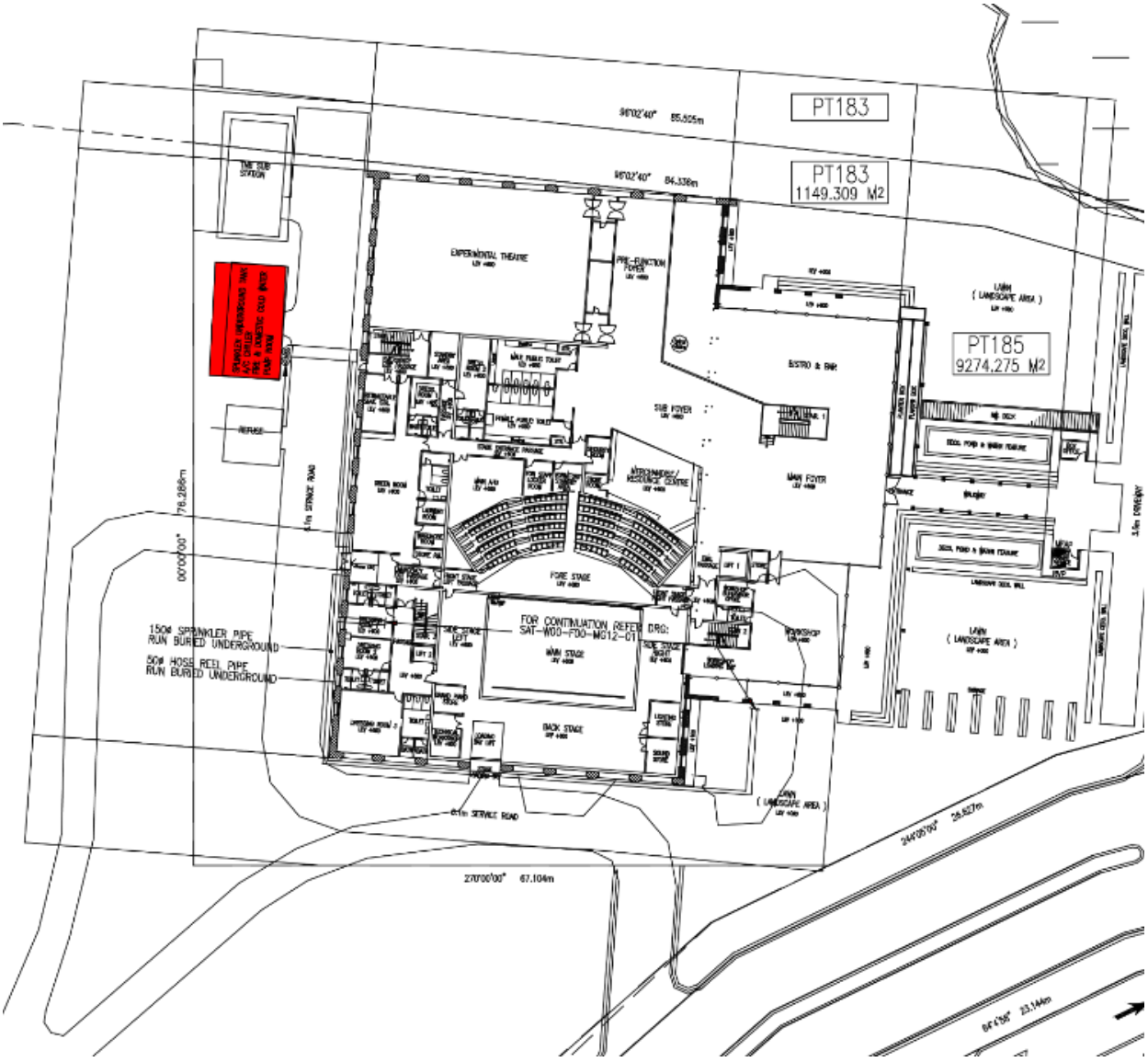


Figure 5.36: Diagram showing the location of the pump room located outside of KLPAC.

The pump room, or fire pump plays an important role under the active fire protection system. It is usually located at the lowest floor. The pump room provides immediate and faster means of fire control and delivers the required water flow. The pump room function with 3 elements, each of them have different role, which is the duty pump, standby pump and jockey pump. Where there is and fault in the system, it will be indicated in the pump room and control panel. The pressure gauge will control the pressure so that it is at the right and appropriate water pressure. It will control the pressure so that it is at the right and appropriate water pressure. It will automatically cut out the water at certain circumstances.

Fire pumps should be located at a level just below the bottom of the fire tank, so that all the water in the tanks can flow into the pumps by gravity. There is a main pump and a backup pump that is electric, and a second backup pump that is diesel- powered, in case the electricity fails. There is also a fourth type of pump called a jockey pump. This is a small pump attached to the system that continually switches on to maintain the correct pressure in the distribution systems, which is normally 7 Kg/cm2 or 100 psi. If there is a small leakage somewhere in the system, the jockey pump will switch on to compensate for it. Each jockey pump will also have a backup. The pumps are controlled by pressure sensors. When a fire fighter opens a hydrant, or when a sprinkler comes on, water gushes out of the system and the pressure drops. The pressure sensors will detect this drop and switch the fire pumps on. But the fire pump can only be stopped manually.

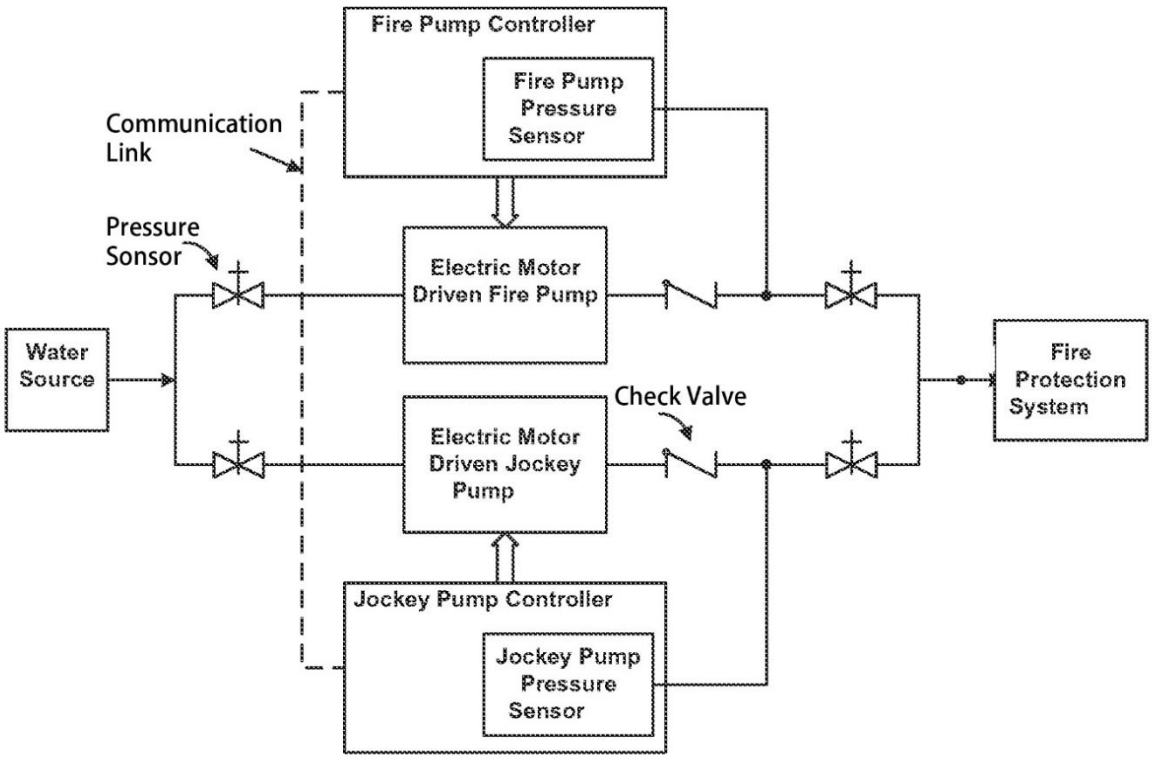


Figure 5.37: Fire and Jockey pump controller sending lines

Source: (https://law.resource.org/)

5.3.3.4 FIRE HYDRANT

Figure 5.38: A fire hydrant found outside of KLPAC.

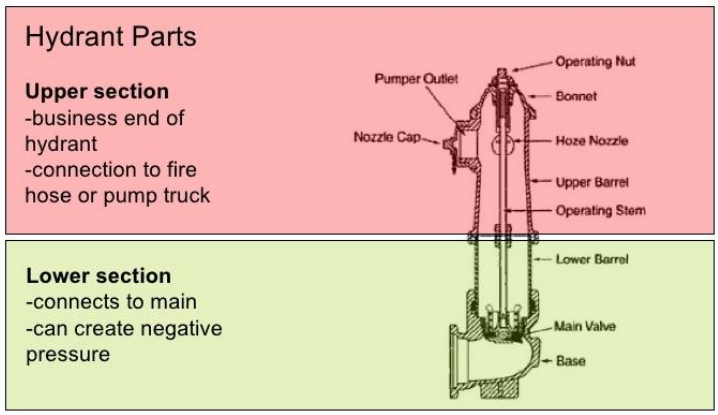


Figure 5.39: Main parts of a typical fire hydrant

Source: (http://www.kmphydrants.com/)

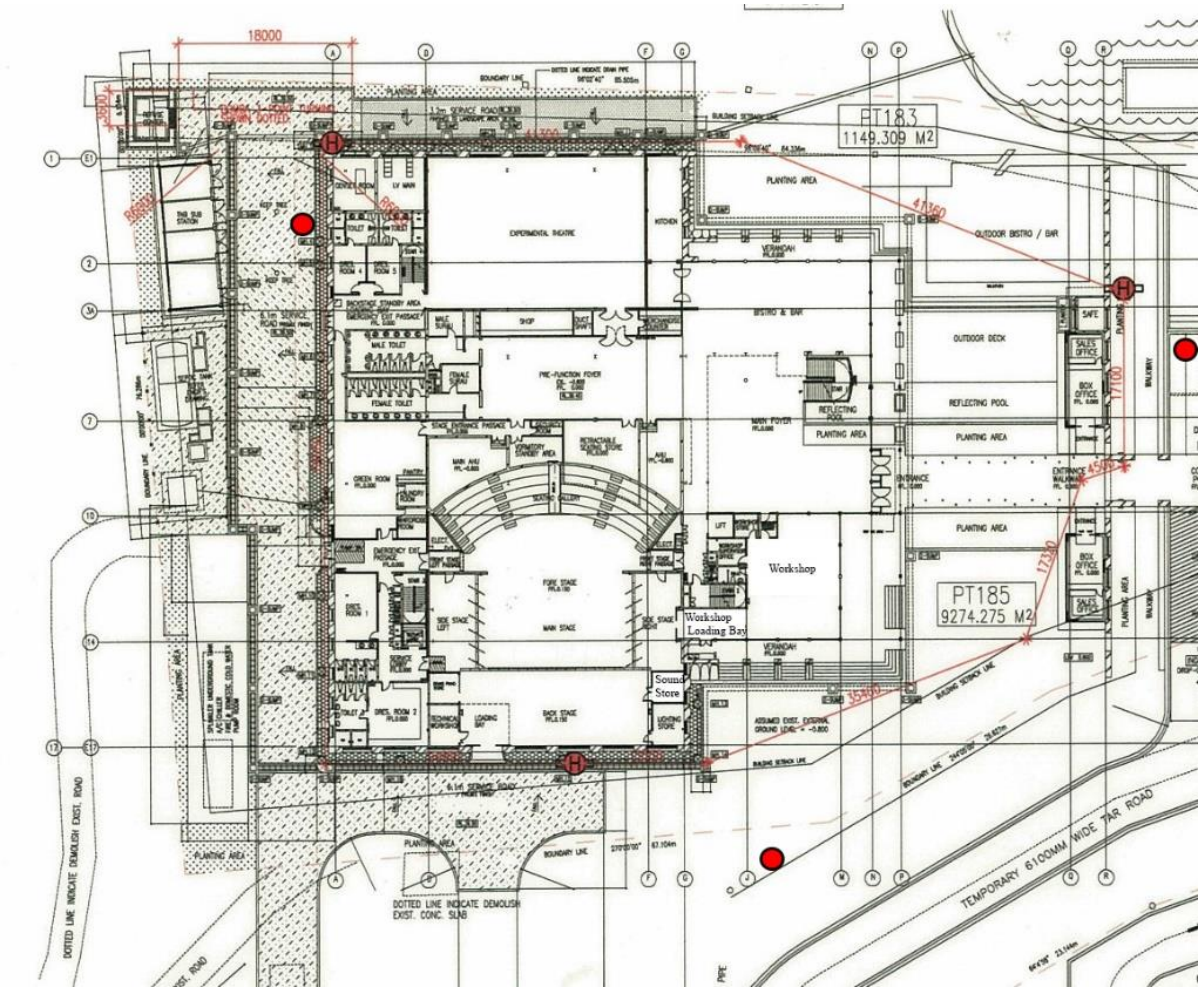


Figure 5.40: Diagram showing the locations of the fire hydrant around KLPAC.

A fire hydrant is a connection point by which fire fighters can tap into a water supply. All the fire- fighting system consist of hydrants connected to the same pipeline. It contains source of water provided with municipal water service. The other end of the pipeline is attached to the pumps and water supply tank of the fire-fighting room. It is an effective and efficient means of extinguishing large fire; the fire hydrant system enables the fire fighter to attack the seal of the fire from a distance. A fire hydrant is a vertical steel pipe with an outlet, close to which two fire hoses are stored. During an emergency which more water is required to overcome the fire accident situation, fire fighters will go to the outlet, break open the hoses, attach one to the outlet, and manually open it so that water rushes out of the nozzle of the hose. As soon as the fire fighter opens the hydrant, water will gush out, and sensors will detect a drop in pressure in the system. This drop in pressure will trigger the fire pumps to turn on and start pumping water at a tremendous flow rate.

It needs to have:

- Maximum spacing of 150m apart, next to roads
- Maximum 70m distance from building entry
- A minimum distance of 6m to a building

UBBL – Section 225. (2)

Every building shall be served by at least one fire hydrant located not more than 91.5 meters from the nearest point of fire brigade access.

5.3.4 ACTIONS (NON-WATER BASED SYSTEM)

5.3.4.1 CARBON DIOXIDE ($C0_2$) SUPPRESSION SYSTEM

Figure 5.41: CO_2 fire suppression found in KLPAC.

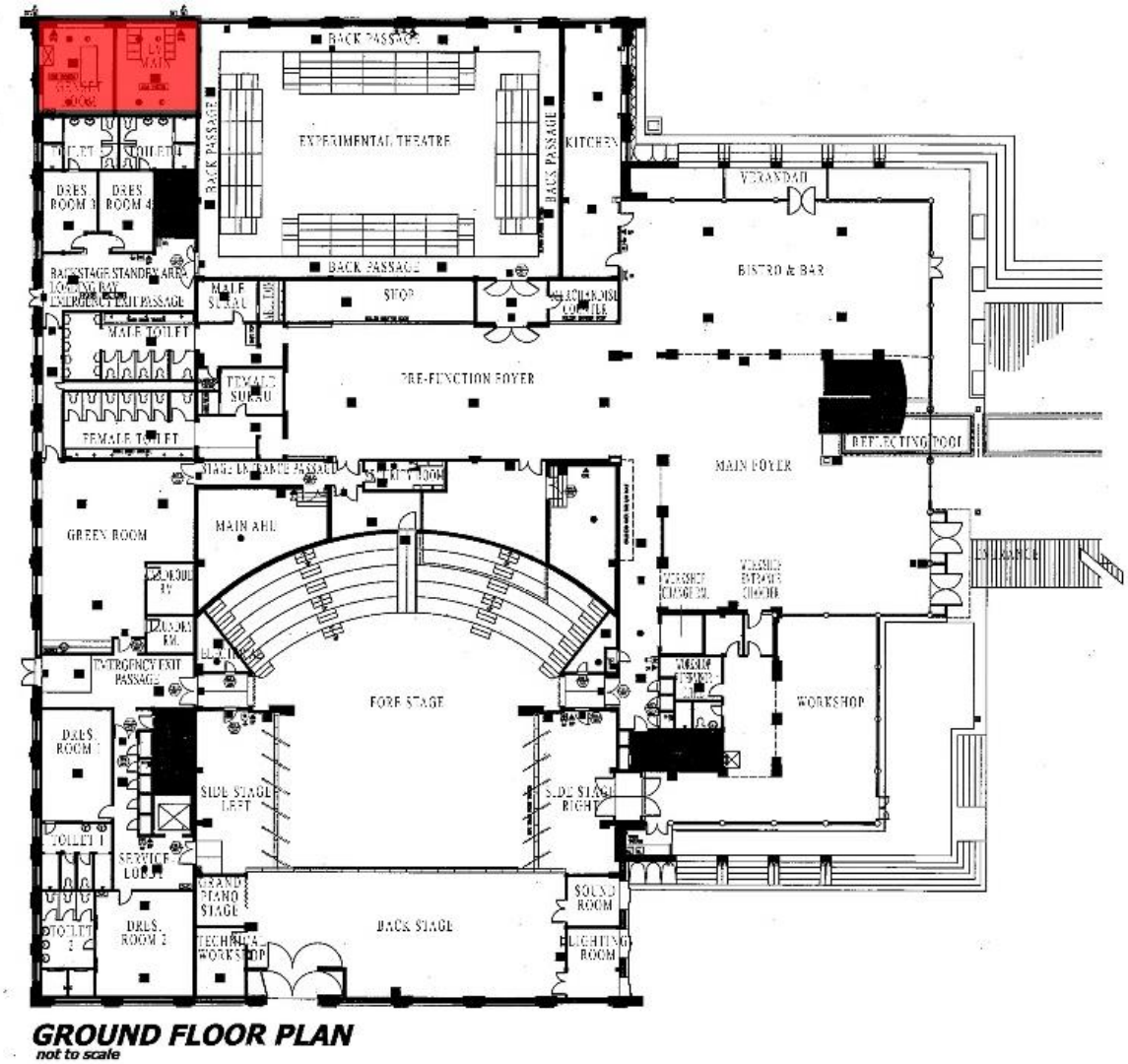


Figure 5.42: Diagram showing the location of the of CO_2 suppression system.

The CO_2 Fire suppression system is a type of system where carbon dioxide are stored in cylinders as a liquid under great pressure. CO_2 extinguishes fire primarily by lowering the level of oxygen that supports combustion in a protected area. Carbon dioxide is lethal to a person's health so occupants must evacuate swiftly in a limited amount of time or should be used in normally unoccupied hazard locations. The CO_2 fire extinguishing system can be controlled and activated by manual, mechanical trigger systems or by automatic fire detection systems. With the Carbon Dioxide (CO_2) suppression system, it will be triggered when heat or smoke detectors detects the presence of fire outbreaks and it will release a blanket of CO_2 gas to the room though high pressure storage cylinders. The gases are sent via pipes to ceiling and under floor distributors. After the fire emergency and the gas operation is over, two types of indicators will display at the CO_2 control panel to show the current room situation. Red means CO_2 gasses are still present whereas green means CO_2 gas level has dropped to a safe.

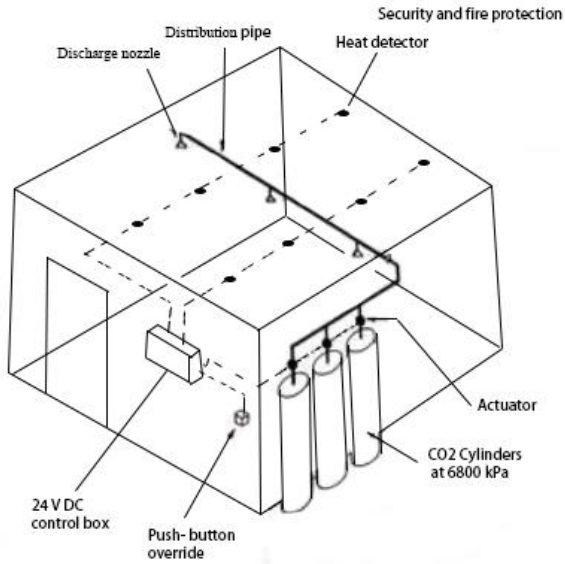


Figure 5.43: Installation of carbon dioxide

Source: (http://www.enggcyclopedia.com/)

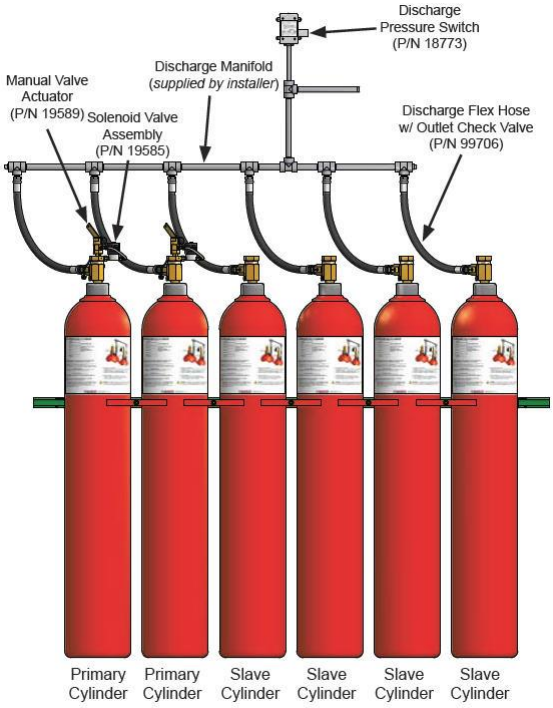


Figure 5.44: Typical Primary and Slave Cylinder Arrangement

Source: (http://www.janusfiresystems.com/)

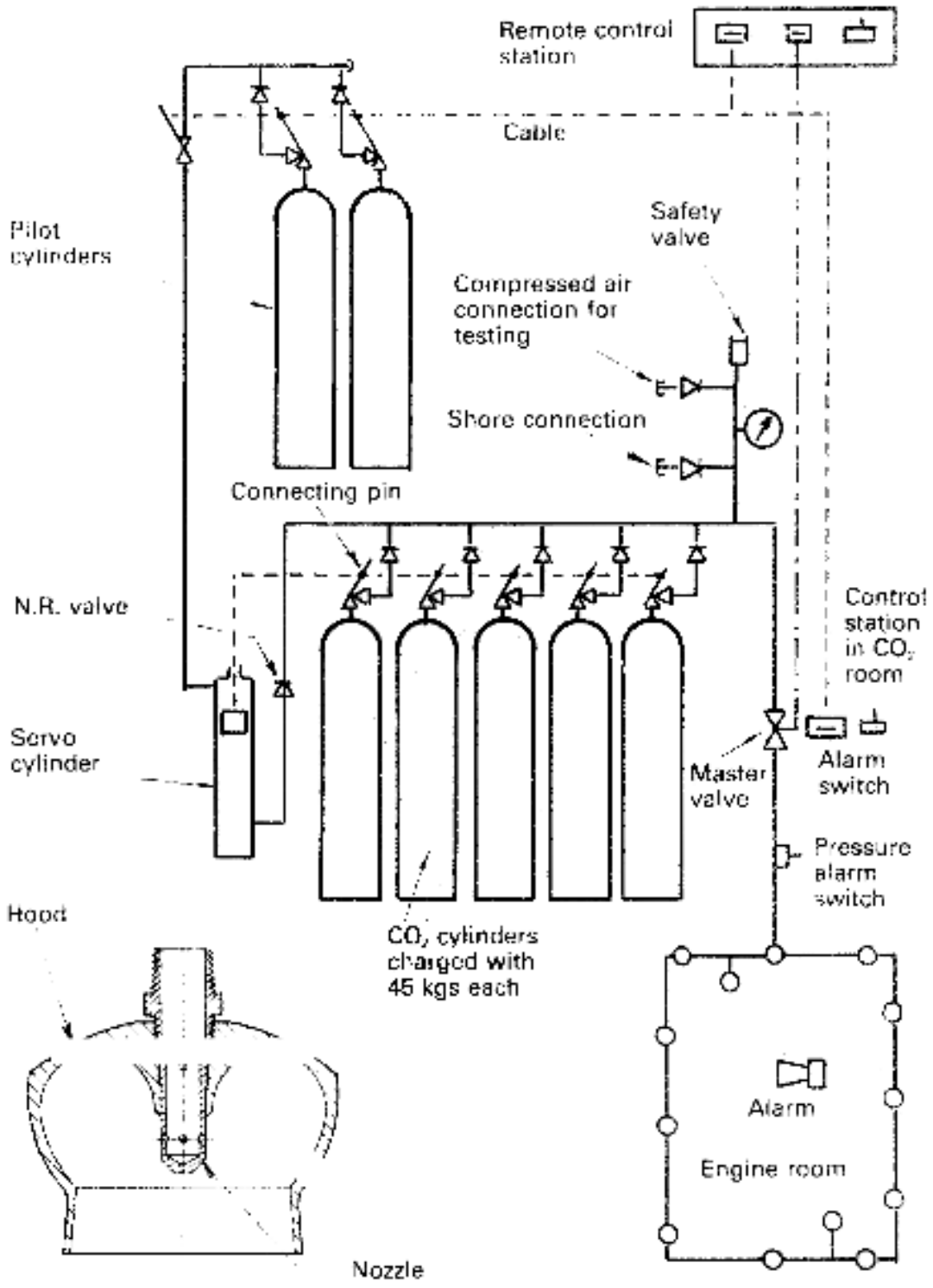


Figure 5.45: Schematic diagram of CO_2

Source: (http://www.machineryspaces.com/）

5.3.4.2 FIRE EXTINGUISHER

Figure 5.46: Fire extinguishers found along the emergency exit routes and along the doorways.

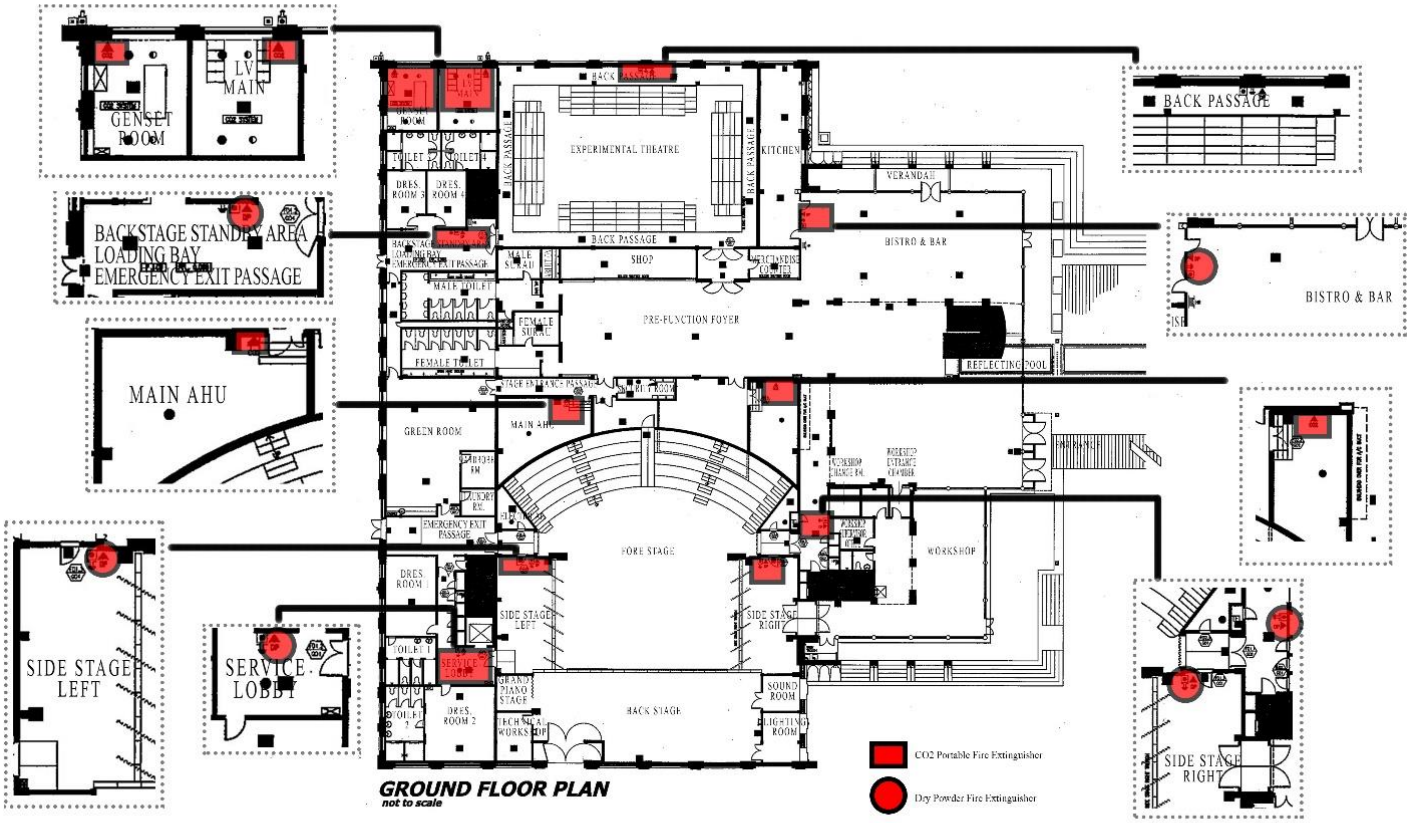


Figure 5.47: Diagram showing the locations of fire extinguishers at the ground floor, KLPAC.

Fire extinguisher, or extinguisher, is an active fire protection device manually used to extinguish and stub out small fires only. The number and location of fire extinguisher are determined by the hazard of the occupancy. Fired extinguisher can be divided into 5 major class, each of them are specifically function and respond to different type of fire situation. KL PAC uses monoammonium phosphate which is a dry chemical that is able to quickly put out the fire. It is a pale yellow powder that is able to put out all three classes of fire; Class A for trash, wood and paper, Class B for liquids and gases, and Class C for energized electrical sources.

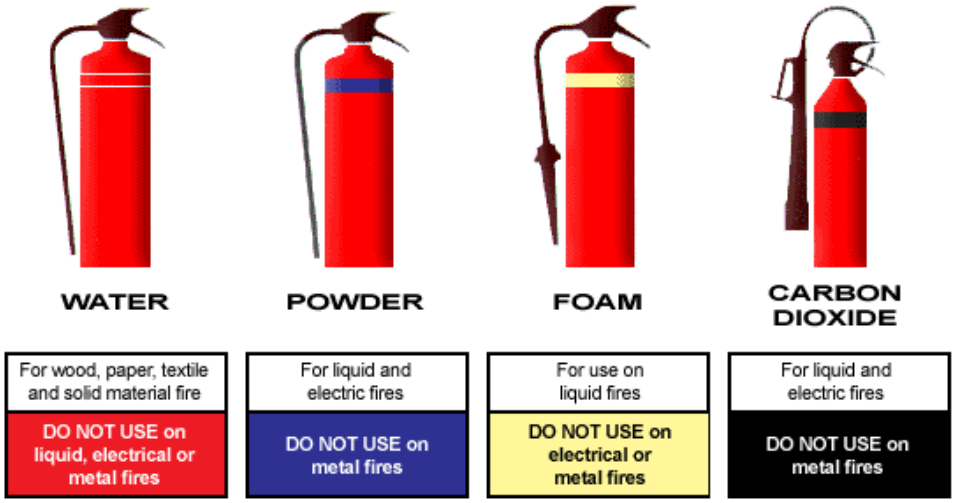


Figure 5.48: Types of fire extinguishers

Source: (http://www.firesafetyequipment.co.uk/)

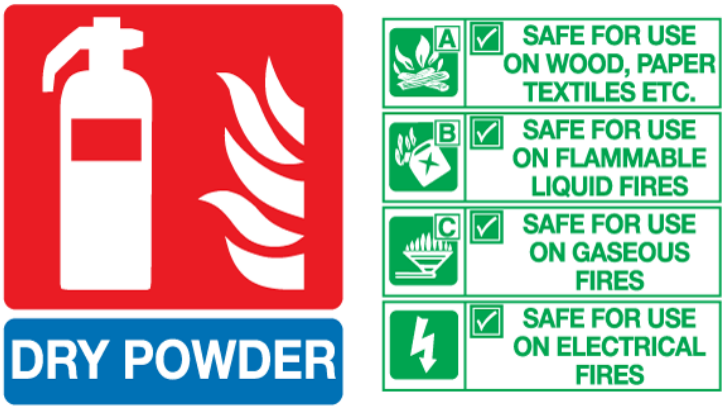


Figure 5.49: The characteristics of dry powder fire extinguisher

Source: (http://www.firesafetyequipment.co.uk/)

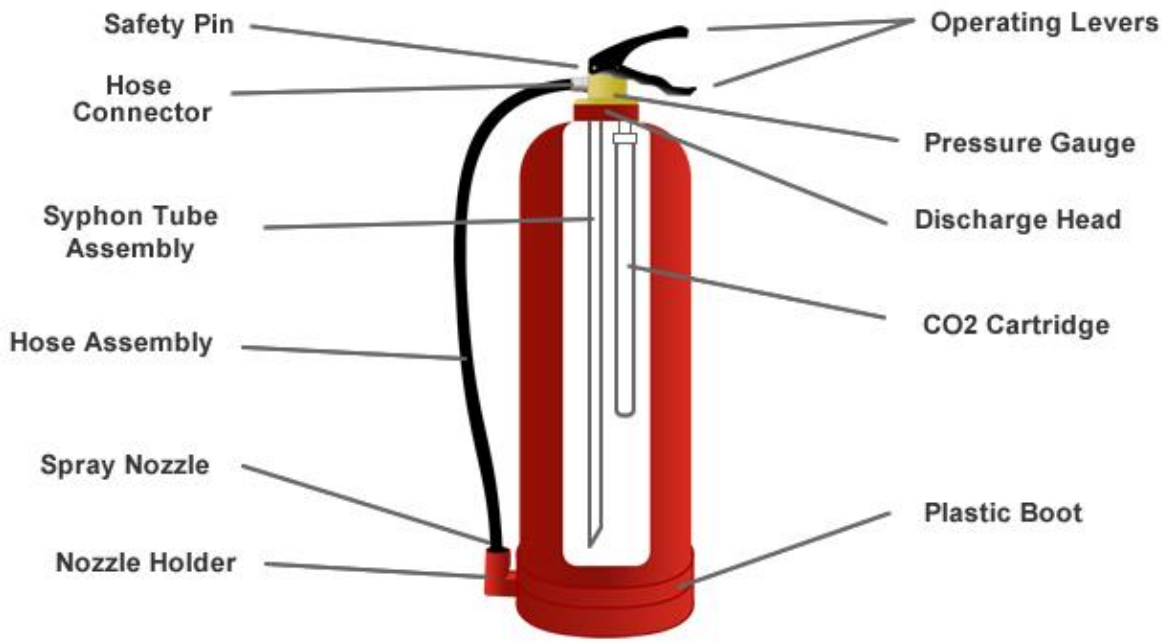


Figure 5.50: Diagram of dry powder fire extinguisher

Source: (http://www.firesafe.org.uk/)

Analysis:

According to UBBL- Section 227, KLPAC is reasonable to uses dry powder fire extinguishers to effectively extinguish the fire because it is a building that having much electrical appliances and material such as wood.

UBBL-Section 227

Portable extinguisher shall be provided in accordance with the relevant codes of practice and shall be sired in prominent positions on exit routes to be visible from all directions and similar extinguishers in a building shall be of the same method of operation.

5.3.4.3 SMOKE CURTAIN

Figure 5.51: Smoke curtain found in Gen Set Room

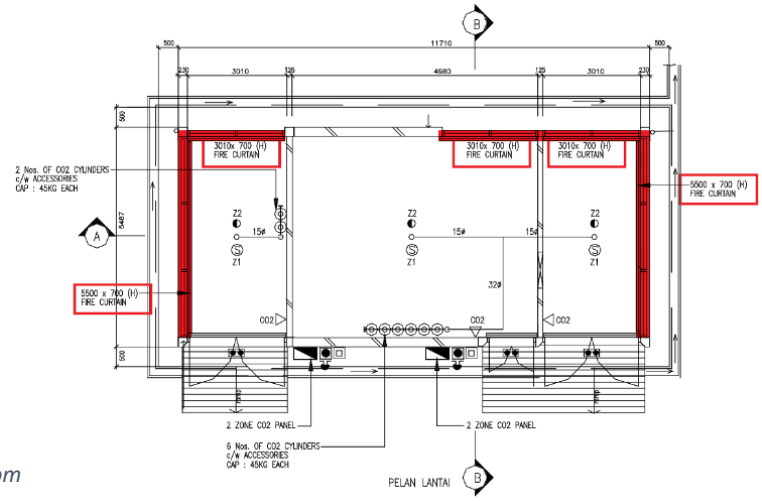
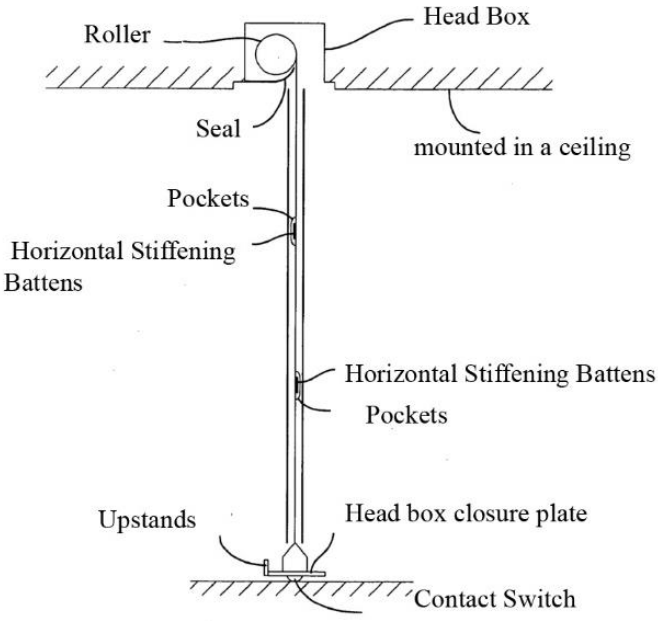


Figure 5.52: Diagram showing the locations of the smoke curtain wall in KLPAC.



UBBL- Section 161. (1)

Any fire stop required by the provision of this part shall be so formed and positioned as to prevent or retard the passage of flame.

Figure 5.53: Diagram of smoke curtain wall.

Source: (http://www.patentsencyclopedia.com/)

Smoke curtain is used in KLPAC as a part of smoke control system during the event of fire emergency. It is to control the flow of smoke as a channeling screen or a smoke reservoir screen. Besides, during the event of fire emergency, it also acts a fire separation between two open spaces typically a lift floor or an escape route in order to prevent the spread of fire from one space to the other.

5.4 Passive Fire Protection System

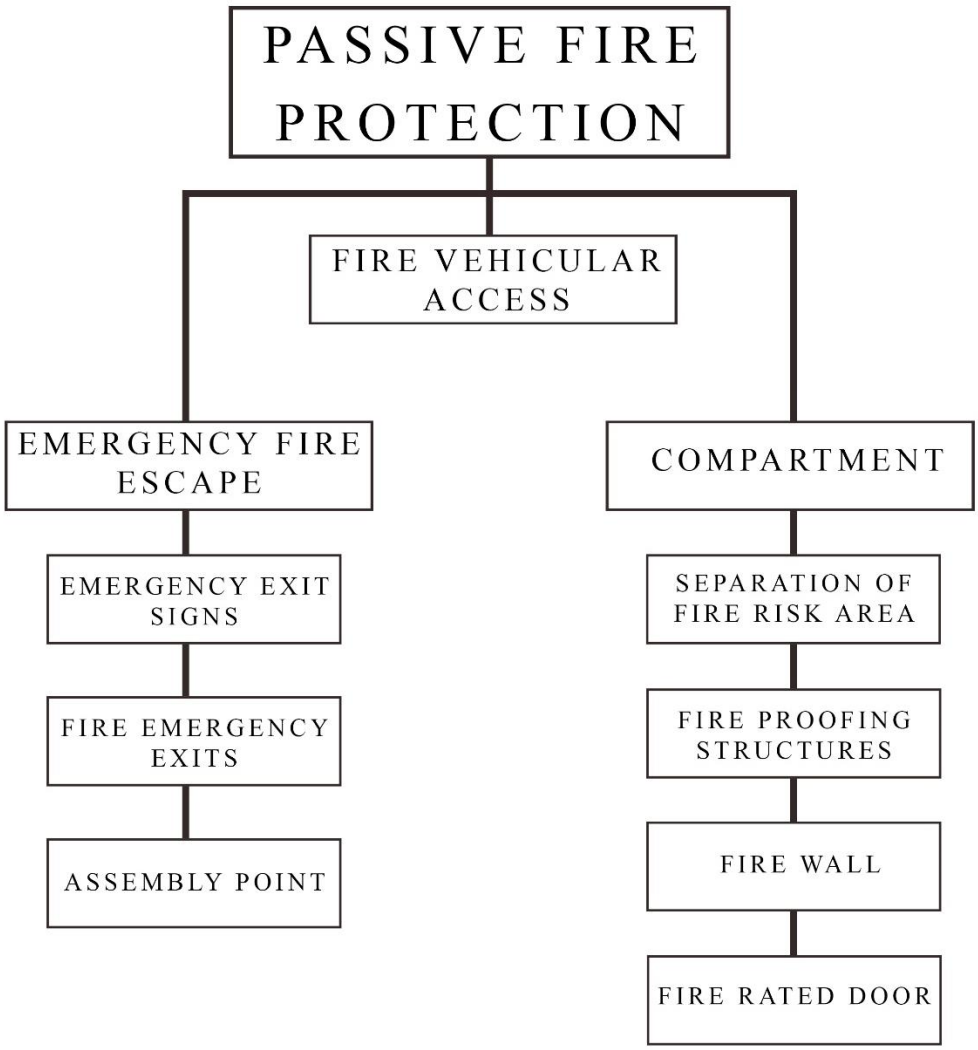


Figure 5.54: Diagram showing the Passive Fire Protection System used in KLPAC.

The diagram above shows the schematic diagram of the passive fire protection systems that have been applied in KLPAC. Passive fire protection system plays a very crucial role in preventing/ slowing down the rate of spread of fire and also protecting the occupants of the KLPAC in the event of fire emergency. We will be discussing about the emergency fire escape, fire vehicular access and also the fire compartment in detail regarding this passive fire protection system applied in KLPAC in this chapter.

5.4.1 Emergency Fire Escape

5.4.1.1 Emergency Exit Signs

Figure 5.55: Images of "KELUAR" signs taken at different locations in KLPAC.

The emergency exit signs are very crucial as they act as the exit indication for the occupants of KLPAC during fire evacuation. According to UBBL and Malaysian Standard that the fire escape doors must be indicated with neon green "EXIT" signs ("KELUAR" as in Bahasa Melayu) above it, accompanied with emergency lights installed. These emergency exit signs must be illuminated 24/7 to ensure their visibility in the darkness during the event of fire emergency. Even though the electrical supply will be cut off after the fire alarm bells haven been triggered, but the emergency exit signs are still able to provide some light to lead the occupants of the KLPAC to approach to a safety outdoor area of assembly point. These emergency exit signs can be found above all the exits, fire rated doors, fire staircases and doorways to ensure that the emergency exit indication for the occupants of KLPAC is clear enough.

UBBL 1984- Section 172

(1) Every exit sign shall have word "KELUAR" in a plainly legible not less than 15omm height with the principle strokes of the letters not less than 18mm wide.

(2) The exits and access to such exit shall be marked by readily visible signs and shall not be obscured by and decorations, furnishing or other equipment.

(3) The sign with the reading of "KELUAR" should indicating the direction shall be placed in every location where the direction of the travel to reach the nearest exit.

(4) All exit signs shall be illuminated continuously during period of occupancy

(5) The design and installation of every emergency exit sign shall be in compliance with MS983 and MS619.

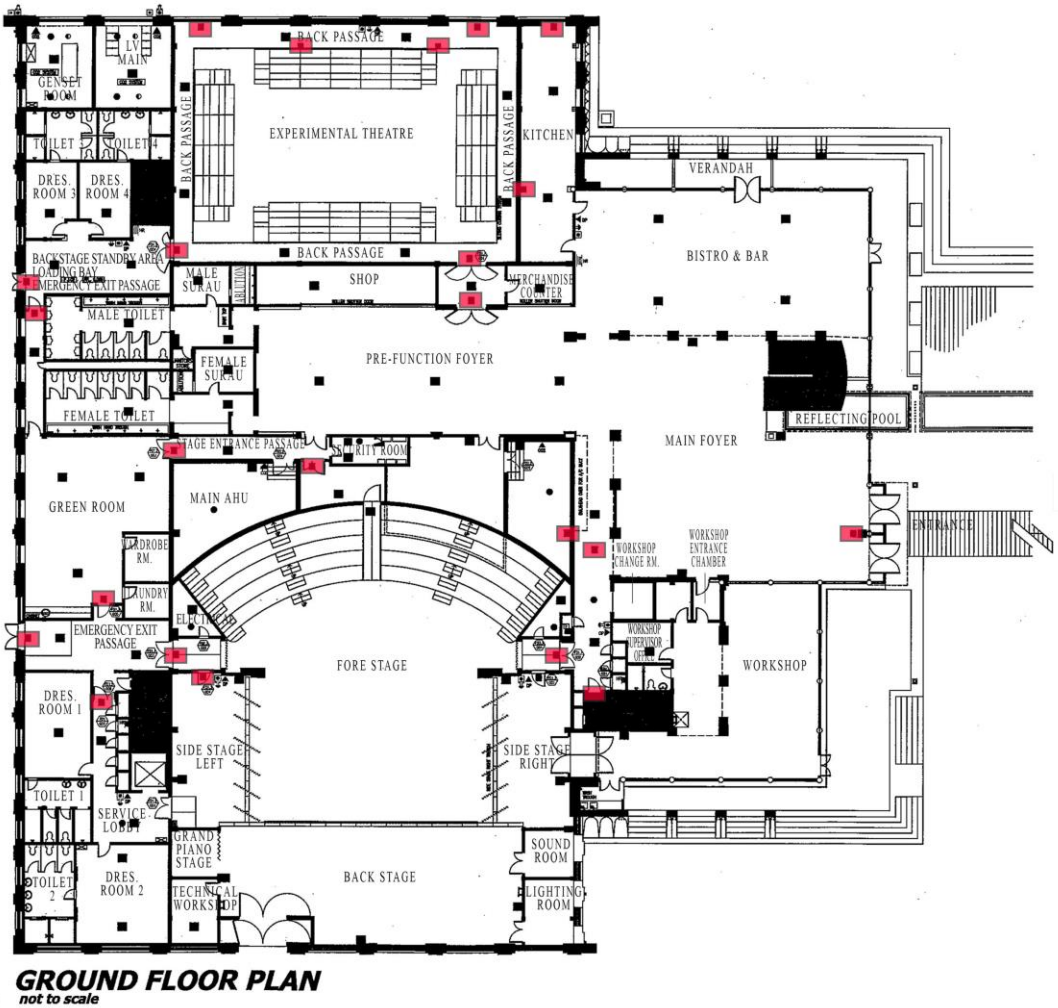


Figure 5.56: Diagram showing the locations of the emergency "KELUAR" signage at the ground floor.

5.4.1.2 Fire Emergency Exits

Figure 5.57: Fire emergency staircase located

Figure 5.58: Emergency route plan that are found at the ground floor.

After looking at the emergency exit signs, now we are going to discuss about the emergency exits that those emergency exit signs are leading to. These exit routes are very crucial and have to be arranged and designed carefully so that the occupants can escape safely to the open assembly point outside of the building during the event of fire emergency. The emergency route plan can be found along the doorways in KLPAC. From the emergency route plan (as shown in Figure 5.58), the occupants can be noticed about the nearest components such as the manual break glass, fire alarm bells and also the fire extinguishers that might help them during the event of the fire emergency.

UBBL- Section 165 (4)

The maximum travel distance to exits and dead end limits shall be as specified in the Seventh Schedule of these By-Laws.

UBBL- Section 169

No exit route may reduce in width along its pathway of travel from the story exit to the final exit.

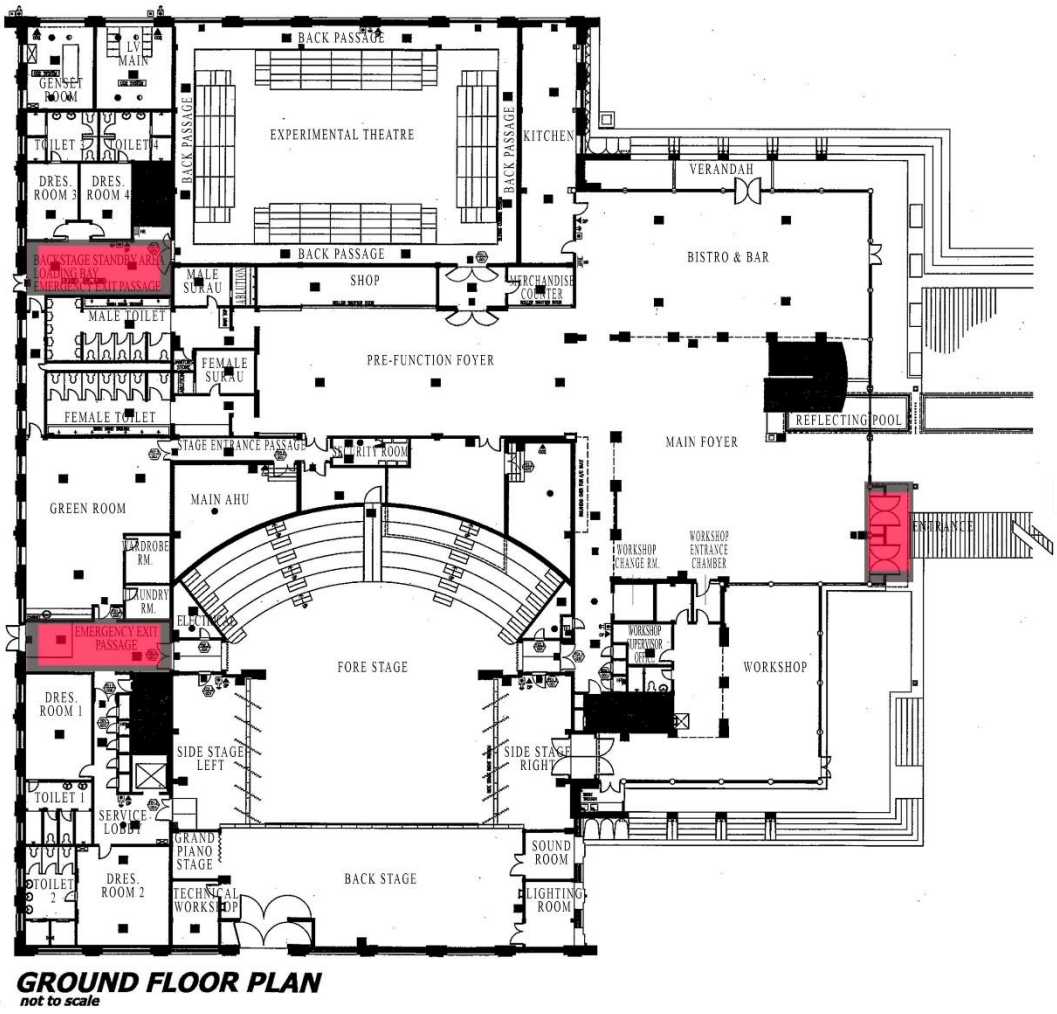


Figure 5.59: Diagram showing locations of all the fire emergency exits at the ground floor.

Figure 5.60: Fire emergency staircase located at the ground floor.

There are several fire emergency staircases (Figure 5.60) that can be found in KLPAC which are accessible for the occupants from the above floors that lead the escape route to the safe outdoor assembly point through the main entrance of KLPAC. Of all these emergency exit routes, they are kept clear all the times to prevent any obstructions during the event of fire emergency that might disturb the process of evacuation and cause some unnecessary injuries. Besides. These emergency exit routes are wide enough in accordance to the dimensions accessible for all the occupants of KLPAC including the disabled to escape smoothly.

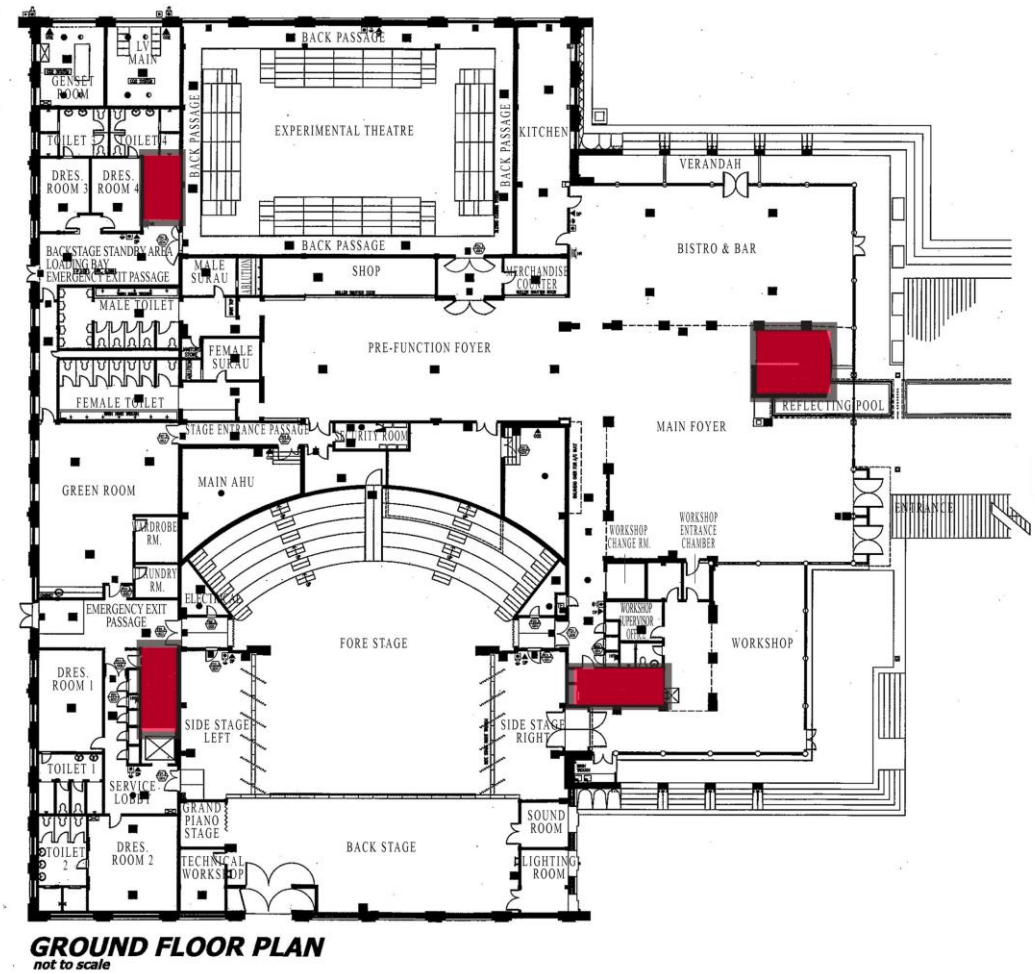


Figure 5.61: Diagram showing locations of all the fire emergency staircases at the ground floor.

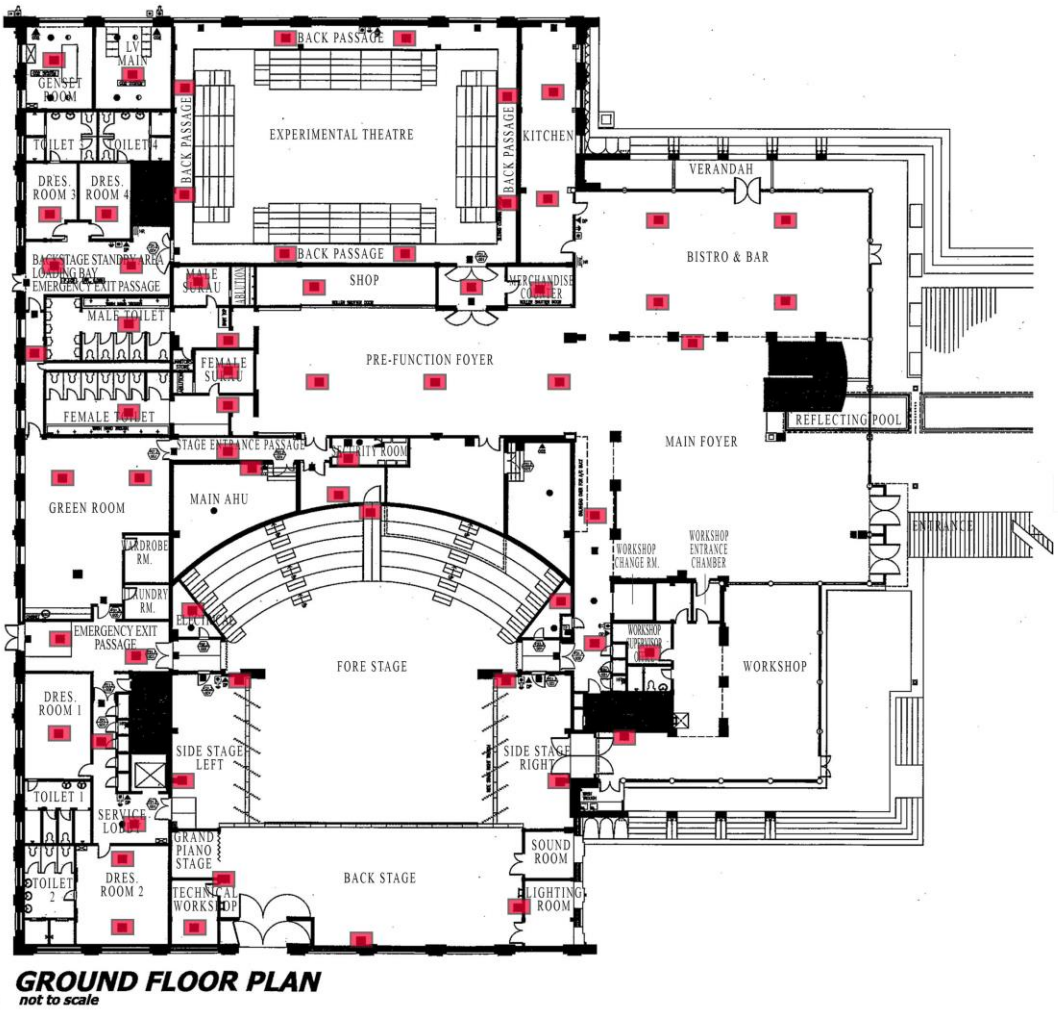


Figure 5.62: Diagram showing locations of all the fire emergency lights at the ground floor.

As we know, emergency lights are very crucial in the case of fire evacuation to ensure a certain degree of visibility for the occupants of the building. There are many emergency lights that can be found along the doorways, inside the rooms, inside the stage even along the foyer to provide lighting for visibility as well as a guidance to lead the occupants to the nearest emergency exit.

Analysis

As mentioned before, the emergency route plans are available along the doorways in KLPAC, but there is no clear indication of the escape route for the occupants to lead them to the safe outdoor assembly point within the shortest time. The indication of escape route is not clear enough that might lengthen and affect the evacuation of the occupants. Besides, there are some obstructions found under the emergency stairacse that might interrupt the evacuation of the occupants and the rescue activities of the fire bridage during the event of fire emergency.

5.4.1.3 Assembly Point

Figure 5.63: Image showing the assembly points of KLPAC during the event of emergency.

In passive fire protection system, all of the emergency escape routes must lead the occupants of the buildings to the safe open outdoor assembly point. In KLPAC, all of the assembly points are located outside the building to ensure the safety of the occupants. Besides, the fire extinguishment and rescue activities by the fire brigade can be carried out smoothly.

UBBL- Section 178

In buildings classified as institutional or places of assembly, exits to a street or large open space, together with staircases, corridors and passages leading to such exits shall be located, separated or protected as to avoid any undue danger to the occupants of the place of assembly from fire originating in the other occupancy or smoke therefrom.

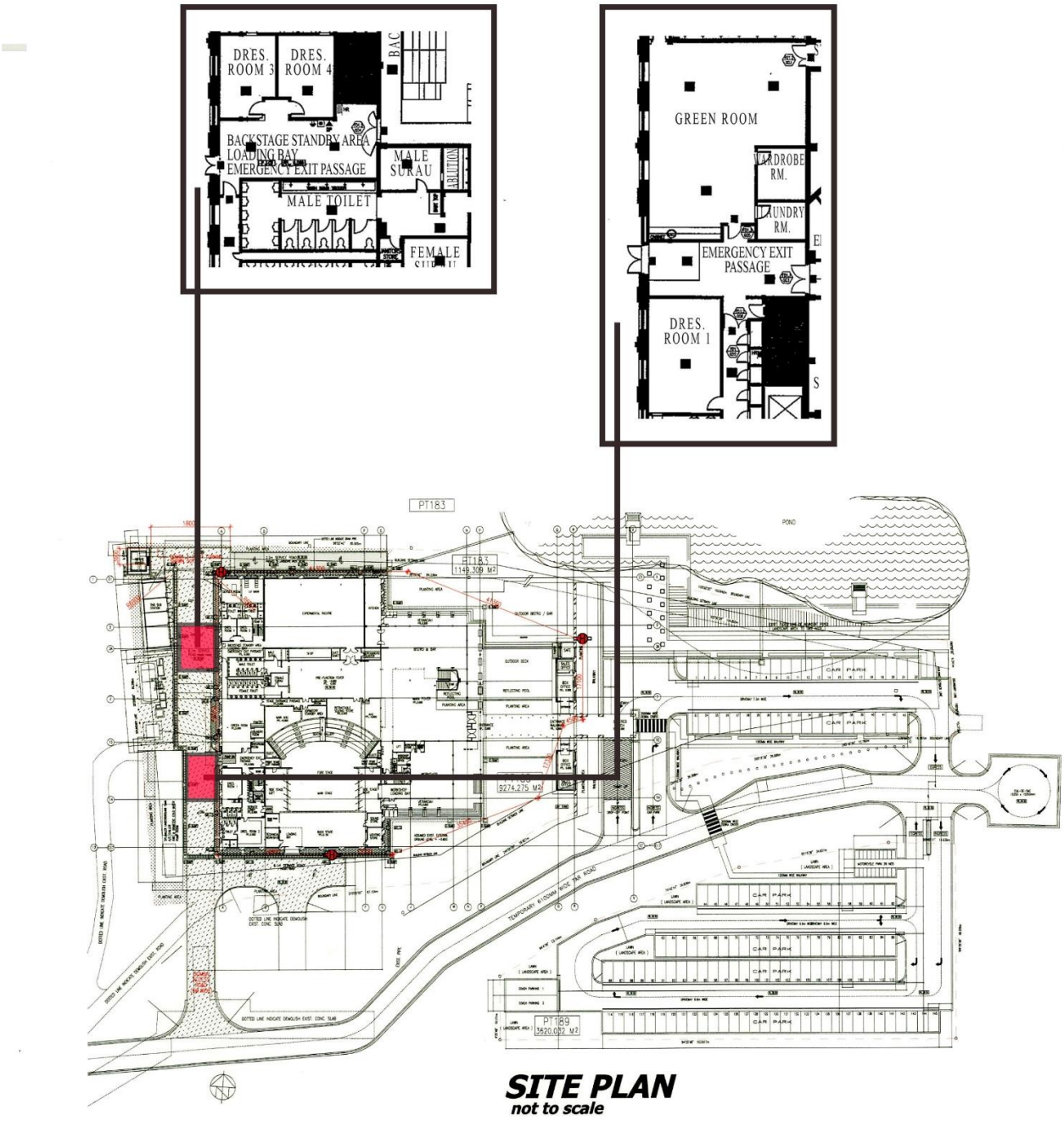


Figure 5.64: Diagram showing the locations of the assembly points that are led by the emergency exit passage at the ground floor.

Analysis

The assembly points are located near to the fire hydrans at the outside which might interrupt the fire-fighting activities as well as the access of the fire vehiculars because the occupants of the KLPAC will be assembled at the nearby location.

5.4.2 Fire Vehicular Access

Figure 5.65: The fire vehicular access outside the KLPAC.

Fire vehicle access around the building is very important as well in order for the fire trucks to get in place especially to the location nearby the fire hydrant for fire-fighting and rescue activities without any obstructions. The access must be wide enough and clear from any blockages to enable high reach appliances, such as the turntable ladders and hydraulic platforms, to be used and also to enable the pumping appliances to supply water and equipment for fire-fighting.

UBBL- Section 225 (2)

Every building shall be served by at least one fire hydrant located not more than 91.5 meters from the nearest point of fire brigade access.

UBBL- Section 247 (2)

Main water storage tanks within the building, other than for hose reel systems, shall be located at ground, first or second basement levels, with fire brigade pumping inlet connections accessible to the fire appliances.

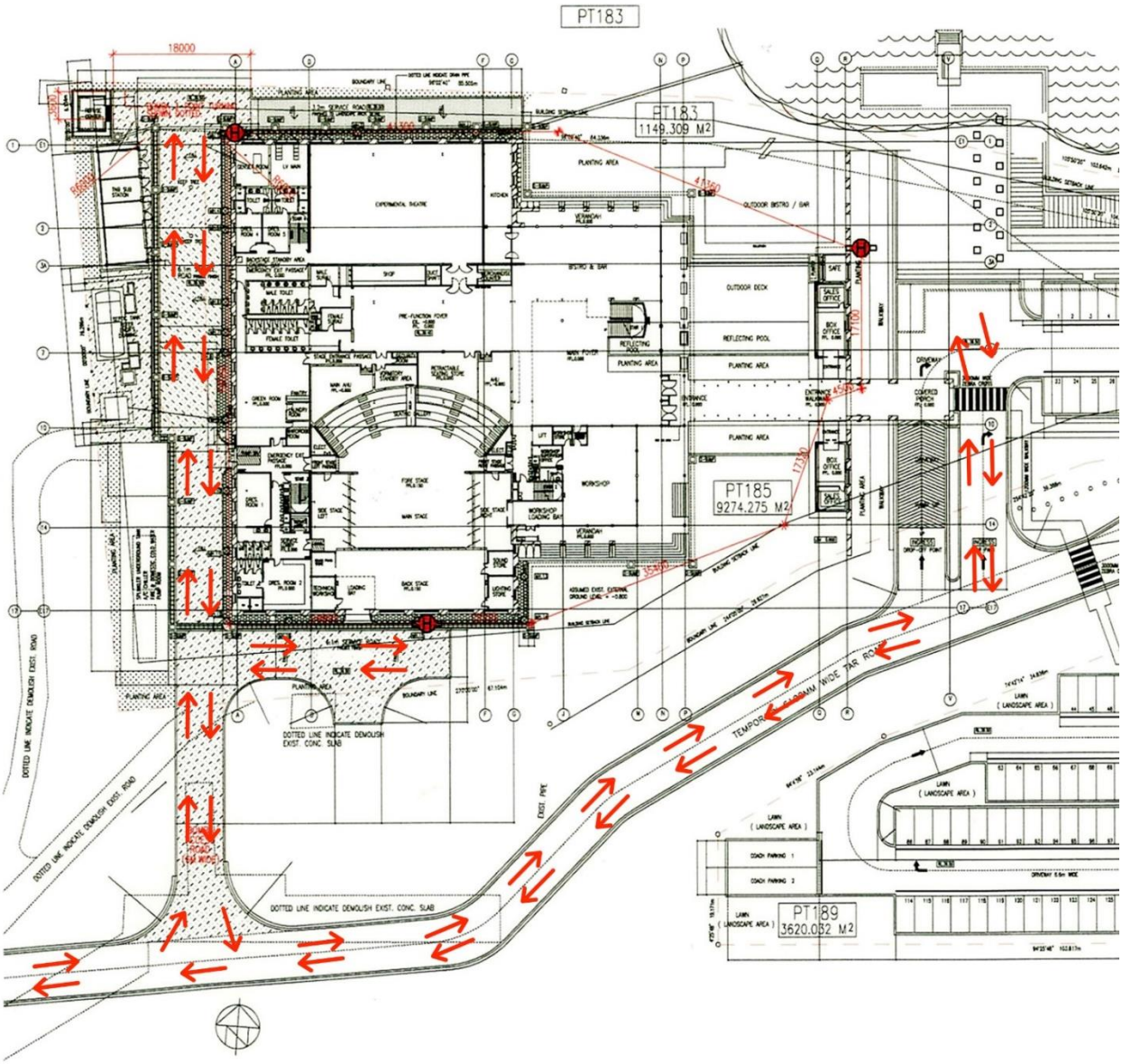


Figure 5.66: Diagram showing the access route for the fire vehicular in KLPAC.

Analysis

In KLPAC, there ae 2 entrances for the fire vehicular access with 3 points of fire hydrant. The access is nicely planned as it is located nearby the fire hydrants so that the fire bridage can work more efficiently in the case of fire emergency. But the fire vehicular access is not wide enough in the case that more fire-trucks are required to enter to the site and also it has to be cleared so that the fire vehicular can enter the site without any obstructions.

5.4.3 FIRE COMPARTMENT

5.4.3.1 SEPERATION OF FIRE RISK AREA

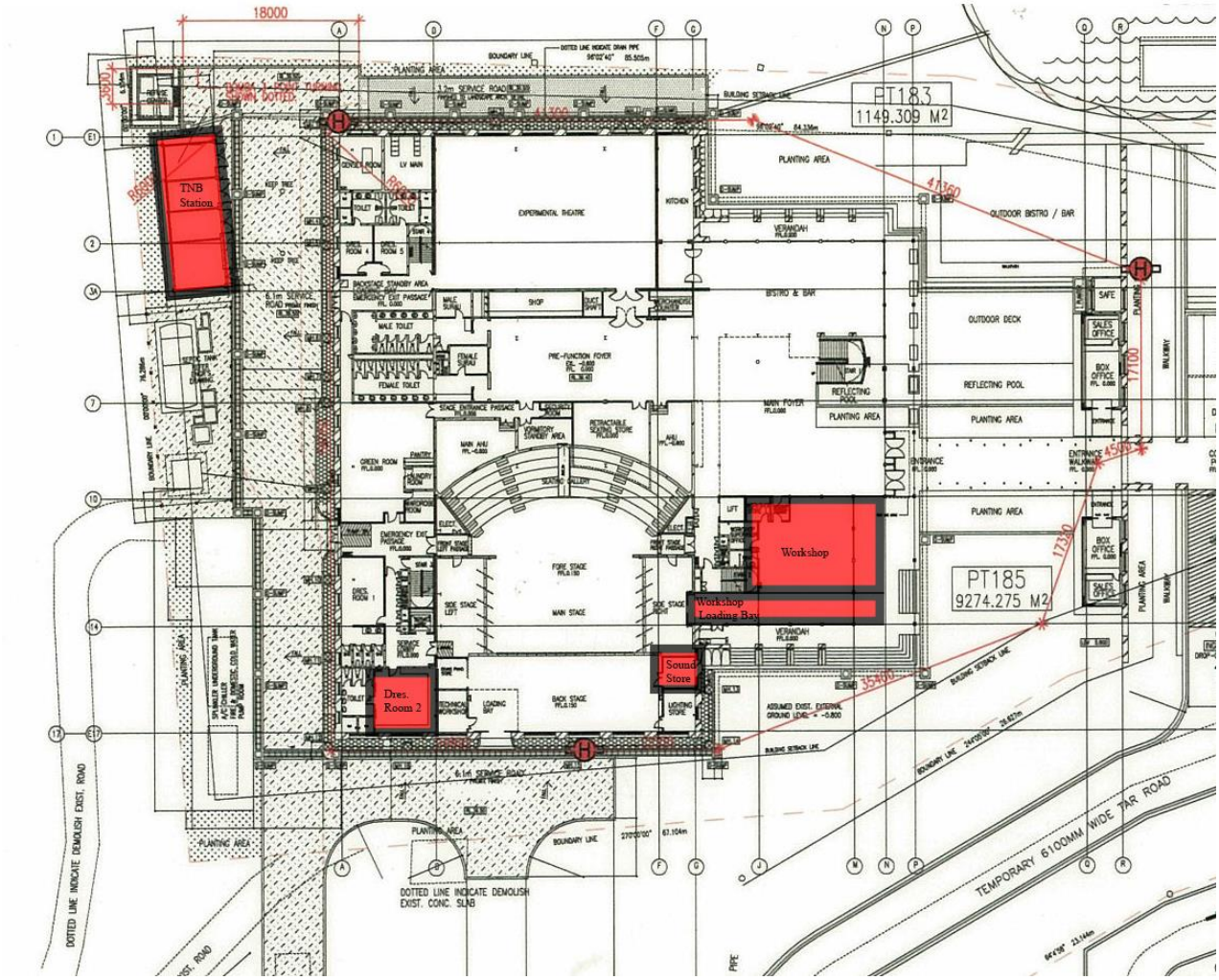


Figure 5.67: Diagram showing the separation of the fire risk area in KLPAC.

Separation of fire risk area is where a corridor forms part of a means of escape in one direction only (dead-end situation) it must be separated from all adjoining areas – except toilets – by fire- resisting construction. Areas of high fire risk (e.g. plant rooms, storage areas for flammables/ highly flammables) must be separated from adjoin areas, especially corridors forming means of escape, by fire- resting construction.

Analysis:

In KLPAC, they have separated the potential fire risk areas from the other areas where are more occupants. In case of any emergency, the TNB station of KLPAC is located outside the building and the workshops is located at the corner where is easy accessible.

UBBL- Section 139

The following area uses shall be separated from the other areas of the occupancy in which they are located by fire resisting construction of elements of structure of a FRP to be determined by local authority based on the degree of hazed:

- Boiler rooms and associated duels storage area
- Laundries
- Repairs shops involving hazardous processes and materials
- Storage are of materials in quantities deemed hazardous
- Liquefied petroleum gas storage areas
- Linen rooms
- Linen rooms
- Flammable liquid stores

5.4.4 FIRE PROOFING STRUCTURES

5.4.4.1 FIRE WALL

Figure 5.68: Firewall at KLPAC office

Fire wall is a lightweight; non-loadbearing walls capable of providing up to 240 minutes' fire resistance. They are an assembly of materials that not only act as a wall to separate the spaces but also separate those high fire risk areas such as transformer room, electrical room and mechanical room. This firewalls were designed to act as a barrier between spaces and prevent the spread of fire in a period of time and give more time for occupants to escape from the building. It buys sufficient times for the occupant and the users to escape.

UBBL- Section 138(C)

Any wall or floor separating part of a building form any other part of the same building, which is used or intended to be used mainly for a purpose failing within a different purpose group as, set out in the Fifth Schedule to these by laws.

UBBL- Section 148(6)

Any compartment walls or compartment floor which is required by these By-Laws to have FRP of one hour or more shall be constructed wholly of non-combustible materials and, apart from any ceiling, the required FRP of wall or floor shall be obtained without assistance form any non-combustible materials.

5.4.4.2 BEAM FIREPROOFING

Figure 5.69: Fire proofing layer on beam.

In KLPAC, the ceiling this fire proofing layer is the most unique way of fire proofing and it is seldom used in Malaysia. This black fireproofing layer is called the dry VERMIPLASTER. This rough layer of dry VERMIPLASTER is a unique lightweight and cost effective mortar based fire protection system providing up to 2 hours' fire protection to structural steel. Its purpose is to keep the stability and bearing capacity of the structural steel till the extinction of the fire or the evacuation of the building. It is a good solution for avoiding the collapse of the building for the prescribed length of time.

Analysis:

As stated in the UBBL, all the beam, column, structure carrying and external walls are required to be constructed of non- combustible materials. Therefore, KLPAC are effectively apply the dry-VERMIPLASTER to cover the beam.

UBBL-Section 143

Any beam or column forming part of, and any structure carrying, and external wall which is required to be constructed of non-combustible materials shall comply with the provisions of paragraph (3) of by-law 142 as to non-combustibility.

5.4.5 Fire Rated Door

Figure 5.70: Fire rated door located at the ground floor.

Figure 5.71: Description about the fire rated door in KLPAC.

Fire rated doors which are thicker than normal door is used for the emergency exits or staircases are essential to keep the occupants of the KLPAC safe during the fire evacuation. The fire rated doors act as a barrier to stop the spreading of fire from the outside of the emergency staircase. These fire rated doors are to be closed 24/7 and also self-closing so that the occupants of KLPAC are safe to utilize the emergency staircases and also to minimize the property damage during the event of fire emergency. KLPAC are using both 1 hour and 2 hours door and frame ratting which are used mainly in the enclosures of vertical communication or egress in different spaces of KLPAC especially the emergency staircases. It means that the fire rated doors can withstand the fire for 1 hour for 1 hour fire rated rood or 2 hours for 2 hours fire rated door during the event of fire.

UBBL- Section 162 (1)

Fire doors of the appropriate FRP shall be provided.

UBBL- Section 162 (2)

Openings in compartment walls and separating walls shall be protected by a fire for having a FRP in accordance with the requirements for that wall specified in the Ninth Schedule to these By-Laws.

UBBL- Section 164 (1)

All fire doors shall be fitted with automatic door closers of the hydraulically spring operated type in the case of swing doors and of wire rope and weight type in the case of sliding door.

UBBL- Section 173 (1)

All exit doors shall be openable from the inside without the use of a key or any special knowledge or effort.

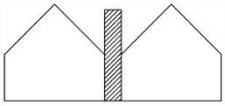
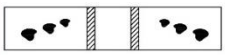
OPENING	WALL RATING	DOOR AND FRAME RATTING	DESCRIPTION AND USE
	4 Hours	3 Hours (180 minutes)	These openings are in walls that separate buildings or divide a single building into designated fire areas.
	2 Hours	1-1/2 Hours (90 minutes)	Openings of this type are used in enclosures of vertical communication or egress through buildings, eg: stairwells and elevator shafts.
	1 Hour	1 Hour (60 minutes)	These door and frame assemblies divide occupancies in a building.
	1 Hour	3/4 Hour (45 minutes)	For use where there are openings in corridors or room partitions.
	2 Hours	1-1/2 Hours (90 minutes)	This opening is in a wall where there is the potential for severe fire exposure from the exterior of the building.
	1 Hour	3/4 Hour (45 minutes)	This opening is in an exterior wall that has the potential to be exposed to moderate to light fire from the exterior of the building.
	1 Hour	1/3 Hours (20 minutes)	These openings are in corridors where smoke and draft control is required. The minimum wall rating is 1 hour.

Figure 5.72: Diagram showing information about fire rated doors.

Source: https://www.steeldoor.org/res/Fire%20Rated%20Doors%20and%20Frames%20Overview.pdf

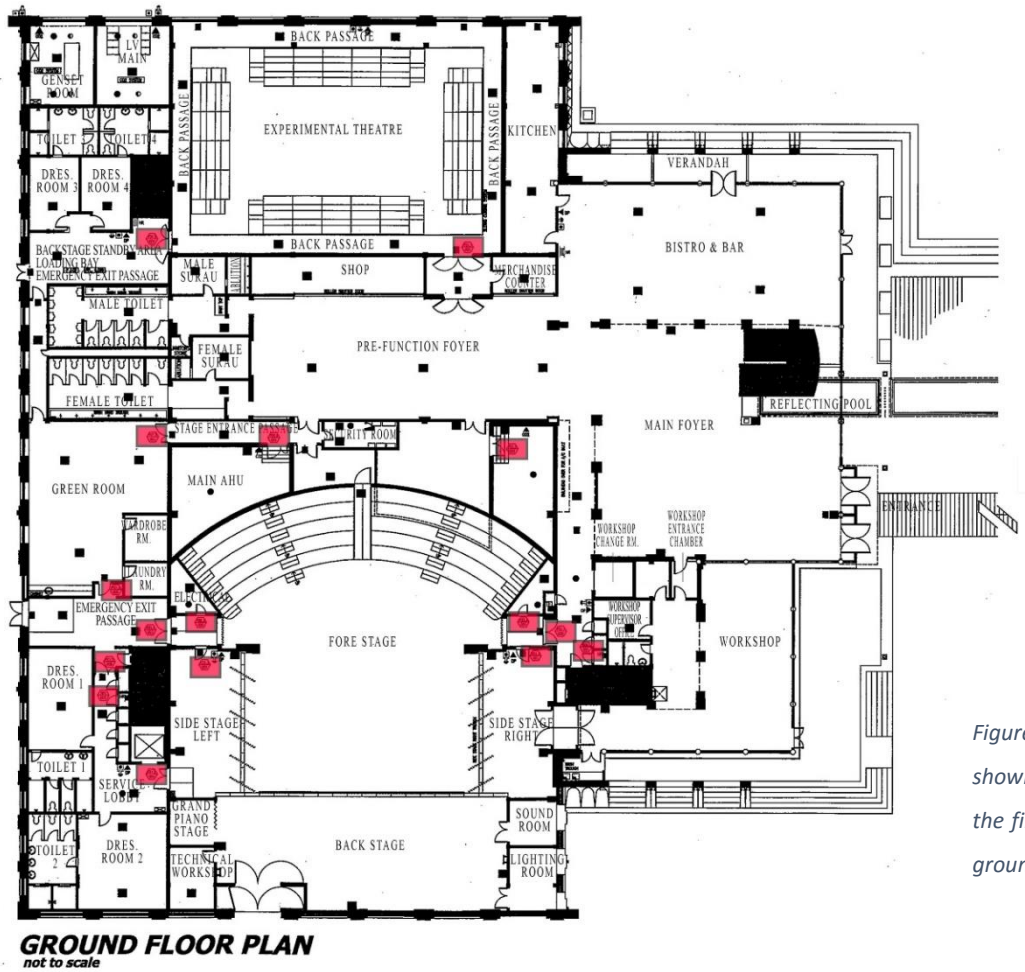


Figure 5.73: Diagram showing locations of all the fire rated doors at the ground floor.

5.5 Conclusion

In conclusion, the overall fire protection system in KLPAC has a proper appliance in used for different function of the spaces to extinguish the fire effectively and to ensure the safety of the occupants. Through our observation and investigation, we can say that the KLPAC has had a proper and efficient fire protection system installed and applied. KLPAC obeys the UBBL required in some instances that most of the strict details required by the UBBL are achieved for example the application of the fire alarm system including the fire control panel, detectors, manual call points, fire alarm bells and the others. Through our observation, there are sprinklers installed along the ceiling throughout KLPAC. Means they are actually well prepared during this early stage of fire protection system, so it is very effective in putting out fire before it grows into a large fire. All of the requirements are achieved except for some little details that have been neglected and might cause unnecessary injuries during the evacuation. For example, the obstructions found under the emergency staircases and also along the emergency exit passage. This could be very dangerous for the occupants of KLPAC during the evacuation as the obstructions might be blocking their ways and causing unnecessary incidents. Besides, some of the smoke detectors installed have been blocked by other structures that will result in cutting down the efficiency of the detectors. In addition, others fire protection system are also applied correctly based on this designation of purpose group. In this building with so many electrical appliances and different materials, KLPAC has been preparing the proper type of fire extinguishers which is dry powder fire extinguishers in order to extinguish the fire effectively. In general, the fire protection systems for both the active and the passive one are adequate and efficient enough to protect the occupants of KLPAC during the event of fire emergency.

6.0 Mechanical Transportation System

6.1 Introduction

The mechanical transportation of people and goods is an energy-using service which needs the designer's attention in building design. Standards of service rise with expectations of quality by the final user and with the provision of access for disabled people. The principles of mechanical transportation systems is to assist movement in and between buildings. Integrated with other services, fire protection, means of escape and correct maintenance of the system are very important. The mechanical transportation of people and equipment around and between buildings is of considerable importance in relation to the degree of satisfactory service provided. Cost-effective and energy-efficient transportation will always be required.

6.2 Literature Review

Mechanical transportation can be divided into two: vertical transportation and horizontal transportation. Elevator, escalator, and paternoster are considered as vertical transportation system while moving walkway is horizontal transportation system.

Elevators can be divided into 3 distinct types: hydraulic, geared or gearless traction and machine-room-less traction. All of these elevators has their own advantages and disadvantages.

Hydraulic Elevator

Figure 6.1 Hydraulic Elevator (Source: Angel elevators, 2012)

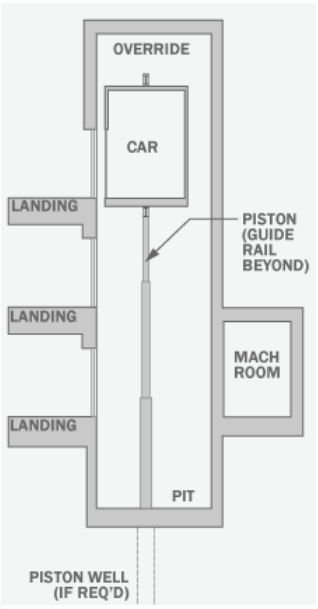


Figure 6.2 Hydraulic Elevator Diagram (Source: Archtoolbox)

This type of elevator is quite common for low level buildings with two to five floors. Hydraulic elevators have a low initial cost and their ongoing maintenance costs are lower compared to the other elevator types. However, hydraulic elevators use more energy than other types of elevators because the electric motor works against gravity as it forces hydraulic fluid into the piston. A major drawback of hydraulic elevators is that the hydraulic fluid can sometimes leak, which can cause a serious environmental hazard.

Geared and Gearless Traction Elevator with Machine Room

Figure 6.3 Traction Elevator (Source: Mewar Elevators, 2015)

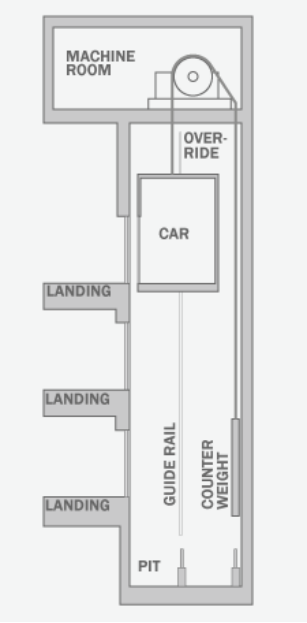


Figure 6.4 Traction Elevator with Machine Room Diagram (Source: Archtoolbox)

Traction elevators are lifted by ropes, which pass over a wheel attached to an electric motor above the elevator shaft. It is important that traction elevator ropes and sheaves are checked for wear on a regular basis. As they wear, the traction between the sheave and the cables is reduced and slippage becomes more regular, which reduces the efficiency and can become dangerous if left unchecked.

Traction elevators have height restrictions that are governed by the length and weight of the cables or ropes. New materials that are stronger and lighter, such as carbon fiber, will allow traction elevators to achieve new heights.

Machine-Room-Less Elevators

Figure 6.5 ***Machine-Room-Less Elevators*** *(Source: TUCH, 2015)*

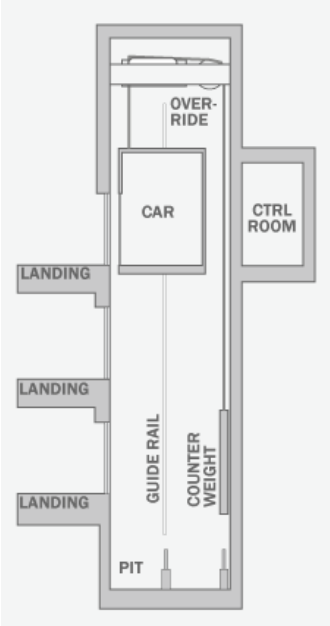


Figure 6.6 Machine-Room-Less Elevator Diagram (Source: Archtoolbox)

Machine-Room-Less Elevators are traction elevators that do not have a dedicated machine room above the elevator shaft. The machine sits in the override space and is accessed from the top of the elevator cab when maintenance or repairs are required. The control boxes are located in a control room that is adjacent to the elevator shaft on the highest landing and within around 150 feet of the machine.

MRL elevators are comparable to geared traction elevators in terms of initial and maintenance costs, but they have relatively low energy consumption compared to geared elevators. They are becoming the most popular choice for mid-rise buildings where the travel distance is up to 250 feet. They are energy efficient, require less space, and their operation and reliability are on par with gear-less traction elevators.

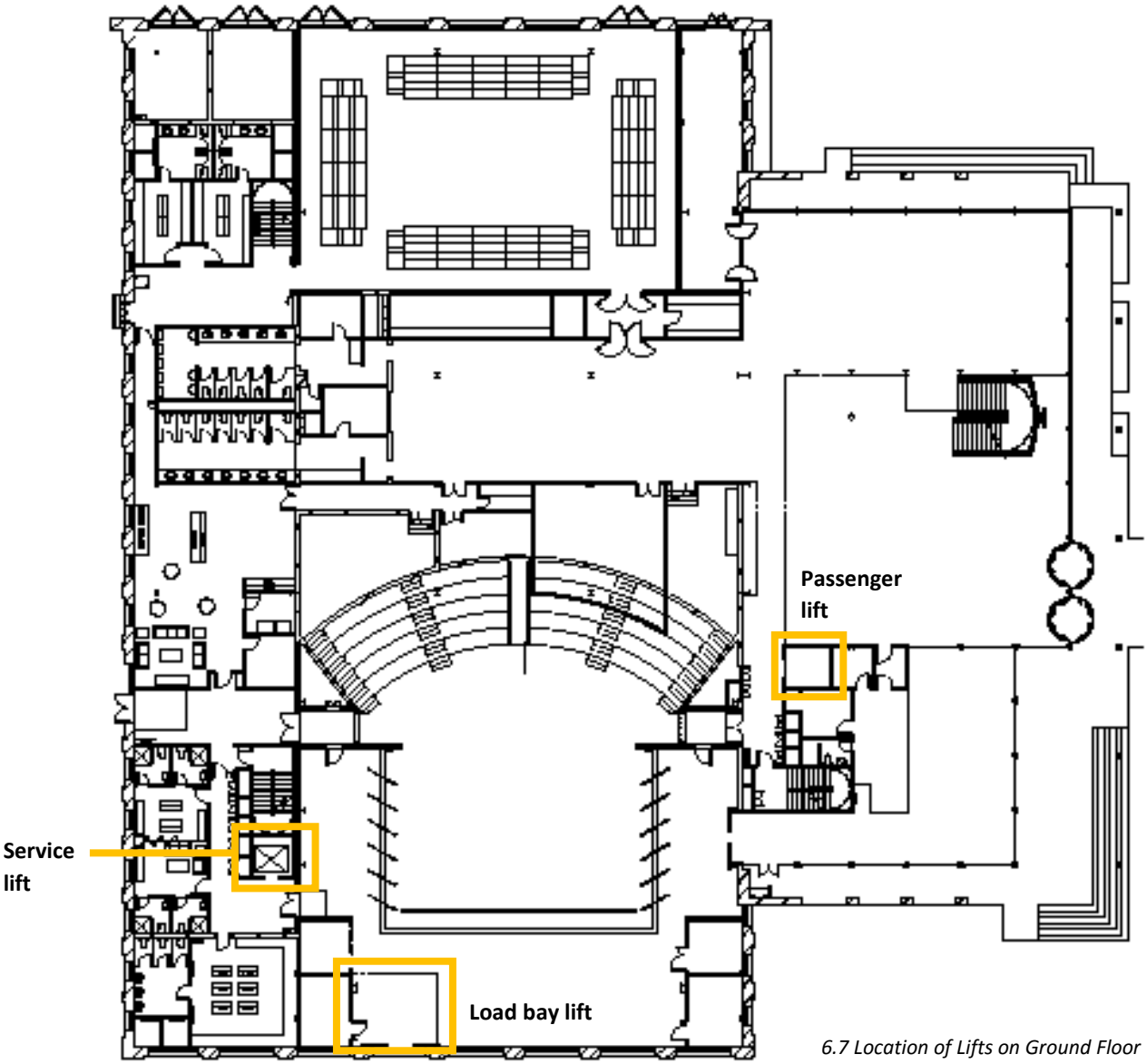
Elevator Type	Application	Building Height	Typical Speeds	Duty	Life Cycle of Driving Machine	Life Cycle of Controller	Advantages	Disadvantages
Hydraulic	Passenger, Service, Freight	Low rise, 2-5 floors	100-150 fpm	Light use	20 years	20 years	Low cost Minimum installation time No loads on building structure	Slow speed Slow acceleration and deceleration rates "In-ground" units require drilling of well hole
Geared Traction	Freight	Low to mid rise, 5-15 floors	100-350 fpm	Moderate to heavy use	30-35 years	20 years	Moderate cost Suitable for heavy freight use	Vibration may be noticeable at higher speeds Imposes all equipment loads on building structure Higher cost to maintain
Compact Gearless Traction (MRLs)	Passenger, Service	Low to mid rise, 4-20 floors	200-500 fpm	Moderate use	15-20 years	15 years	Moderate cost Longer life cycle Higher speeds Improved ride quality No loads on building structure at 200—350 fpm Energy efficient	May require greater pit depth depending on manufacturer Imposes all equipment loads on building structure at 500 fpm only
Gearless Traction	Passenger, Service, Freight	High rise, 12-100+ floors	500-1,800 fpm	Heavy use	50+ years	10-12 years	Longest life cycle Fast speeds Optimum ride quality Maximum performance	Highest installation cost Imposes all equipment loads on building structure Highest cost to maintain

Table 6.1 Type of Elevator (Source: APPA)

According to UBBL, building that exceeds 4 levels should implement vertical transportation system into the building circulation. The only mechanical transportation system that can be found in KLPAC is elevator. This research paper focuses on analysis of transportation system found in KLPAC with reference from UBBL Mechanical Transportation System Requirement. There are 3 types of elevator in KLPAC, which are passenger lift, service lift and loading bay lift.

6.3 Case Study

6.3.1 Drawing



6.7 Location of Lifts on Ground Floor

UBBL 1984

124 – For all non-residential buildings exceeding 4 storeys above or below the main access level at least one elevator shaft be provided.

152 (1) - Every opening in an elevator shaft or elevator entrance shall open into a protected lobby unless other suitable means of protection to the opening to the satisfaction of the local authority is provided. These requirements shall not apply to open type industrial and other special building as may be approved by D.G.F.S.

Figure 6.8 Lift in KLPAC

Type: Passenger Elevator
Model: Sgt 8-CO60-3
Capacity: 545KG/8 Persons
Speed: 60 MPM
Car Door: Two Panel Center Opening

Analysis:

All the stairs are situated closely to the elevators for emergency purposes. The location of the elevators has fulfilled the minimum standard of service which has maximum walking distance of 45m to the elevator lobby. There is only one bomba lift in KLPAC which is the passenger lift.

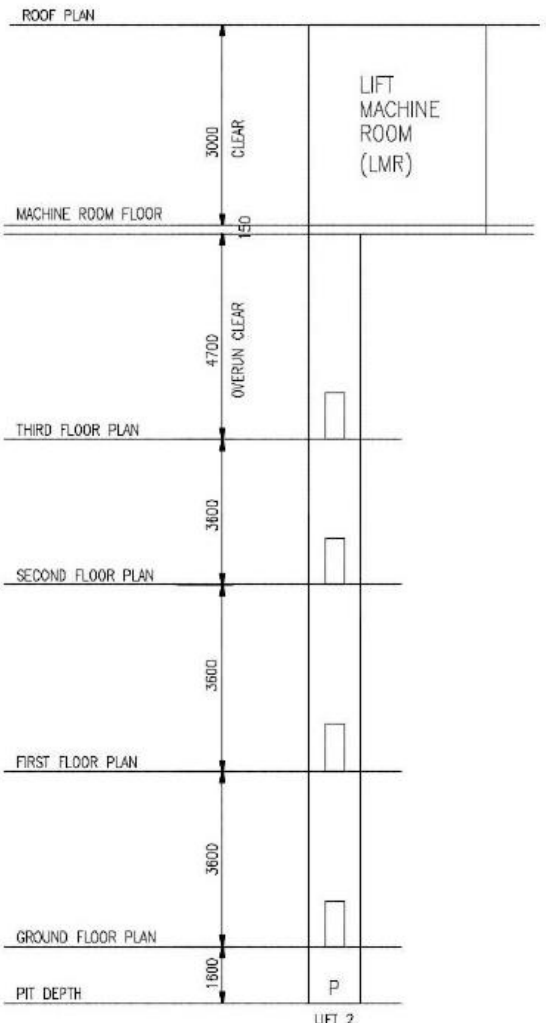


Figure 6.9 Lift Section Schematic Diagram n.t.s

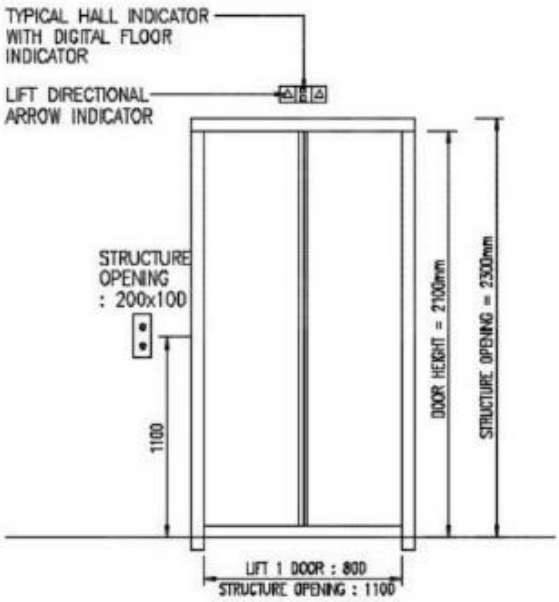


Figure 6.10 Front view of lift n.t.s

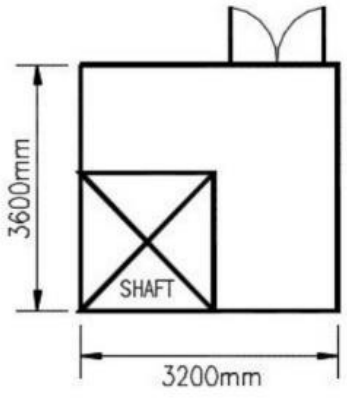


Figure 6.11 Lift machine room n.t.s

6.3.2 Type of Hoist Mechanism- Geared Traction Elevator

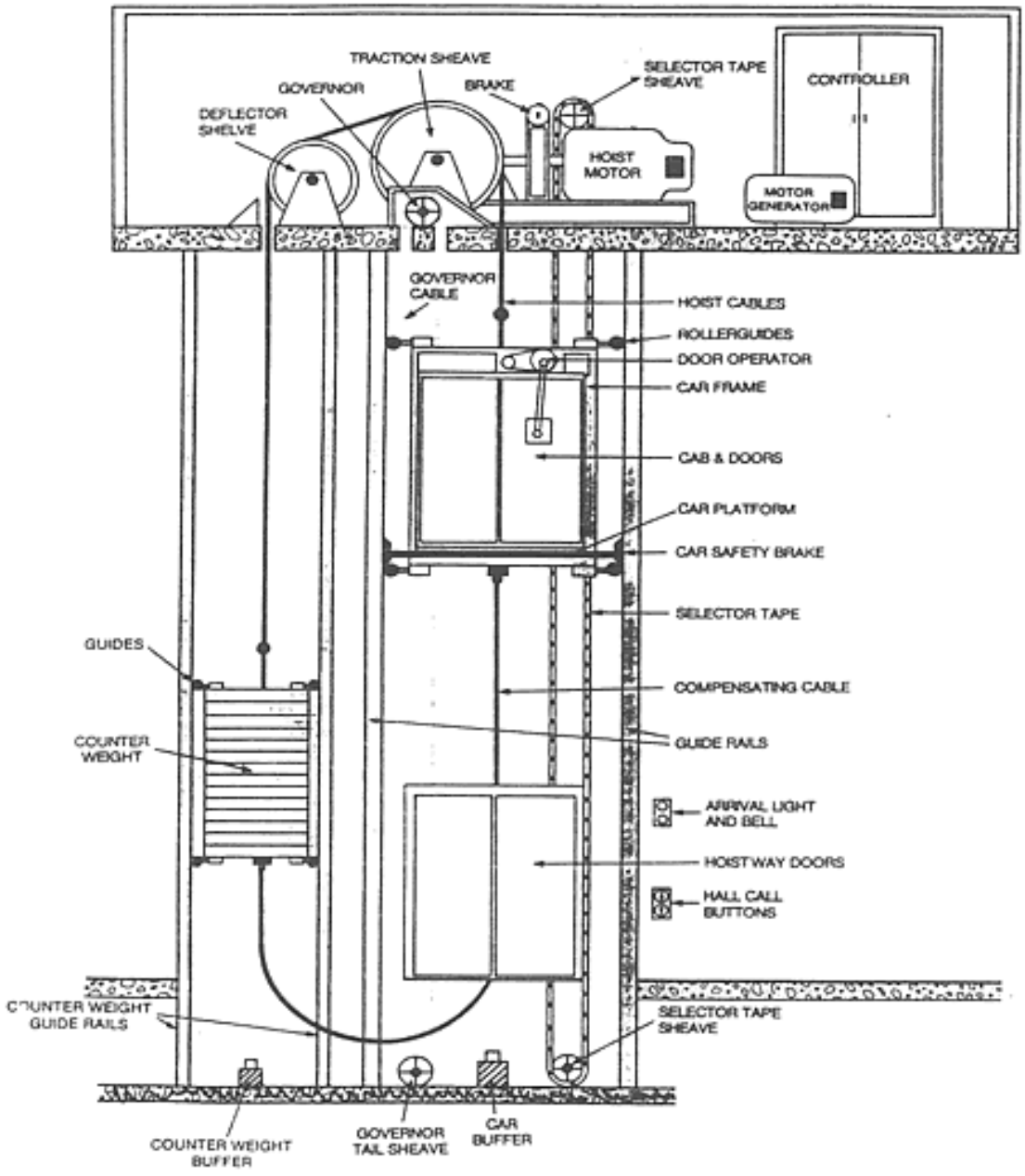


Figure 6.12 Traction Elevator Hoist Mechanism Diagram (Source: Electrical Knowhow, 2012)

The geared traction elevator also called as roped elevator. In geared traction elevators, the car is raised and lowered by traction steel ropes. The ropes that attached to the elevator car are looped around a sheave. A sheave is just a pulley with a grooves around the circumference. The sheave grips the hoist ropes, so the ropes move when the sheave is rotated.

The sheave is connected to an electric motor. When the motor turns one way, the sheave raises the elevator; when the motor turns the other way, the sheave lowers the elevator. The motor turns a gear train that rotates the sheave. Typically, the sheave, the motor and the control system are all housed in a machine room above the elevator shaft.

The ropes that lift the car are also connected to a counterweight, which hangs on the other side of the sheave. The counterweight weighs about the same as the car filled to 40-percent capacity. In other words, when the car is 40 percent full (an average amount), the counterweight and the car are perfectly balanced.

The purpose of this balance is to conserve energy. With equal loads on each side of the sheave, it only takes a little bit of force to tip the balance one way or the other. Basically, the motor only has to overcome friction -- the weight on the other side does most of the work. To put it another way, the balance maintains a near constant potential energy level in the system as a whole. Using up the potential energy in the elevator car (letting it descend to the ground) builds up the potential energy in the weight (the weight rises to the top of the shaft). The same thing happens in reverse when the elevator goes up. The system is just like a see-saw that has an equally heavy kid on each end.

Both the elevator car and the counterweight ride on guide rails along the sides of the elevator shaft. The rails keep the car and counterweight from swaying back and forth, and they also work with the safety system to stop the car in an emergency.

Roped elevators are much more versatile than hydraulic elevators, as well as more efficient. Typically, they also have more safety systems. In the next section, we'll see how these elements work to keep you from plummeting to the ground if something goes wrong.

Analysis:

KLPAC uses geared traction elevator because driving motor is smaller, cheaper, high-speed unit rather the large, low speed unit required by a gearless installation. In general, the geared traction elevator is used for car speeds up to 2.3m/s and maximum rise of about 90m which suited KLPAC requirement.

6.3.3 Elevator Component

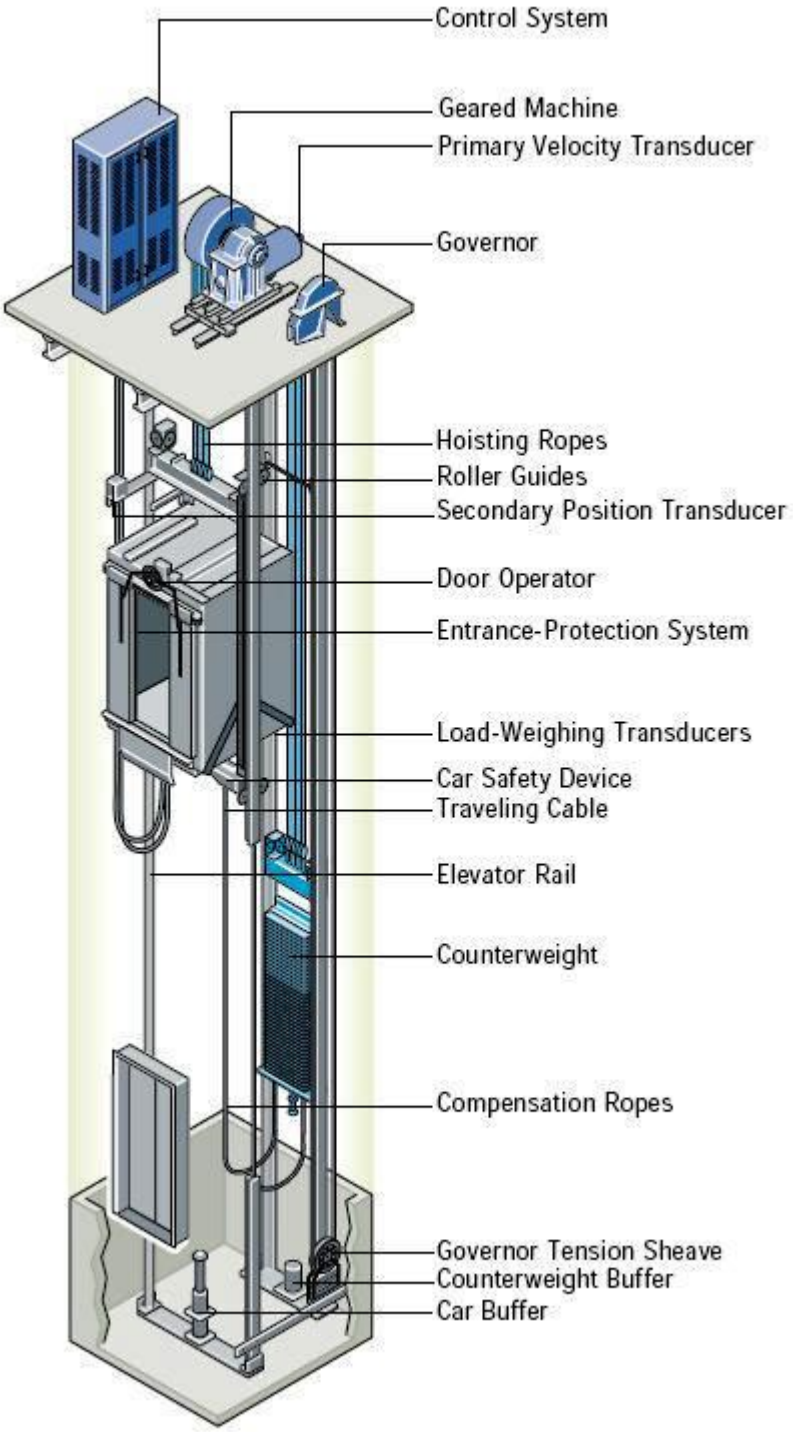


Figure 6.13 Elevator Component Diagram ***(Source: Electrical Knowhow, 2012)***

6.3.3.1 Control System

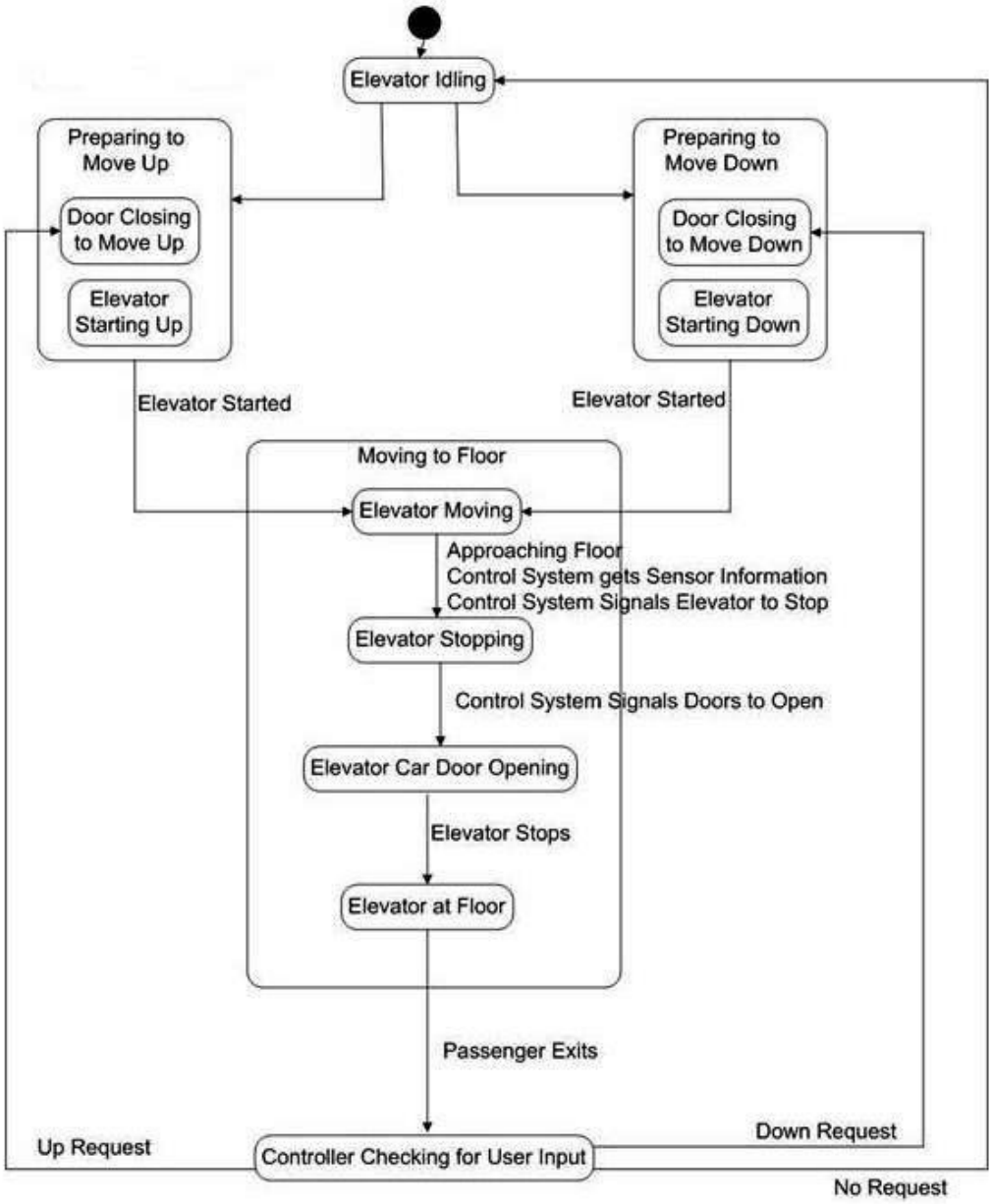


Figure 6.14 Statechart of Control System Behavior (Source: Electrical Knowhow, 2012)

↑*Figure 6.15 Control System of KLPAC*

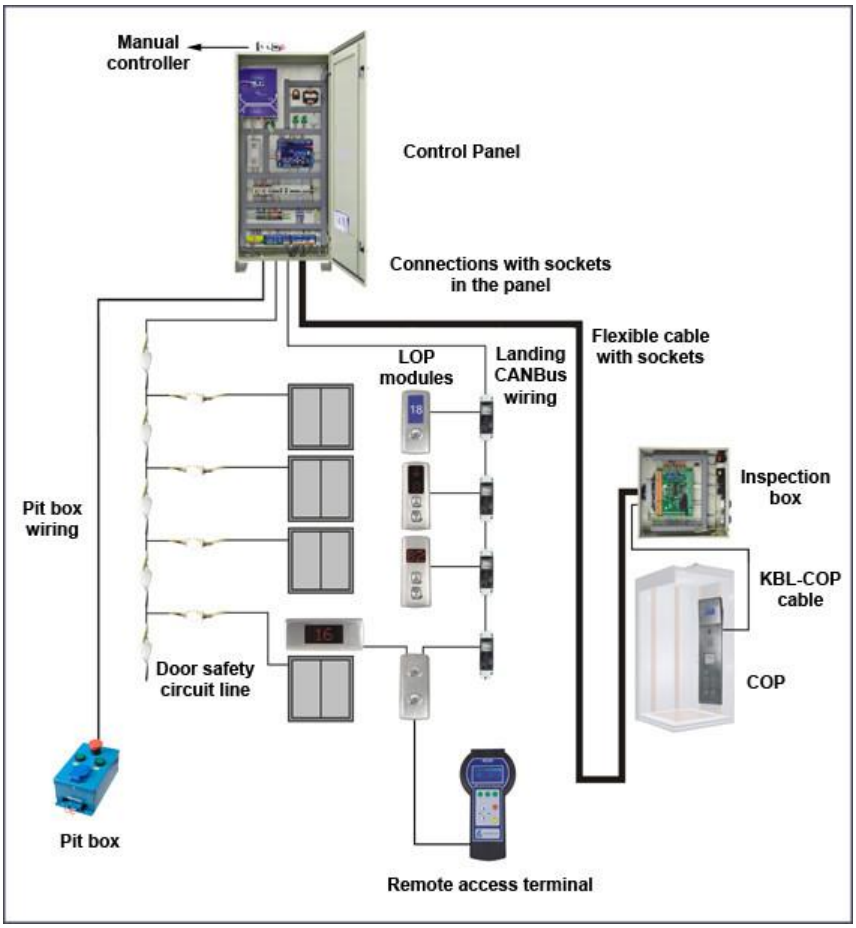


Figure 6.16 Elevator Operating Diagram→ (Source: Alben)

Elevator Control System is the system responsible for coordinating all aspects of elevator service such as travel, speed, and accelerating, decelerating, door opening speed and delay, leveling and hall lantern signals.

It accepts inputs (e.g. button signals) and produces outputs (elevator cars moving, doors opening, etc.). Normally, control system works together with two main safety indicators which are overload and fire service indicator.

The main function of the elevator control system are:

- To bring the lift car to the correct floor.
- To minimize travel time.
- To maximize passenger comfort by providing a smooth ride.
- To accelerate, decelerate and travel within safe speed limits.

6.3.3.2 Geared Machine

Figure 6.17 Geared Machine in KLPAC

MS 81-1:2012 – Clause 15.4.1 .A notice bearing the following minimum inscription: "BILIK JENTERA LIF BAHAYA DILARANG MASUK TANPA KEBENARAN" should be provided.

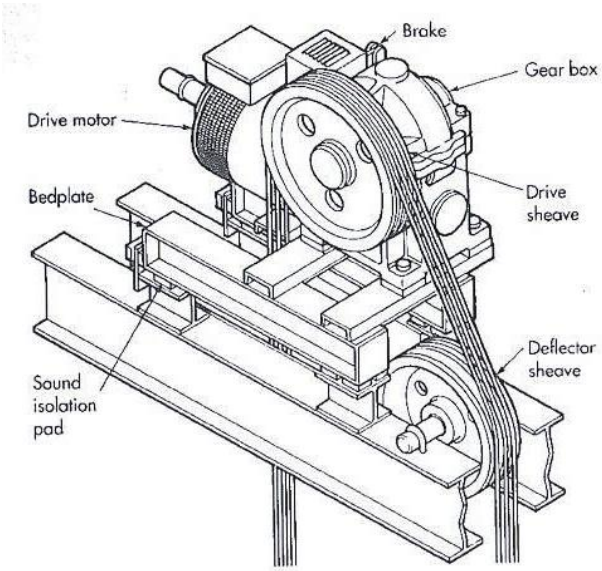


Figure 6.18 Geared Machine Components (Source: Electrical Knowhow, 2012)

Geared traction machines are driven by AC or DC electric motors. The machines use worm gears to control mechanical movement of elevator cars by "rolling" steel hoist ropes over a drive sheave which is attached to a gearbox driven by a high-speed motor.

A geared traction machine can also give almost the same high-quality, accurate, smooth ride as is available from a gearless installation with an appropriate drive and control system. It is suitable for low to mid-rise buildings and the speed is lower compared to gear-less machine which ranged around 200 to 500 feet per minute.

6.3.3.3 Governor

Figure 6.19 Governor of KLPAC

Governor system is built around a sheave positioned at the top of the elevator shaft.

Analysis:

Governor in traction elevators is the main safety tools to make sure elevators are safe supported by breaking system.

6.3.3.3.1 Safety System

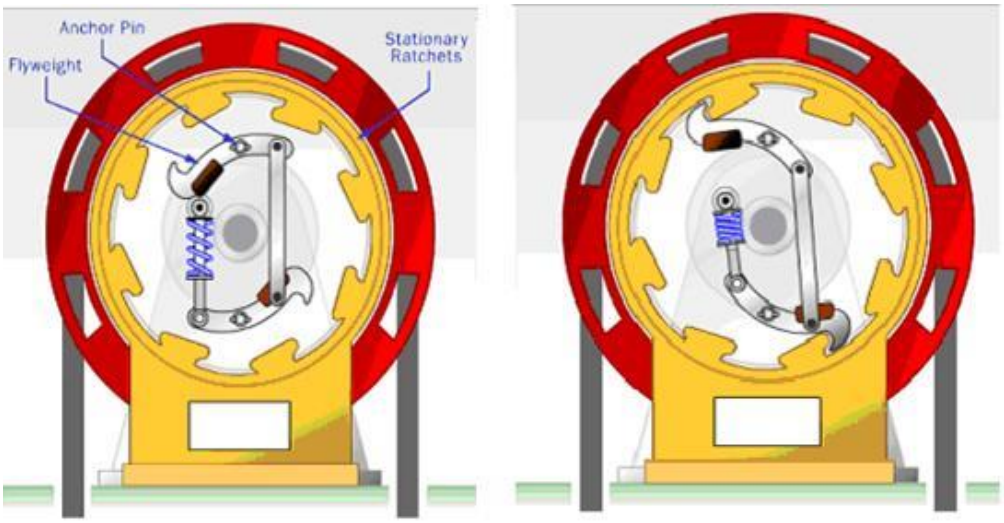


Figure 6.20 Safety System in Governor (Source: DGFASLI)

Safeties are activated by a governor when the elevator moves to quickly. The governor rope is looped around the governor sheave and another weighted sheave at the bottom of the shaft. The rope is also connected to the elevator car, so it moves when the car goes up and down. As the car speeds up, so does the governor.

6.3.3.4 Cabin in Elevator

Elevator Cabins are used to travel occupants between floors. It houses and protects passengers from the elevator shafts and provides user comfort such as ventilation, lighting and etc.

Analysis:

Type of cabin used in elevator of KLPAC is normal cabin.

Figure 6.21 Type of Cabin of KLPAC Elevator (Source: Electrical Knowhow, 2012)

6.3.3.5 Door system

Elevator doors are one of the most important safety feature available in a lift. It serves as a barrier between the waiting lobby and the elevator shafts. This is to prevent people to fall into the elevator shafts and thus getting injured or falling to their deaths.

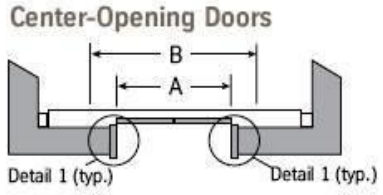


Figure 6.22 Type of Door System of KLPAC Elevator ***(Source: Electrical Knowhow, 2012)***

Analysis:

The type of doors used in KLPAC is Centre Opening Door which are the most common elevators found in almost every buildings. These type of doors consists of two panels that meet in the middle, and slide open away from each other. This door opens and closes very fast, therefore it has a very high efficiency, however, the width of the door cannot be fully utilized.

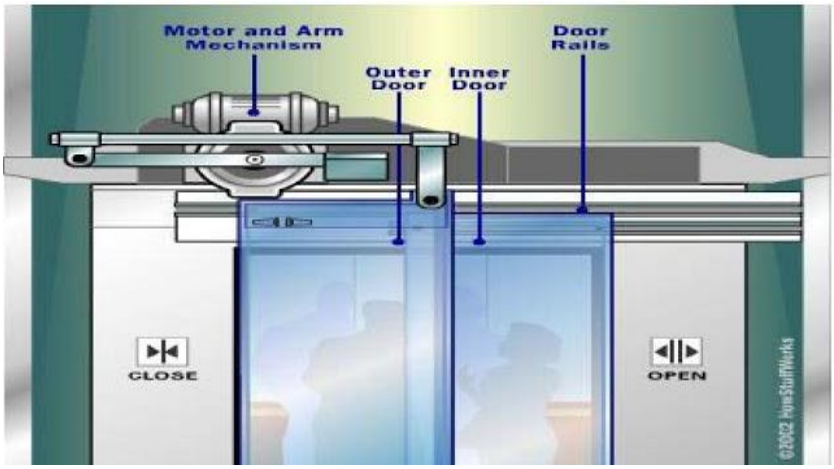


Figure 6.23 Door Opening Device Diagram ***(Source: Electrical Knowhow, 2012)***

On top of each elevator cab is a door opening device. This device opens the inner door of the elevator cab and the outer door of the elevator shaft simultaneously at each floor. The controller interacts with the door opening device by sending signals to open or close the doors and by receiving signals when the doors have been completely opened or closed. The signals that the controller receives also indicate which cab they are coming from.

MS 2021-1, Safety rules for the construction and installation of lifts - Part 1: Electric lifts.

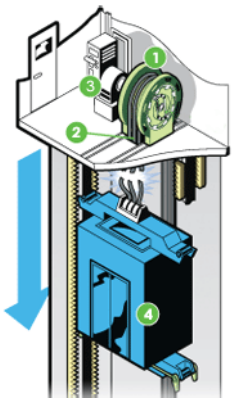
5.2.2.2.1 Emergency doors shall be capable of being self-closing.

5.7.3.2 If there is an access door to the pit, other than the bottom terminal landing door, it shall comply with the requirements of 5.2.2.

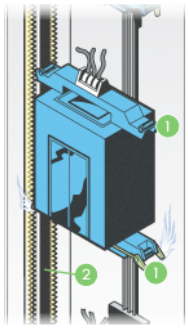
6.3.3.6 Safety break

There a few brake systems in a typical elevator system. These include the electromagnetic and mechanical brakes. The electromagnetic brakes activate automatically if there is a sudden loss of power or when the car is stationary. The mechanical brakes at the sheave itself also stop the car from moving when the car is inactive.

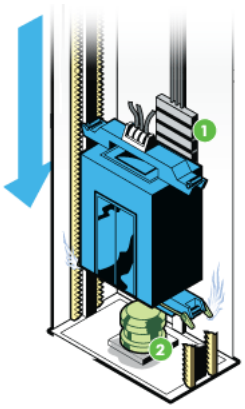
6.3.3.6.1 Snapping Cables



1. Steel cables bolted to the car loop over a sheave.
2. The sheave's grooves grip the steel cables.
3. The electric motor rotates the sheave, causing the cables to move.
4. As the cables move, the car is lifted.



1. If the cables snap, the elevator's safeties would kick in. safeties are braking systems on the elevator.
2. Safeties clamp the steel rails running up and down the elevator shaft, while others drive a wedge into the notches in the rails.



1. The cables that lift the car are also connected to a counterweight which hangs down on the other side of the sheave.
2. The built-in shock absorber of the bottom of the shaft-typically a piston in an oil-filled cylinder-helps cushioning the impact in the event of snapping cables.

Figure 6.24 Snapping Cables (Source: HowStuffWorks, 2004)

6.3.4 Special Operating mode

6.3.4.1 Down Peak

During down-peak mode, elevator cars in a group are sent away from the lobby towards the highest floor served, after which they commence running down the floors in response to hall calls placed by passengers wishing to leave the building. This allows the elevator system to provide maximum passenger handling capacity for people leaving the building.

6.3.4.2 Fire Service

Fire service code will vary depends on the location of the elevator. Fire service is usually split up into two modes: phase one and phase two. These are separate modes that the elevator can go into.

UBBL 1984

153 (1) - All elevator lobbies shall be provided with smoke detectors

155 (2) - If mains power is available all lifts shall return in sequence directly to the designated floor, commencing with the fire lifts, without answering any car or landing calls, overriding the emergency stop button inside the car, but not any other emergency or safety devices, and park with doors open.

155 (3) - The fire lifts shall then be available for use by the fire brigade on operation of the fireman's switch.

155 (4) - Under this mode of operation, the fire lifts shall only operate in response to car calls but not to landing calls in a mode of operation in accordance with by-law 154.

6.3.4.2.1 Phase One

Phase one mode is activated by a corresponding smoke sensor or heat sensor in the building. The elevator will automatically go into phase one when an alarm has been activated. The elevator will wait an amount of time, then proceed to go into nudging mode to tell everyone the elevator is leaving the floor. Once the elevator has left the floor, depending on where the alarm was set off, the elevator will go to the fire-recall floor. However, the elevator will have an alternate floor to recall to if the alarm was activated on the fire-recall floor. When the elevator is recalled, it proceeds to the recall floor and stops with its doors open. The elevator will no longer respond to calls or move in any direction. There is a fire-service key switch located on the fire-recall floor. The fire-service key switch can turn fire service off, turn fire service on or to bypass fire service. The only way to return the elevator to normal service is to switch it to bypass after the alarms have reset.

6.3.4.2.2 Phase Two

Phase-two mode can only be activated by a key switch located inside the elevator on the centralized control panel. This mode was created for firefighters so that they may rescue people from a burning building. The phase-two key switch located on the COP has three positions: off, on, and hold. By turning phase two on, the firefighter enables the car to move. However, like independent-service mode, the car will not respond to a car call unless the firefighter manually pushes and holds the door close button. Once the elevator gets to the desired floor it will not open its doors unless the firefighter holds the door open button. This is in case the floor is burning and the firefighter can feel the heat and knows not to open the door. The firefighter must hold door open until the door is completely opened. If for any reason the firefighter wishes to leave the elevator, they will use the hold position on the key switch to make sure the elevator remains at that floor. If the firefighter wishes to return to the recall floor, they simply turn the key off and close the doors.

Analysis:

With the use of smoke detector at every lift lobbies in KLPAC and locates fire staircase with firewall beside every elevator, the building has met the requirement of UBBL. During the event of fire, no one should use the elevator. People are recommended to use Fire stairways with firewall is always located beside the elevator, including in KLPAC.

6.3.4.3 Emergency power operation

When power is lost in a traction elevator system, elevators will come to a halt. Each car in the group will return to the lobby floor one by one, open its doors and shut down. People in the remaining elevators may see an indicator light or hear a voice announcement informing them that the elevator will return to the lobby

UBBL 1984

Emergency mode of operation in the event of mains power failure. 154(1) - On failure of mains power of lifts shall return in sequence directly to the designated floor, commencing with the fire lifts, without answering any car or landing calls and park with doors open.

6.3.5 Maintenance

It is important that traction elevator ropes and sheaves are checked for wear on a regular basis. As they wear, the traction between the sheave and the cables is reduced and slippage becomes more regular, which reduces the efficiency and can become dangerous if left unchecked.

Traction elevators have height restrictions that are governed by the length and weight of the cables or ropes. New materials that are stronger and lighter, such as carbon fiber, will allow traction elevators to achieve new heights. KLPAC's mechanical transportation system receives maintenance monthly by maintenance men of Dover Elevators.

6.4 Conclusion

KLPAC uses geared traction elevators are middle of the road in terms of initial cost, ongoing maintenance costs, and energy consumption. The elevators are suitable for mid-rise building like KLPAC.

Overall, KLPAC complies the By-Law requirement for mechanical transportation system. All elevators in KLPAC have safety component needed. Besides, maintenance is carried out once a month regularly to ensure best condition of the mechanical transportation system in KLPAC.

7.0 References

(2016). Retrieved 22 June 2016, from https://www.amca.org/UserFiles/file/FireSmokeDampers.pdf

Amal. (2014, January 20). *Elevator control system*. Retrieved June 12, 2016, from Electrical Knowhow, http://www.electrical-knowhow.com/2012/04/elevator-control-system.html

Ananthanarayanan, P. N. (2005). *Basic refrigeration and air conditioning* (2nd ed.). New Delhi: Tata McGraw-Hill.

Bell, A. A. (2003). *HVAC design portfolio: 865 airside systems flow diagrams and details*. New York: McGraw-Hill.

Cornwall Fire & Rescue Service. (June, 16). *Passive and Active Protection.* Retrieved June 18, 2016, from https://www.cornwall.gov.uk/community-and-living/cornwall-fire-and-rescue-service-homepage/business-fire-safety/protecting-your-building/passive-and-active-protection/

Ductless Mini-Split Air Conditioners. (n.d.). Retrieved June 22, 2016, from http://energy.gov/energysaver/ductless-mini-split-air-conditioners

Elevator types. Retrieved June 22, 2016, from Archtoolbox, https://www.archtoolbox.com/materials-systems/vertical-circulation/elevatortypes.html

Exhaust Fan Ventilation System Design, Installation, Troubleshooting. (2016). *Inspectapedia.com*. Retrieved 22 June 2016, from http://inspectapedia.com/BestPractices/Ventilation_Exhaust_Only.php

Fike (n.d.). *CO2 Fire Suppression System, Fire Suppression Solutions.* Retrieved from http://www.fike.com/products/co2-fire-suppression-system/

Firewize (n.d.). *Fire Control Centres*. Retrieved from http://firewize.com/book/technical-data/fire-control-centres

Gupta, A. (2012, July 25). *Elevators types and classification - part One*. Retrieved June 12, 2016, from Electrical Knowhow, http://www.electrical-knowhow.com/2012/04/elevators-types-and-classification-part.html

Harris, T. (2002, February 12). *How elevators work*. Retrieved June 13, 2016, from HowStuffWorks, http://science.howstuffworks.com/transport/engines-equipment/elevator3.htm

Health and Safety Executive. *Active & Passive Fire Protection.* Retrieved June 8, 2016, from http://www.hse.gov.uk/comah/sragtech/techmeasfire.htm

Health and Safety Executive. *General fire safety*. Retrieved from http://www.hse.gov.uk/construction/safetytopics/generalfire.htm

HomeAir Air-conditioning - CALL 0 4 0 8 8 0 1 9 8 5. (n.d.). Retrieved June 21, 2016, from *http://www.homeair.com.au/reverse_cycle.htm*

How an Exhaust Fan System works | DoItYourself.com. (2016). *Doityourself.com*. Retrieved 22 June 2016, from http://www.doityourself.com/stry/how-an-exhaust-fan-system-works#b

HowStuffWorks. (2005, April 28). *What if you were on an elevator and the cable broke?* Retrieved June 13, 2016, from HowStuffWorks, http://science.howstuffworks.com/science-vs-myth/everyday-myths/question730.htm

HowStuffWorks. (2005, April 28). *What if you were on an elevator and the cable broke?* Retrieved June 14, 2016, from HowStuffWorks, http://science.howstuffworks.com/science-vs-myth/everyday-myths/question730.htm

Hundy, G. F., Trott, A. R., Welch, T., & Trott, A. R. (2008). *Refrigeration and air-conditioning* (4th ed.). Amsterdam: Butterworth-Heinemann/Elsevier.

Installation of the Split Air Conditioners: Deciding the Location of Indoor and Outdoor Units. (n.d.). Retrieved June 19, 2016, from http://www.brighthubengineering.com/hvac/45249-indoor-and-outdoor-installation-of-split-air-conditioners-deciding-the-location/

Integration: HVAC fans and smoke control | Consulting-Specifying Engineer. (2016). *Csemag.com*. Retrieved 22 June 2016, from http://www.csemag.com/single-article/integration-hvac-fans-and-smoke-control/bb3da27c2bc951c536cd1cae8f38f3b1.html

Mechanical Ventilation in Buildings – What You Need to Know - TheGreenAge. (2015). *TheGreenAge*. Retrieved 22 June 2016, from http://www.thegreenage.co.uk/mechanical-ventilation-in-buildings-what-you-need-to-know/

Natural Ventilation | Sustainability Workshop. (2016). *Sustainabilityworkshop.autodesk.com*. Retrieved 22 June 2016, from http://sustainabilityworkshop.autodesk.com/buildings/natural-ventilation

Osafe Fire Inspection (n.d.). *Fire Extinguisher*. Retrieved from http://osafefi.com/?ws=pages&pages_id=4228

Parts of Split Air Conditioners: Outdoor Unit. (n.d.). Retrieved June 18, 2016, from http://www.brighthubengineering.com/hvac/45044-parts-of-the-split-air-condioners-outdoor-unit/#imgn_3

Patent application (n.d.). *Smoke curtain.* Retrieved from http://www.patentsencyclopedia.com/app/20090266498

Protec. *Wet/Dry Riser Systems*. Retrieved from https://www.protec.co.uk/product-page/sprinklers-and-water-mist/product/product/wet-dry-riser-systems/

See all Applications. (n.d.). *Fire Hydrant Systems.* Retrieved from https://www.allpumps.com.au/applications/fire-hydrant-systems

Protection. Retrieved Jun 8, 2016, from http://www.sharpfibre.com/blog/5/examining-the-relationship-between-active-and-passive-fire-protection

Spectrumfire. *Fire Hose Reel System*.Retrieved from http://www.spectrumfire.com/products/fire-hose-reel-system

Supply Ventilation. (2016). *Greenbuildingadvisor.com*. Retrieved 22 June 2016, from http://www.greenbuildingadvisor.com/green-basics/supply-ventilation

Supremexfireextiguisher. *Fire Extinguisher, A B C Type Dry Powder Fire Extinguisher, CO2 Fire Extinguisher*. Retrieved from http://www.supremexfireextinguisher.com/fireextinguisher.html

Tao, W. K., & Janis, R. R. (1997). *Mechanical and electrical systems in buildings*. Englewood Cliffs, NJ: Prentice Hall.

The Kuala Lumpur performing arts centre. Retrieved June 12, 2016, from Malaysia Convention & Exhibition Bureau, http://venue.myceb.com.my/venue/the-kuala-lumpur-performing-arts-centre#verticalTab4

Traction elevators. Retrieved June 13, 2016, from http://elevation.wikia.com/wiki/Traction_elevators

Wall Mounted Indoor Unit: Ductless Split Air Conditioner Parts. (n.d.). Retrieved June 22, 2016, from http://www.brighthubengineering.com/hvac/45046-parts-of-the-split-air-conditioner-wall-mounted-indoor-unit/

Wormald. (n.d.). *Fire Sprinkler Systems, Fire Sprinkler System, Automatic Sprinkler Systems.*Retrieved from https://www.wormald.com.au/systems/fire-sprinkler-systems