


JKR 20300-025-09
CKE.GP.08.03(00).2011

PANDUAN TEKNIK


REKABENTUK ELEKTRIK

Edisi 4

CAWANGAN KEJURUTERAAN ELEKTRIK
IBU PEJABAT JKR MALAYSIA

	PANDUAN TEKNIK CAWANGAN KEJURUTERAAN ELEKTRIK EDISI 4	CKE.GP.08.03(00).2011
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1.1 Introduction

This is the fourth edition of the Panduan Teknik, originally published in 1976. It is meant as a guideline for new Jabatan Kerja Raya (JKR) Electrical Engineers in headquarters (HQ) design office during the course of their daily duties. This document outlines the JKR standard practices which have been sourced from experiences of Senior Practicing Engineers and with reference to the current Government circulars specifically pertaining to procurement.


This document is not comprehensive nor exhaustive, thus other documents should be referred to, when embarking on the actual work at hand.

1.2 Design Procedure and Criteria

A good design is one that is safe, economical, maintainable and functional to the customer's satisfaction. The design engineer (DE) is also encouraged to seek the advice and expertise of his more experienced colleagues.

The design of the systems, all works performed, all materials and equipments supplied shall comply with the rules and regulations, circulars, laws and by-laws and be carried out in accordance to the following:

- a) Suruhanjaya Tenaga, ST
- b) Suruhanjaya Komunikasi & Multimedia, MCMC
- c) Jabatan Alam Sekitar, DOE
- d) Jabatan Bomba & Penyelamat, JBPM
- e) Jabatan Keselamatan & Kesihatan Pekerjaan, DOSH
- f) Ministry of International Trade & Industry, MITI
- g) Treasury Circulars
- h) Garis Panduan dan Peraturan bagi Perancangan Bangunan Oleh Jawatankuasa kecil Piawaian & Kos bagi Jawatankuasa Perancang Pembangunan Negara, Jabatan Perdana Menteri, EPU
- i) The Electricity Supply Act 1990
- j) The Electricity Regulation 1994
- k) MS IEC 60364 – Electrical Installations Of Buildings
- l) Uniform Building By-Laws, UBBL
- m) Relevant parts of ANSI/EIA/TIA 568, ANSI/EIA/TIA 569-A, ANSI/EIA/TIA 606, and ANSI/EIA/TIA 607 standards
- n) The relevant codes of practice issued by SIRIM and in the absence of which those issued by the British Standards Institution/IEC

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- o) JKR Technical Circulars and Specifications
- p) Local Authorities
- q) Utility companies
- r) All other authorities having jurisdiction over the works


1.3 Planning Stage

Many factors need to be ascertained during the planning stage. Upon receiving the design brief from the client, the DE must first analyse the client's requirement and prepare a concept design based on the electrical, telecommunication and mechanical load requirement. The DE then prepares a preliminary cost estimate which must be forwarded to the Quantity Surveyor, to be included in the Preliminary Detail Abstract (PDA) costing for the entire project.

At this stage too, meetings, discussions and coordination need to be carried out within the project team. The builder's works in connection with electrical works have to be coordinated with the architect, civil and structural engineers. Preliminary electrical requirement for mechanical loads have to be obtained from the mechanical engineers.

The following are some of the points to be coordinated:

- a) Architect
 - i) The location of the main switchboard (MSB) with respect to the location of the substation. Ideally it should be adjacent to the substation. However as a rule of thumb it should not be more than **20 meters** away. Otherwise additional sub switch room(s) may be required, thus adding to the cost of the project. **(Reference : Tenaga Nasional Berhad (TNB) Electricity Supply Application Handbook, ESAH)**
 - ii) Ducting for incoming cables must also be incorporated.
 - iii) The numbers, sizes and locations of risers – the risers are needed to house the electrical boards, strategically located not only for aesthetic reasons but more importantly for safety, maintainability and serviceability.
 - iv) Openings in walls and floor slabs are required to allow for concealed conduits and trunking routes.
 - v) The type of ceiling to be installed, the ceiling space required for luminaire installation and etc.

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b) Structural Engineer

- i) To ensure ducting and trench details for substation and switch rooms are incorporated into structural drawings.
- ii) To discuss on openings and/or haunches in beams - if there is insufficient space under the soffit of the beam to cater for services, and finalize the opening sizes.
- iii) To coordinate possible bonding to the structure for lightning protection system.

c) Mechanical Engineer


- i) To ascertain the required electrical power for all mechanical equipment e.g. air conditioning system, water pumps, sewage pumps, fire fighting facilities, etc.
- ii) To identify the proposed location of power points and isolators required.

Simultaneously, supply authority (e.g. TNB, SESCO, etc) shall be informed of power supply requirements – Once the load estimate and location of intake have conceptually been agreed, TNB is approached for confirmation of availability of supply. If a substation is required, then it becomes necessary to coordinate with the architect to provide the substation(s). The DE shall request for estimated connection charges that would be involved.

Telecommunication Company (TELCO), (e.g. Telekom Malaysia, Time, etc.) also needs to be informed of communication line requirements early in order to ensure that communication lines and other requirements are ready upon completion of construction works. Similarly, requirement of other authorities need to be liaised.

Once agreement has been reached with all relevant parties, detailed design and drawings can commence. For standard buildings such as schools or quarters etc., the standard drawing are already available and the works is much simplified.

During this stage too, the DE must prepare the design development plan (works schedule) and discuss with the project team on the method of procurement. Appendix 1 shows the example on the Activity/Project Planning to assist the new DE.

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1.4 Detail Design Stage

The information and feedbacks received from various parties and authorities during planning stage is used for the actual detailed design. The common electrical services designed in building works are:


- a) Internal illumination
- b) Power points (13A socket, isolator, etc)
- c) Mechanical equipment loads e.g. air conditioning loads, pumps, lifts, etc.
- d) Internal distribution system
- e) Emergency/Back up supply
- f) External 11kV reticulation and substation requirements
- g) Lightning protection, surge protection and earthing system
- h) Information, telecommunication and Public Address Branch Exchange (PABX)
- i) Public address and sound reinforcement systems
- j) Security and intruder system
- k) External lighting

The first step of the design is to trace the floor layout plan from the architectural drawings, prepare the electrical layout plan and insert the location of luminaire (based on illumination calculation) and its switches, electrical socket outlets and all the other power points as required. This is the easiest but most time consuming exercise. Cawangan Kejuruteraan Elektrik (CKE) is in the midst of removing this step and replacing it. An automated Schedule of Accommodation (SoA) is in the pipe line.

The second step is the design of the final circuits and its associated distribution boards (DB). The items to be considered comprise of the total load (both the total connected load, TCL and maximum demand, MD), cable sizes, circuit protective device and the safety isolation devices.

The third step is to design the electrical distribution system (schematic drawing, switch board systems) and the cabling involved.

In its simplest terms the design of electrical installation involves the laying out of electrical equipment such as light fitting, socket outlets, switches, fans, etc, and making up the associated circuitry of schematic wiring diagrams showing how they are connected to the incoming supply and also how they are interconnected. The design shall also follow the relevant **JKR Elektrik Standard Specification L-S1 to L-S20, JKR Technical Circulars and current JKR practice.**

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The DE must check and ensure that the design drawings prepared are correct and meets the client brief. Amendments will be carried out by the relevant subordinate or by the DE. After having satisfied that the drawings are correct, the drawings shall be cross checked by another designer before forwarding to the head of design team (HODT) for review. The design shall then be presented to the Design Review Committee before verification.

Refer JKR Sistem Pengurusan Kualiti (SPK) website <http://spk.jkr.gov.my> for details of this review and verification flow.

1.5 Preparation of Bill of Quantities

Before any procurement, a Bill of Quantities (BQ) has to be prepared. The draft is prepared based on the drawings and DE has to ensure that the entire scope of works is included to minimise variations during construction.


1.6 Preparation of Tender Document (TD) and Table Tender Document (TTD)

TD prepared shall comprise of:

- a) Drawings
- b) Relevant specifications
- c) BQ
- d) Important Notes to Tenderers
- e) Supporting JKR 203N1 and N2 forms (for nominated sub contracts only)
- f) Technical schedule and manufacturer's name/brand of materials
- g) Information on the required heads and subheads for the works, location of the site, the name of the Main Contractor for the project, indication of the expected completion period and the closing date of the tender

All the above are bound together forming a TD for checking by the DE according to the checklist. Presently, CKE already practices on CD Tendering for selected projects.

Next, TTD must be prepared. The TTD shall comprise of all the above plus the Tender Notice, JKR 203N (Condition of Contract), JKR 203N3 to N7 series of form also known as the standard nominated sub contract document.

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For main contract (known as direct contract in CKE), JKR 203 (based on Specification and Drawing – Lump sum contract) or 203A (based on BQ only) contract forms may be used.

This is a very simple yet very important step. This TTD shall be the reference document for tenderers who intend to purchase and participate in the tender.

Having completed and verified the TTD, the TTD and TD are sent to the Tender Secretariat at Kementerian Kerja Raya (KKR), before or on the date of the said advertisement where qualified tenderers may purchase the TD.

1.7 Preparation of Tender Evaluation Report

Once the tender is closed, the Tender Secretariat will return all the TD submitted by the tenderers to the Design Office for evaluation.

It has to be stressed that the tender evaluation process is **confidential**. Therefore the handling of this procedure must adhere to the confidentiality flow of work/information practice in the department.


Evaluations of the tenders are done in two stages.

Stage 1:

- Statistical analysis of tender price (cut off analysis)
- Completeness of Tender submission
- Mandatory documents
- Financial capabilities
- Analysis on present performance of the tenderer
- Technical analysis of equipment or methods compliance to specification

Stage 2 (only applicable to tenderers offering prices below cut off):

- Analysis on past performance of the tenderer
- Analysis on manpower/staff
- Tender price
- Sufficiency of minimum capital (Kecukupan modal minimum selepas mengambilkira Faktor Rendah Harga, FRH)

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Those tenderers, who pass the second stage evaluation, shall be further assessed based on Special Criteria for final recommendation.

The report will then be assessed by the Tender Evaluation Committee. Pengarah Kanan CKE (PKCKE) then recommends and submits the report to the Urusetia Lembaga Tender (Tender Board Secretariat).

1.8 Appointment of Nominated Subcontractor (NSC)

Upon approval by the Tender Board, the successful tenderer shall be informed of his success as the NSC for the works and the NSC shall obtain the necessary policies and bonds. The policies and bonds must be checked according to Treasury Circular and Instructions. Having done these, the DE wills officially handover the entire supervision of the works and its associated contract administration and management up to and including the closing of the accounts, to the state JKR Electrical offices. Refer to the *Kit Selia Elektrik*.


Simultaneously, the DE shall:

- a) Prepare the necessary JKR203 forms,
- b) Submit them to the Superintending Officer, SO,
- c) Assist the SO to obtain the signatures of the Main Contractor and his NSC i.e. the Letter of Acceptance (LA), etc.,
- d) Distribute copies of JKR203N1 to N7 to the relevant parties,
- e) Get the JKR203N form stamped,
- f) Prepare the Contract Document,
- g) Distribute the Contract Document to the relevant parties.

1.9 Site Supervision

The site supervision shall be carried out by state JKR Electrical offices named by the SO as his specialist SO Representative, SOR.

Subsequently, the DE's involvement in the project will be on a periodical basis only i.e. the occasional site visit and or upon request for more details or clarification from the state offices. He shall carry out the design audit and design changes where necessary.


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1.10 Towards a Quality Asset Development

To align to the JKR Strategic Framework achieving JKR's vision and mission to be the centre of excellence, a holistic approach towards asset facility management is imperative. Thus CKE has formed a flying squad to become the audit group during the development stage. The reported findings from these audits shall be shared as lessons learnt for continuous improvement within the CKE.

The members of this squad are representatives from the various units in CKE. CKE's flying squad shall visit the site during the construction, pre-occupancy and post-occupancy stages, to audit the following:

- a) SPK compliance
- b) Supervision works
- c) Testing
- d) Compliance to contract
- e) Design audit
- f) Hand-over procedures, etc.

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Appendix 1

JADUAL PERANCANGAN AKTIVITI / PROJEK


Projek :

Kos PDA :
Jurutera Elektrik (JE) :
Penolong Jurutera (PJ) :
Juruteknik (JT) :


BIL	PROJEK / AKTIVITI	PRO. Q: JKR.PK		DOKUMEN SOKONGAN / BORANG			PIC	STATUS	FILE REF. NO
		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
A	PERANCANGAN PROJEK								
A.1	Penerimaan Projek		01						
A.1.1	Buka Fail	02			√	▪ CE/ISO2000/1			
A.1.2	Rekod Pendaftaran Fail Projek	02			√	▪ CE/ISO2000/2			
A.2	Pasukan Rekabentuk								
A.2.1	Lantikan HODT & J/kuasa rekabentuk		01		√	▪ CE/ISO2000/3			
A.2.2	Majukan lantikan HODT kepada HOPT		01	√	√	▪ JKR.PK(O).01-3 ▪ CE/ISO2000/4			

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
A.3	Brief Projek								
A.3.1	Permohonan projek brief		01		√	▪ CE/ISO2000/5			
A.3.2	Kajian / semakan projek brief			√		▪ JKR.PK(0).01-3			
A.3.3	Lawatan tapak								
A.3.4	Perbincangan dengan pihak pelanggan								
A.3.5	Pindaan terhadap brief (jika perlu)		01	√		▪ JKR.PK(0).01-1			
A.3.6	Pengesahan brief terkini dari pihak pelanggan		01	√		▪ JKR.PK(0).01-2			
A.3.7	Verifikasi harta pelanggan		02	√		▪ JKR.PK(0).01-2			
A.4	Q-Plan & D-Plan								
A.4.1	Sediakan D-Plan		02	√		▪ JKR.PK(0).02-1	JE		
A.4.2	Majukan D-Plan kepada HOPT				√	▪ CE/ISO2000/6	JE		
A.4.3	Dapatkan salinan Q-Plan		01	√	√	▪ JKR.PK(0).01-4 ▪ CE/ISO2000/5 ▪ CE/ISO2000/6	JE		
A.4.4	Lantikan pegawai mengurus tender (PMT)				√	▪ CE/ISO2000/7	JE		

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A.4.5	Pendaftaran projek : e-Pengurusan / SKALA						JE		
B	Rekabentuk Konsep								
B.1	Open design file and book						PT		
B.1.1	Kaji lukisan arkitek						JE		
B.1.2	Bincang skop kerja						ALL		
B.1.3	Rancang rekabentuk konsep						JE		
B.1.4	Kira keluasan lantai						PT		
B.1.5	Anggar harga				√	▪ CE/ISO2000/9A	JE		
B.1.6	Surat kepada QS untuk anggar harga PDA				√	▪ CE/ISO2000/9A	JE		
B.1.7	Salinan PDA								
B.1.8	Anggar beban				√	▪ CE/ISO2000/9B	JE		
B.2	Perbincangan Design Concept dgn KJE		01		√	▪ CE/ISO2000/8	JE		
B.2.1	Electrical design system								
B.2.2	Revise design concept								

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C	Rekabentuk Awalan								
C.1	Plan for room requirements						JE/PT		
C.2	Liase with architect for space requirement: Electrical, Telephone, PA, Security, etc.						JE		
C.3	Prepare sketches of the required room size and locations						JE/PT		
C.4	Write information for coordination to						JE/PT		
C.4.1	Mechanical (load requirement)						JE/PT		
C.4.2	Architect (room requirement & build-ins)						JE/PT		
C.4.3	Client equipments (special requirement) /						JE/PT		
C.4.4	Structural depth (beams special installation)						JE/PT		
C.5	Perbincangan dgn Design Group						JE		

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C.5.1	Pembahagian tugas & WBS				√	▪ CE/ISO2000/11	JE		
C.5.2	Electrical system (HT, LV Reticulation)								
C.5.3	Pemilihan lampu, symbols to be used, drawing style, drawing no & targets & KPI								
C.6	Write to TNB to liase for location and size of Sub-ST		01		√	▪ CE/ISO2000/10A	JE		
C.6.1	Obtain approval from TNB								
C.7	Attend the required co-ordination meeting						JE		
D	Rekabentuk Terperinci								
D.1	Telephone system								
D.1.1	Obtain Tel. U/floor trunking layout from architect						JE		
D.1.2	Locate Tel point & design telephone system						JE/PT		
D.1.3	Draw Telephone system						JT		

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
D.1.4	Plot for checking and review 1		03		√	▪ CE/ISO2000/10B	JT		
D.1.5	Amend and print 3 sets to send to local TELCO for approval				√	▪ CE/ISO2000/8	JE		
D.1.6	Obtain approval from TELCO						JE		
D.2	Lighting Design								
D.2.1	Calculate lux level				√	▪ CE/ISO2000/12	JT		
D.2.2	Trace architectural drawing according to the list of drawing prepared						JT		
D.2.3	Locate all luminaires						JT		
D.2.4	Locate all s/s/o						JT		
D.2.5	Locate all ICT/LAN point						JT		
D.2.6	Locate all PA point						JT		
D.2.7	Plot / print for checking						JT		
D.2.8	Drawing checked, discuss & amend			√		▪ JKR.PK(0).02-2	JT		
D.3	Design Schematic								
D.3.1	Design the schematic including the DB						JT		

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D.3.2	Insert schematic labelling in the layout						JT		
D.3.3	Draw the schematic diagram						JT		
D.3.4	Calculate load of each DB and balance it						PT		
D.3.5	Check the drawing so as the labelling tally with schematic and the load						PT		
D.3.6	Amend and recheck until satisfactorily done						JE		
D.3.7	If OK plot and pass to JEP for design review 1						JE		
D.3.8	Design review 1			√		▪ JKR.PK(0).02-2	JEP/JE		
D.3.9	Amend drawing and recheck			√		▪ JKR.PK(0).02-2	JE/JT		
D.4	Distribution system					▪ JKR.PK(0).02-2			
D.4.1	Collect, list and calculate all loads		02		√	▪ CE/ISO2000/12	PT/JT		
D.4.2	Calculate volt drop & check cable size						PT/JT		
D.4.3	Check switch gear rating						JE/PT		

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D.4.4	Locate and label mechanical switchboards						JE/PT		
D.4.5	Design SSB schematic						JE/PT		
D.4.6	Design riser diagram						JE/PT		
D.4.7	Draw block diagram						JE/PT		
D.4.8	Main Tel. schematic diagram & PABX						JE/PT		
D.4.9	Main PA schematic diagram						JE/PT		
D.4.10	Lightning protection system						PT/JT		
D.4.11	Plot, check and amend						PT/JT		
D.4.12	Plot, recheck and send for design review 2						JE		
D.5	Design Review 2						JEP/JE		
D.5.1	Design LV boards & discuss with JEP			√		▪ JKR.PK(0).02-2	JE		
D.5.2	Draw MSB and associated boards			√		▪ JKR.PK(0).02-2	JE		
D.5.3	Check and send for design review 3						JE		

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
D.6	Design review 3						JEP/JE		
D.6.1	Amend and plot for verification						JT		
E	Verifikasi Rekabentuk								
E.1	Pengesahan JEP								
E.1.1	JEP: Review rekabentuk			√		▪ JKR.PK(0).02			
E.1.2	JEP: Pengesahan rekabentuk			√		▪ JKR.PK(0).02			
E.2	Pengesahan KJE								
E.2.1	KJE: Review rekabentuk			√		▪ JKR.PK(0).02			
E.2.2	KJE: Pembetulan lukisan / rekabentuk			√		▪ JKR.PK(0).03			
E.2.3	KJE: Pengesahan rekabentuk			√		▪ JKR.PK(0).02			
E.3	PCKE: Pengesahan rekabentuk			√		▪ JKR.PK(0).02			
E.4	Validasi rekabentuk (jika perlu)								
F	Penyediaan Dokumen Tender & Perolehan								

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
F.1	Penyediaan senarai bahan								
F.1.1	Sediakan senarai kuantiti, senarai jenama barangan		02				PT		
F.2	Mohon no. tender						PT		
F.2.1	Tentukan kelas pretender						PT		
F.2.2	Sediakan butiran pengiklanan						PT		
F.2.3	Sediakan LO untuk iklan						PT		
F.2.4	Sedia surat & hantar iklan						PT		
F.2.5	Iklan tender						PT		
F.3	Sediakan spesifikasi & lukisan		02				PT		
F.3.1	Sediakan borang-borang tender						PT		
F.3.2	Sediakan TD & TTD		03				JE/PT		
F.3.3	Senarai semakan TD & TTD		03	√		■ JKR.PK(O).03-4a (NSC) ■ JKR.PK(O).03-4b (DC)	JE/PT		

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
F.3.4	KJE: check and approve the TTD								
F.4	Send to Urusetia Tender						JE/PT		
F.5	Pengiklanan								
F.5.1	Lawatan tapak jika perlu						JE		
F.5.2	Jualan dokumen tender								
F.5.3	Sediakan anggaran jabatan						JE		
F.5.4	Lantikan semula pegawai penilai, jika perlu						JEP/JE		
F.6	Penerimaan dokumen tender						JE		
F.6.1	JE: penilaian tender								
F.6.2	JEP: semakan penilaian tender								
F.6.3	JEP: semakan & pengesyoran penilaian tender								
F.6.4	KJE: semakan & pengesyoran penilaian tender								

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
F.6.5	PCKE: pengesahan & pengesyoran tender								
F.6.6	JE: sediakan 10 set laporan tender								
F.6.7	Hantar laporan tender ke Urusetia Lembaga Perolehan						JE		
F.7	Keputusan dari Lembaga Perolehan								
G	Penyediaan Dokumen Kontrak								
G.1	PCKE serah kpd. KJE/JEP/JEK/JE								
G.2	Pemberitahu penerimaan tender s.k. KJEN						JE/PT		
G.2.1	Penyediaan SST & borang-borang kontrak						PT		
G.2.2	Kick off meeting dan penyerahan pada KJEN						JEP/JE		
G.2.3	Edaran SST & borang-borang kontrak kpd kontraktor & pihak-pihak terlibat						PT		

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
G.2.4	Matikan setem						PT		
G.2.5	Menyedia dokumen kontrak						PT		
G.2.6	Hantar kepada BINDERS untuk buat dokumen kontrak.						PT		
G.3	Pengesahan dokumen kontrak						KJE		
G.4	Edaran kontrak Dok.						PT		
H	Pembinaan								
H.1	Site meetings						ALL		
H.2	Site visits / supervisions						ALL		
H.2.1	Check and approve samples						ALL		
H.2.2	Approve shop drawings						JE		
H.3	Evaluation on progress for payment						PT/JT		
H.3.1	Prepare claim recommendation letter						JE/PT		
H.4	Factory visit for switchboards						JE/PT		

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
H.5	Liaise with TENAGA for						JE		
H.5.1	ACB settings						JE		
H.5.2	substation approval						JE		
H.5.3	connection charges						JE		
H.5.4	connection of supply						JE		
H.6	Liaise with TELCO for						JE		
H.6.1	supervision of manholes fabrication						JE		
H.6.2	TELCO inspection						JE		
H.6.3	application for telephone lines						JE		
H.7	All supervision forms to be filled accordingly						PT/JT		
H.8	Final measurement on site						PT/JT		
H.9	V.O. forms						JE/PT		
H.10	PPJHK						JE		
I	Testing & Commissioning & Handover								

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
I.1	Testing on site						ALL		
I.2	Check as installed drawings						ALL		
I.2.1	Receive, records and distribute man & distribute as installed drawing						PT		
I.3	Pre Handling Over Inspection						ALL		
I.4	Final rectification								
I.5	Handling over								
J	Defects Liability Period								
J.1	Do final payment and close of account						JE		
J.2	Handle complaints and rectification works						PT		
J.3	Defects joint inspection every 3 months						ALL		
J.4	Final site checking or defects 3 months before DLP ends						ALL		
J.5	Making good – Final								

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		(P)	(O)	JKR	CE	NAMA / KOD BORANG			
J.6	Release performance bond						JE		
J.7	Prepare letter and pass all files for closing						PT		
J.8	Close file						JE		

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2.1 Room Requirements

If the estimated maximum demands (MD) is more than 1000kVA the DE must plan for 11kV main supply intake on consumer side.

For HV supply, TNB normally requires only a HV switch room to house their switchgears. Adjacent to TNB switch room, the DE is required to provide HV switch room(s), transformer room(s), LV switch rooms and standby generator set room. All these rooms should be adjacent or as close as possible to each other to minimize voltage drop.

In some cases, TNB also requires the consumer to provide space for their transformers and LV distribution board if LV supply is required for the other LV consumers in the same site / vicinity.

If LV supply is taken, the TNB requires either a single chamber (1 transformer room) or double chamber (2 transformer rooms) substation. The type of substation required will be decided by TNB upon receiving estimated load from DE. The DE is required to provide a main switch room adjacent to TNB substation.


Criteria to be considered when planning for the location of these rooms:

- located within the building where the load centre is;
- near to one another;
- easily accessible by vehicles and personnel for operation and maintenance purposes;
- easily accessible to heavy machinery during installation, replacement and refurbishment when necessary;
- have adequate ventilation;
- away from water sources;
- free from flood.

Should the above criteria could not be met, the DE should coordinate for additional requirements with the architect such as double wall if adjacent to the toilet, etc.

In addition to the above rooms there should be electrical services ducts (riser rooms) to house vertical mains and sub mains for electrical loads at upper floors such as lift control room, air conditioning plants, floor switch boards (SSB / DB), etc.

Electrical riser rooms should be located as close to the LV switch room as possible. They should be vertically aligned and ideally be centrally located in the building to

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minimize unnecessary long run of final circuits. There may be a need for more than one electrical riser room depending on the design of the floor layout.

For buildings with integrated building management system a command control centre shall be provided to house all the M&E control systems.

For high rise buildings or in the case where heavy loads are located at high levels, it may be necessary to provide substation at this levels. In this case the floors for these substations must be specially designed by the structural engineer to cater for the equipment load. Thus, the structural engineers should be informed early during the design stage.

Main switch board room should be large enough to allow easy installation and maintenance. Usually not less than 1.0 m clearance should be allowed between the wall and the rear of the switch boards. The front clearance of the switch board should be minimum 1.5 m to provide sufficient space for operation and maintenance of the switch gears.

Main switch board room should be directly accessible from the exterior of the building.

Early planning and close coordination with the architect, structural engineer and mechanical engineer is required in order to obtain the above mentioned requirements.

Refer guideline for coordination of builder's works in connection with electrical requirement as shown in Table 2.1 for guideline.

2.2 Requirements of TNB Substation

Three set of approved substation design should be obtained from District Business Manager and forwarded to architect and structural engineer to be included in the building contract. No other services shall pass through the substation. Cawangan Kejuruteraan Mekanikal should be contacted to provide automatic fire fighting systems for the substation.

Lighting points and switch socket outlets shall be provided with a DB. The DB shall be tapped from TNB LV board.

LV meter panels shall be located in the substation i.e. at TNB switch gear room or at adjacent main switch room or at adjacent meter kiosk.




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Table 2.1: Guideline for Coordination of Builders Works in Connection with Electrical Requirement

NO	REQUIREMENT	PROPOSED SIZE (mm) (W X D)	CRITERIA / GUIDE
1.0	HT Substation (Refer to Figure 2.1)		Build up area > 9100 sq.m
1.1	TNB HT Room	5500 × 5500	Door: 2400(W) × 3000(H) Composite / HDPE
1.2	TNB Transformer Room	2500 × 5500	Door: 2400(W) × 3000(H) Composite / HDPE
1.3	HT Switchgear Room (Consumer)	5500 × 5500	Door: 2400(W) × 3000(H) Composite / HDPE
1.4	Transformer Room (Consumer)	2500 × 5500	For 1 (one) Transformer only (ventilation) Door: 2400(W) × 2400(H) Composite / HDPE
2.0	TNB Substation (Refer to Figure 2.2)		Build up area > 9100 sq.m
2.1	TNB Switchgear Room	4600 × 5500	Door: 2400(W) × 3000(H) Composite / HDPE
2.2	TNB Transformer Room	3000 × 5500	Door: 2400(W) × 3000(H) Composite / HDPE
3.0	LV Rooms		
3.1	Main Switchboard, MSB Room (Refer to Figure 2.3)	4000 × 5500	Build up area up to 6100 sq.m Door: 2400(W) × 3000(H) Composite / HDPE Exhaust Fan required
3.2	Generator Room / House (Refer to Figure 2.3)	6000 × 5500	Door: 2000(H) × 2000(W) Acou. by Electric Contractor No ventilation required by Mech.
3.3	Sub Switchboard, SSB Room	2500 × 2500	At least one for every block, on the ground floor similar to MSB room.


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NO	REQUIREMENT	PROPOSED SIZE (mm) (W X D)	CRITERIA / GUIDE
3.4	Electrical Riser room (DB/SSB Room) (Refer to Figure 2.4)	900 x 600	At least one on every floor. If floor SSB is to be installed in the same room then the room should be resized accordingly.
3.5	Floor Opening (Refer to Figure 2.4)	Subject to size and number of trunking installed	Will be covered by approved 2 hrs fire barrier, by Electric Contractor Door: to follow UBBL 75 mm kerb around the floor opening 50 mm kerb across the door
3.6	UPS Room	2500 × 3500	24 hrs Air Conditioning
3.7	Battery Room	2500 × 1500	Glazed tiles up to 1500mm from floor level Adjacent to UPS room
3.8	Electrical Maintenance Crew Office	3500 × 3500	Air Conditioned For big projects where there are in-house maintenance crew
3.9	Command Control Centre	5000 × 5000	Control centre to be shared by CCTV, security, BAS, Fire Prevention, P.A System, etc. Min. 300mm raised floor system required. Half-glass (tinted 1 way)/ half brick wall required for partition facing lobby; others, full brick with solid.
3.10	Tenant Meter Panel		Must be identified for quarters (Ground Floor) and multi tenant building (within the vicinity of mail box)
3.11	Ceiling Space for Recessed Luminaire Mounting (Refer to Figure 2.5)	The space required depends on the type of luminaire used	For fluorescent luminaire (150mm) For Down lights (250mm) For Bay lights (450mm) The total depth of ceiling space should include beam + a/c duct + luminaries If the required ceiling space cannot be provided, haunches in the beam should be coordinated with the structural engineer.

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NO	REQUIREMENT	PROPOSED SIZE (mm) (W X D)	CRITERIA / GUIDE
3.12	Trenching Requirement for HT and LV Room (Refer to Figure 2.6)		<p>Layout of the trenches may differ according to the layout of the building and distribution system.</p> <p>If the ground beams are too deep for standard trench depth (900-1200mm), openings in the beam should be coordinated and designed for by the structural engineer.</p>
3.13	Cable Access Ducts into Trenches (Refer to Figure 2.7)		Min 3 no. 150mm dia. G.I. / Composite fiber glass / heavy duty uPVC.
3.14	Cable Access Ducts into Pits (Refer to Figure 2.7)		Min 2 no. 150mm dia. G.I. / Composite fiber glass / heavy duty uPVC.
3.15	Cable Access Ducts into Junction Boxes (Refer to Figure 2.8)		Junction box in RC column: 150mm x 150mm x 50mm with service door, for decorative fence lighting.

Note: All sizes given may differ according to the size of the project.

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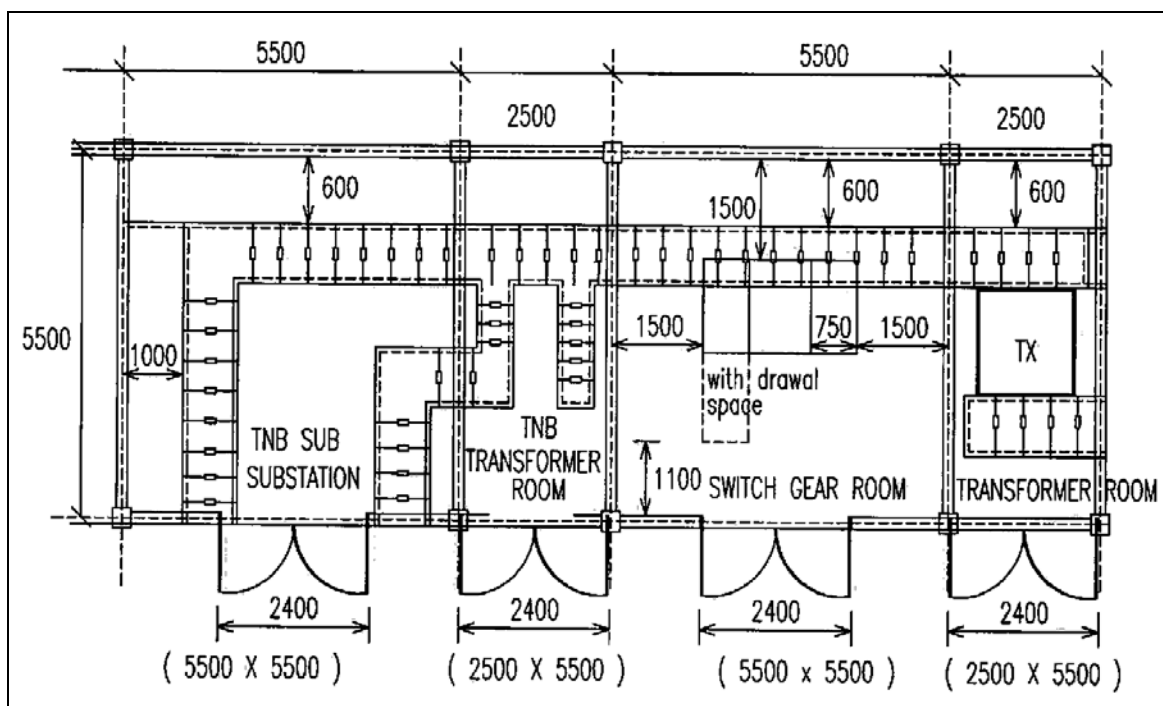


Figure 2.1: Typical 11kV Intake Substation

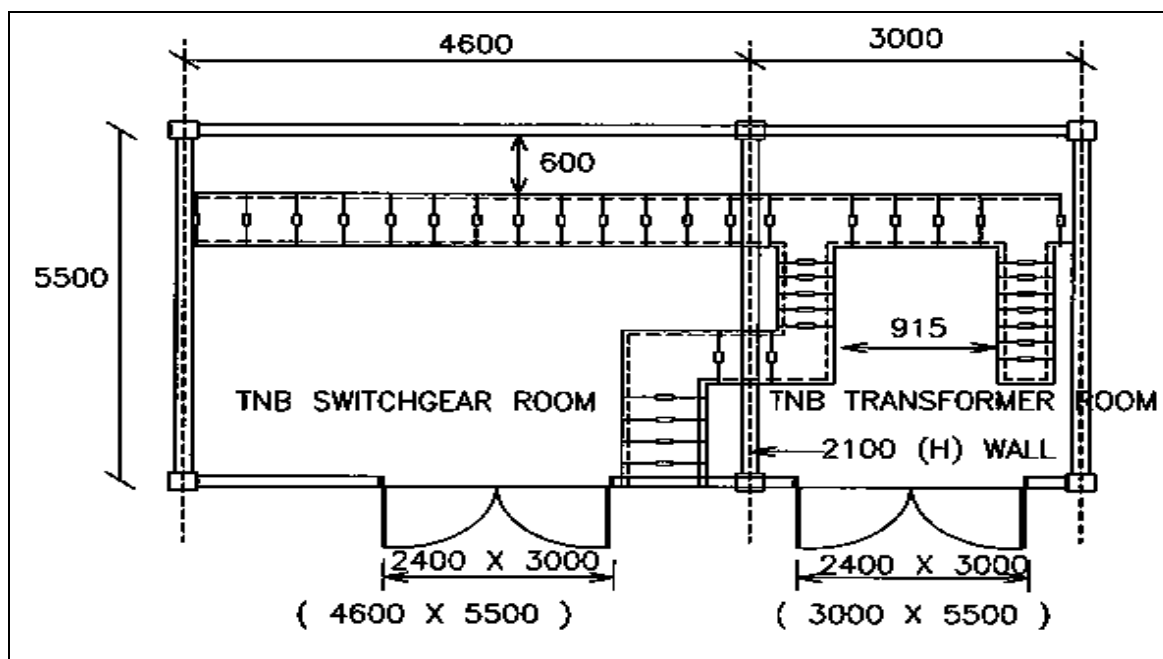



Figure 2.2: Typical Single Chamber TNB Substation

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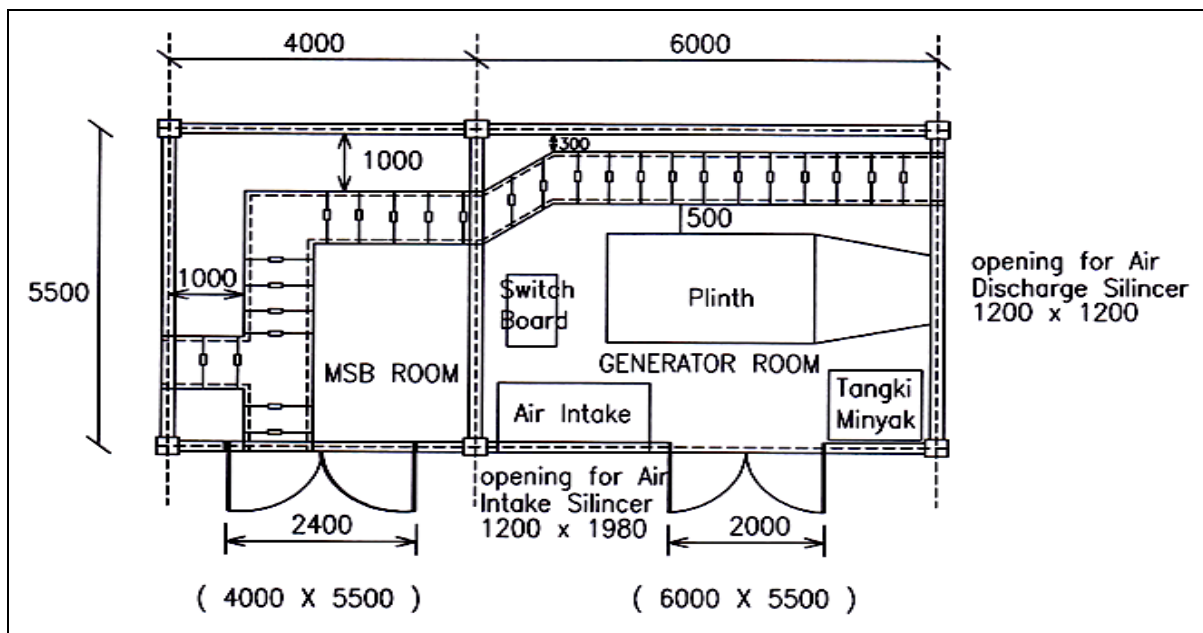


Figure 2.3: Typical Combined Switch Room & Generator Room

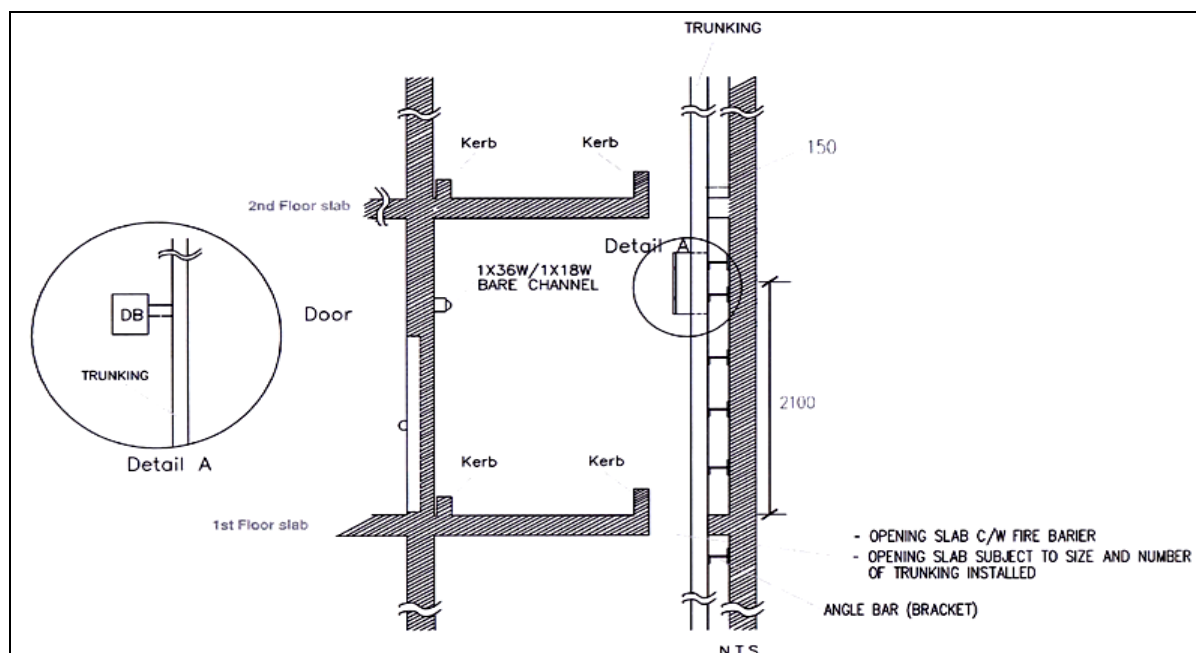



Figure 2.4: Riser Room & Floor Opening

Note: All dimensions are indicative, actual details to be coordinated with the supply authority.

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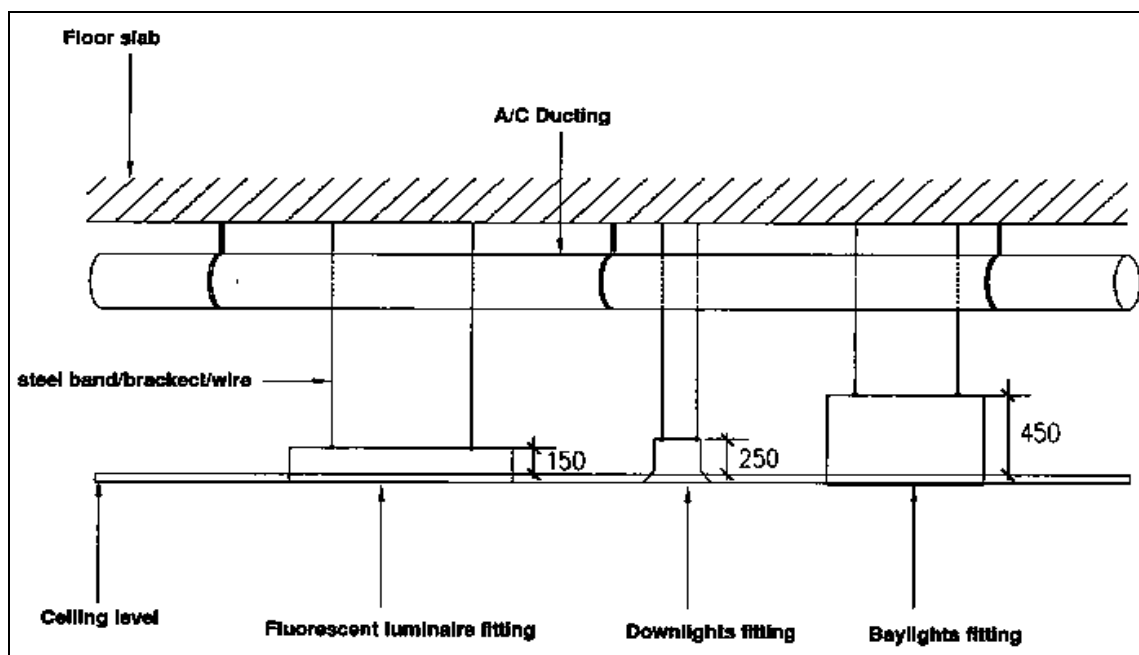


Figure 2.5: Ceiling Space for Luminaire Mounting

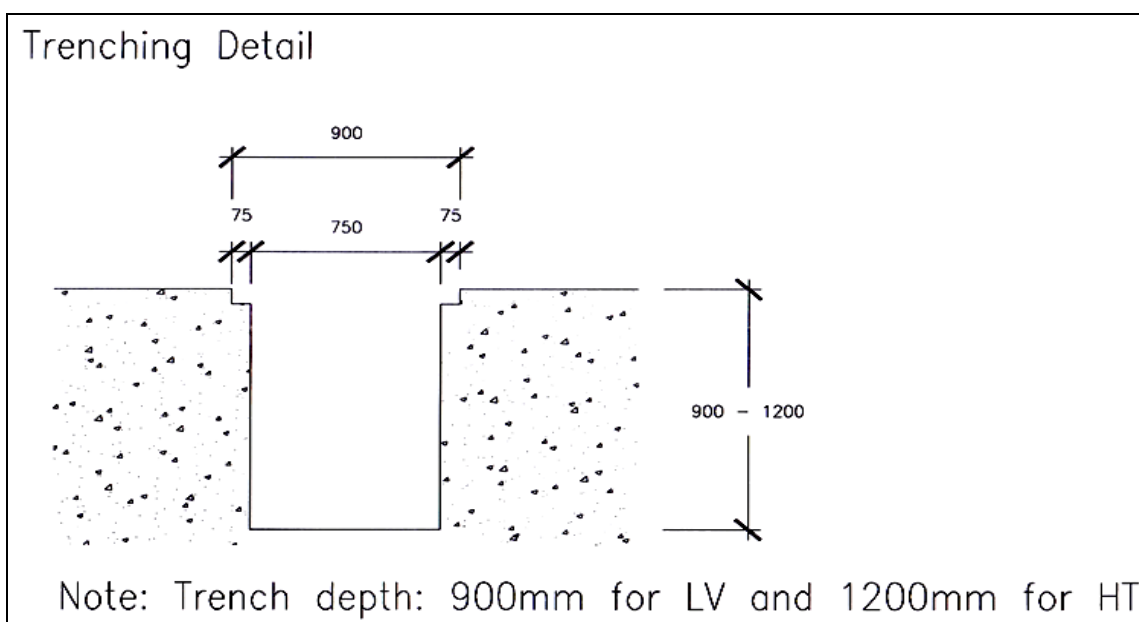



Figure 2.6: Trenching Requirement

Note: All dimensions are indicative, actual details to be coordinated with the supply authority.

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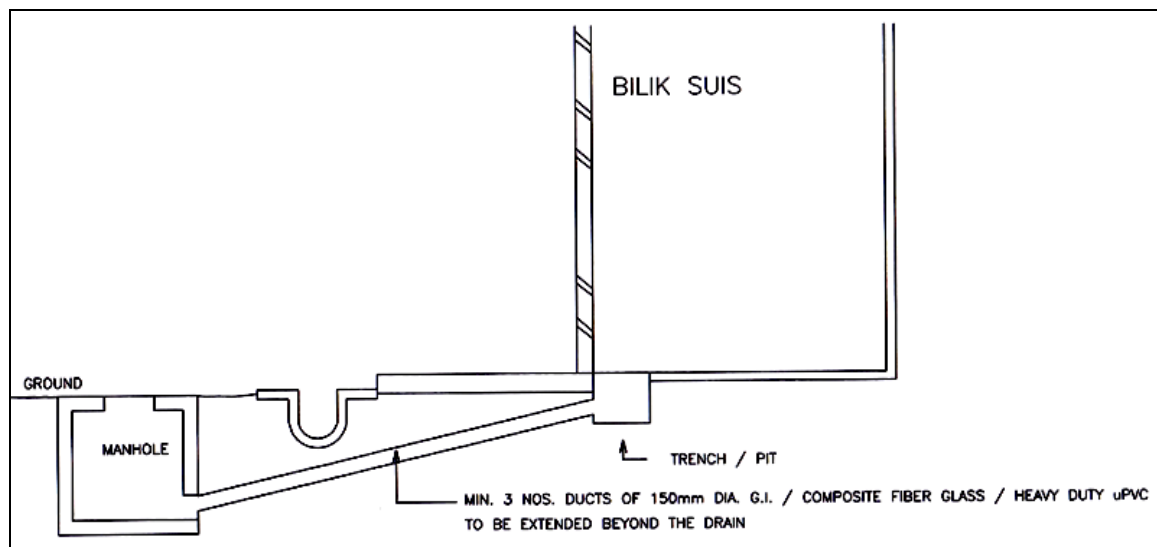


Figure 2.7: Cable Access Ducts Into Trench / Pits

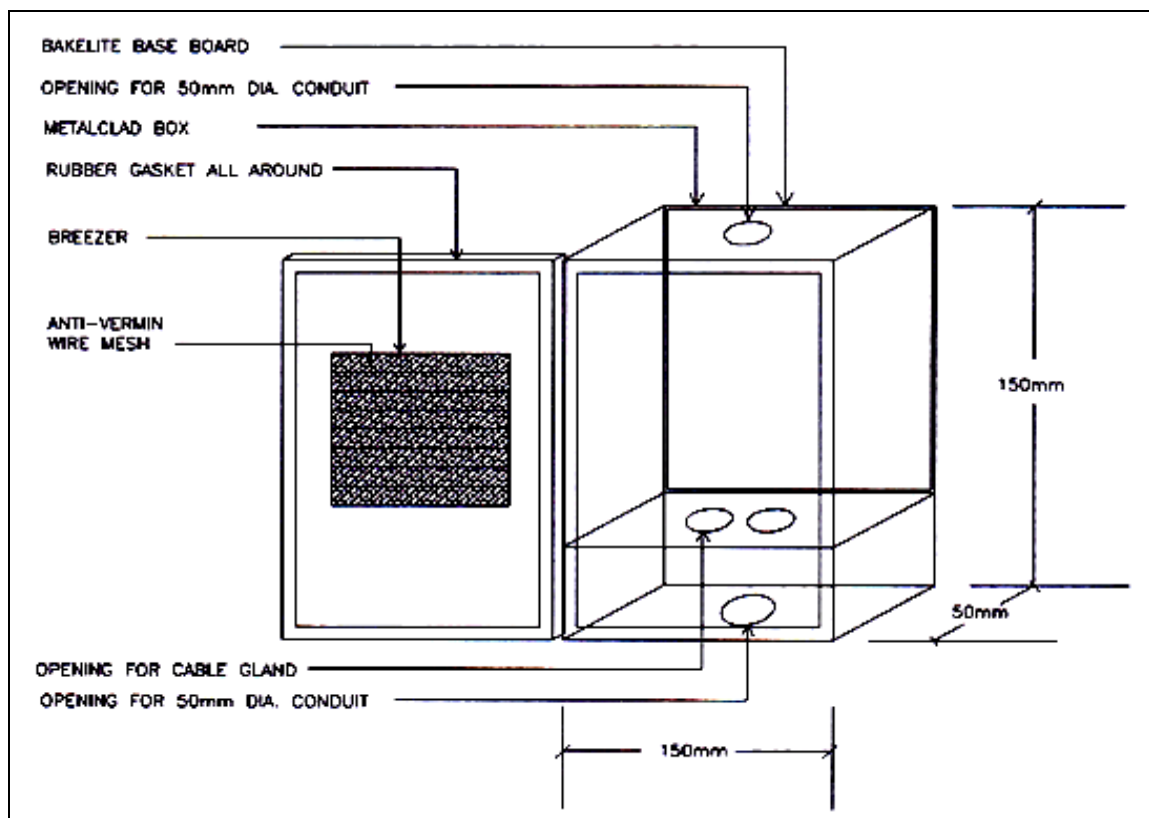



Figure 2.8: Cable Access Ducts Into Junction Boxes for Fence Lighting

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3.1 Introduction

In lighting design, the DE has to ascertain that his design provides adequate lighting. Drawings showing the plan and cross section of each room including the proposed constructional detail of the ceiling and wall, furniture and equipment or machinery layout are required in lighting design. In order to make necessary detailed calculation concerning the type and quantity of lighting equipment, additional information on the surface reflectance of walls, ceiling and floors is required. The level of illumination obtained must conform to the IES Code or in our case, to JKR Standards. (See Appendix 1).

3.2 Basic Information On Lighting

3.2.1 Classification of Fittings

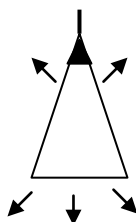
The precise definitions can be formulated in terms of percentage of upward light (to total light output) as illustrated below:-

- Direct



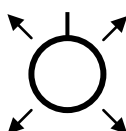
0 – 10%

- Semi Direct




10 – 40%

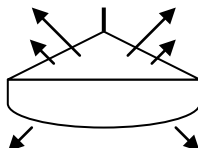
- General Diffusing



40 – 60%

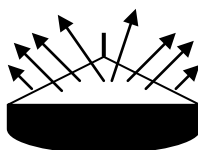
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- Semi Indirect



60 – 90%

- Indirect



90 – 100%

3.2.2 Selection of Light Source

The choice of lamp type is clearly of importance in any lighting design. Among the lamp characteristics which have to be taken into account are efficiency, heat output, size, life, robustness, colour properties and maintainability.

3.2.3 Efficiency


Efficiency is measured in lumen per watt. Generally discharge and fluorescent types have much higher efficiencies than the tungsten filament lamps. Efficiency of tungsten filament lamp is in the range of 10 to 15 lumen / watt, for high pressure mercury the range is 40 to 50 and tubular fluorescent lamps is between 30 to 60.

3.2.4 Heat Output

Less heat is produced in mercury of fluorescent scheme as compared to a tungsten scheme due to the lower wattage necessary to produce the same lumen output. (Every watt of electrical energy put into an interior lighting system ultimately appears as heat).

3.2.5 Size

The small size of the filament lamp is valuable whenever precise light control is needed, e.g. when a definite beam of light is called for. Directional control of the output from a

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fluorescent tube is very limited because of its considerable length. The size of the luminaire selected is important so as to blend with the internal decoration of the room or the room's function.

3.2.6 Lamp Life

The lifetime of a tungsten lamp is dependent on its light output, as one designed for a long life will have a low light output and vice versa. BS 161 quotes a life of 1,000 hours of tungsten lamp, representing an optimum compromise based on the principle of getting the most light per unit cost. In contrast the life to fail of a mercury lamp or fluorescent tube is less important as the lamp life is long.

However the light output falls progressively with time and a stage will be reached where replacement is worthy so as get a greater light output for the same consumption of electricity.

3.2.7 Effect of Vibration of Life-Time


Vibration while the lamp is in used can cause premature failure of filament lamps. Fluorescent & mercury type are less affected by vibration. However, if the design calls for filament lamps, robust type luminaire may be used.

3.2.8 Lamp Colour Temperature

Filament lamps produce a warm effect, which is different from daylight. 'Natural' colour is similar to daylight.

Mercury lamps are bluish-white in appearance and in their colour corrected form, have an effect on colour which is acceptable in many industrial interiors.

Fluorescent tubes offer an extensive colour choice. They fall into two groups, namely 'high efficiency' and 'de-luxe'. The former produces some 50 to over 60 lumens per watt but with some sacrifice of colour quality (however the colour rendering is still better than that of colour corrected mercury lamp). The de-luxe colour is nearly to those of 'natural' colour but with lower efficiency (30 to 40 lumens per watt).

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3.2.9 Comparison between Tungsten and Fluorescent Schemes

In broad terms a tungsten filament scheme is relatively cheap to install but expensive to run. It would be recommended for low initial expenses cases. Low usage or it is used intermittently with frequent switching.

Initial cost of a fluorescent scheme is higher but the extra cost been compensated with higher efficiency lamps.

In a great deal of lighting for effect, in display and in prestige interiors, the precise control possible with the small tungsten source makes it the immediate choice. Normally the fluorescent scheme is the choice for the general lighting of an interior.

3.2.10 Comparison between Colour Corrected Mercury and Fluorescent Scheme.

For many commercial and some industrial situations the colour performance of mercury discharge lamps is inadequate but it can still be accepted.


The limitation of the tubular fluorescent lamp appears in the loading possible per fitting. In heavy industry, the presence of a travelling crane high mounting of fluorescent fitting is necessary. Thus in large industrial interiors it is possible to concentrate the lighting into a relatively small number of high loaded points with resultant economics and materials in both installation and maintenance.

3.2.11 Glare

Glare is experienced if a source of light (be it a window, a luminaire or a reflecting shiny surface) is too bright compared with the general brightness of the surrounding. Glare will makes it more difficult to see detail or contrast in an object and it is known as disability glare. Discomfort glare is the more common type of glare experienced in interiors. It causes visual discomfort, though this may not be apparent but the effect is sense of tiredness, especially towards the end of a working day. This discomfort will also have an effect on working efficiency.

3.2.12 Glare Index

The level of discomfort glare can be expressed numerically as a glare index. (The method of calculating glare index is a bit too details to be included in this manual,

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however the reader can consult the references mentioned to learn the method). The glare index worked out for a particular interior should not be more than the limiting value found in the IES Code for that particular activity.

3.2.13 Controlling glare

- a) One way of reducing glare is to direct visual task away from the line of sight of a bright luminaire.
- b) When luminaries are mounted in regular pattern, the glare index should be calculated and if it is greater than the limiting value then the following changes might be necessary:-
 - i) a change in the orientation of the luminaire
 - ii) a change in the type of luminaire
 - iii) a change in the room surface reflectance
- c) Open luminaries should be fitted with louvers whose cut off angle is sufficient to prevent the lamp being seen at normal angle of view.
- d) Unscreened fluorescent lamps should be mounted in line with the normal direction of view and not across it.
- e) Other guidelines.


3.2.14 Reducing Fire Hazards

Chokes in fluorescent fittings are a fire hazard due to the high temperatures (130°C - 160°C) when they are in operation.

Fluorescent fittings should be separated from the ceiling (Using insulation blocks) by an air gap to reduce fire hazards.

Mineral-insulated copper-sheathed cable should be used for wiring in places that are constantly exposed to heat, oil or moisture.

Arc-free (sparkles) switches and fire-proof fittings should be employed in environments where explosive gas mixtures might be present.

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3.2.15 Flicker

The 50 Hz flicker in discharge lamps can prove distracting to some people. For fluorescent tube, the 50 Hz flicker occurs mainly at the lamp ends, and the effect is more apparent in 5 ft. 80 W tubes than the lower rated current tubes. Flicker can be reduced in these fluorescent lamps of high rated current (5 ft., 6 ft., and 8 ft., tubes) by employing the shielded electrode type.


Confusing stroboscopic patterns seen when moving objects are illuminated by discharge lamps (as experienced in workshops) can be diminished by supplementing the light over the task areas with light from local incandescent lamps.

3.2.16 Lighting and Noise

The induction coil (part of the control of discharge lamps) is usually a source of noise. The fitting housing may become a resonator for this noise especially if it has loose fitting parts which are free to vibrate. Thus special precautions must be taken when lighting equipment is installed in very quiet interiors, such as libraries and places of worship.

3.3 Interior Lighting Design Work Sheet

Calculation may be made more quickly and efficiently using a well designed format as follows:

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INTERIOR LIGHTING DESIGN WORK SHEET

Project : _____ **Room :** _____
Date : _____ **Design By :** _____

Room Data

Room Dimensions	1.	Length : m
	2.	Width : m
	3.	Floor Area : m ²
	4.	Ceiling ht. : m
Surface Reflectance	5.	Ceiling : %
	6.	Wall : %
	7.	Floor : %
Work plane height	8.	m
Luminaire mounting height	9.	m
Room Index (Kr)	10.	

Lamp & Luminaire Data

11.	Manufacturer	
12.	Catalogue Reference	
13.	Lamps per luminaire	
14.	Lumen per lamp	
15.	Coefficient of Utilization	
16.	Maintenance Factor	
17.	Design Factor	
18.	Spacing / Mounting ht. Ratio	

Illuminance

No. of luminaires required to produce desired illumination in LUX		
19.	Desired illuminance :	lux
20.	No. of luminaires :	
Illuminance achieved for No. of luminaires installed by considering spacing / mounting ht. Ratio		
21.	No. of luminaires installed :	
22.	Illuminance achieved :	lux

Calculation Room Index (Kr)

(Line 10) Room Index (Kr)


$$\begin{aligned}
 &= \frac{Length \times Width}{Hm \times (Length + Width)} \\
 &= \frac{Line\ 1 \times Line\ 2}{(Line\ 9 - Line\ 8) \times (Line\ 1 + Line\ 2)} \\
 &= \text{Line 10}
 \end{aligned}$$

Calculating No. of Luminaires

No. Of Lum.	$= \frac{Length \times Width \times Desired\ Illuminance}{Lamp.\ per\ Luminaire \times Lumen\ Lamp \times C.O.U \times M.F \times D.F}$
Line 20	$= \frac{Line\ 3 \times Line\ 19}{Line\ 13 \times Line\ 14 \times Line\ 15 \times Line\ 16 \times line\ 17}$

Calculating Illuminance Achieved

Illum. achieved	$= \frac{Length \times Width \times Desired\ Illuminance}{Lamp.\ per\ Luminaire \times Lumen\ Lamp \times C.O.U \times M.F \times D.F}$	[lux]
Line 22	$= \frac{Line\ 21 \times Line\ 13 \times Line\ 14 \times Line\ 15 \times Line\ 16 \times line\ 17}{line\ 3}$	

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3.3.1 Room Data

This is physical data obtained from blue print or by actual measurement. Inside dimension should be used.

3.3.2 Lamp and Luminaire Data


A wide range of luminaires are available from various manufacturers for various application like commercial, industrial, decorative, high bay, etc. for light sources – halogen lamp, CFL, fluorescent tube, HPMV, etc. Refer to Appendix 2 (Lamp – Lumen table) and Appendix 3 (Luminaire – Coefficient of Utilization table)

3.3.3 Coefficient of Utilization, (C of U)

Coefficient of Utilization is the ratio of the actual flux received on a working plane to the installed flux. It is a measure of the degree to which the installed lamps has been use fully applied. The ratio depends on the proportions of the room, the design of the fitting, and the reflection factors of the rooms' surfaces. Illumination (E) thus can be expressed as:

$$E = C \text{ of } U \times \text{Installed flux per unit area}$$

Note: This formula holds only if the lighting installation is perfectly clean.

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3.3.4 Practical Example on Average Illumination

This is the measure of the average concentration of light on a surface. The unit of illumination is the lux (lumen/sq. metre) where lumen is the unit of light. Thus if 50% of the light output of 1 x 18 watt fluorescent lamps ultimately fall on a working plane measuring 2 m by 3 m. What is the average illumination?

The lighting design Lumens (LDL) of the lamps is given by Appendix 2 to be 1130 lumens (lm).


$$\begin{aligned}
 \text{Total light output} &= 4 \times 1130 \text{ lm} \\
 \text{Light reaching surface} &= \frac{50}{100} \times 4 \times 1130 \\
 &= 2260 \text{ lm} \\
 \text{Area} &= 2 \times 3 \text{ m}^2 \\
 \text{Average illumination} &= \frac{\text{Incident Light}}{\text{Area}} \\
 &= \frac{2260}{2 \times 3} = 376.67
 \end{aligned}$$

3.3.5 Installed Flux (Lumen)

If we take the light output of the luminaire (light fitting) and multiply by their number, the product represents the installed flux.

A room is fit by 2 x 18 watt fluorescent lamps and tungsten bulb 100 watt lamp. What is the installed flux?

$$\begin{aligned}
 \text{Installed flux} &= (2 \times 1130) + (1 \times 1160) \\
 &= 3420 \text{ lm}
 \end{aligned}$$

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3.3.6 Maintenance Factor

Dirt of the fitting has the effect of reducing its light output from it. The conventional assumption is that on average, lighting installation delivers 80% of the light it would do if it were perfectly clean. Thus the average maintenance factor = 0.8. A higher maintenance factor, say 0.9 can be assumed if the fittings are cleaned regularly or it could be as low as 0.5 in a foundry. Taking dirt into account, the modified illumination (E), formula achieved is:


$$E = C \text{ of } U \times \text{Maintenance Factor} \times \text{Installed flux per unit area.}$$

3.4 Practical Design Example

The DE usually knows the illumination desired. He also has a prior knowledge of the luminaire he wishes to use. He has to calculate the installed flux and thus number of fittings needed.

Consider the following general office of floor dimension 12 m (L) by 6 m (W) and ceiling height 3 m. JKR illuminations standards recommended an illumination of 500 lux. How many lamps are needed to attain this illumination level?

By using the previous Interior Lighting Design Work Sheet, the calculation now will be as follow:

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INTERIOR LIGHTING DESIGN WORK SHEET

Project : ABC Office
Date : 25/10/2005

Room : General Office
Design By : DV

Room Data

Room Dimensions	1.	Length : 12	m
	2.	Width : 6	m
	3.	Floor Area : 72	m ²
	4.	Ceiling ht. : 3	m
Surface Reflectance	5.	Ceiling : 50	%
	6.	Wall : 50	%
	7.	Floor : 10	%
Work plane height	8.	0.85	m
Luminaire mounting height	9.	3.0	m
Room Index (Kr)	10.	1.86	

Lamp & Luminaire Data

11.	Manufacturer	XYZ Sdn. Bhd.
12.	Catalogue Reference	Mirror Optics
13.	Lamps per luminaire	2
14.	Lumen per lamp	3250
15.	Coefficient of Utilization	0.58
16.	Maintenance Factor	0.8
17.	Design Factor	0.95
18.	Spacing / Mounting ht. Ratio	1.5

Illuminance

No. of luminaires required to produce desired illumination in LUX			
19.	Desired illuminance	500	lux
20.	No. of luminaires	13	nos
Illuminance achieved for No. of luminaires installed by considering spacing / mounting ht. Ratio			
21.	No. of luminaires installed	12	nos
22.	Illuminance achieved	477	lux

Calculation Room Index (Kr)

(Line 10) Room Index (Kr)

$$= \frac{Length \times Width}{Hm \times (Length + Width)}$$

$$= \frac{Line 1 \times Line 2}{(Line 9 - Line 8) \times (Line 1 + Line 2)}$$


$$= \text{Line 10}$$

Calculating No. of Luminaires

No. Of Lum.	$= \frac{Length \times Width \times \text{Desired Illuminance}}{Lamp. per Luminaire \times Lumen Lamp \times C.O.U \times M.F \times D.F}$
Line 20	$= \frac{Line 3 \times Line 19}{Line 13 \times Line 14 \times Line 15 \times Line 16 \times line 17}$

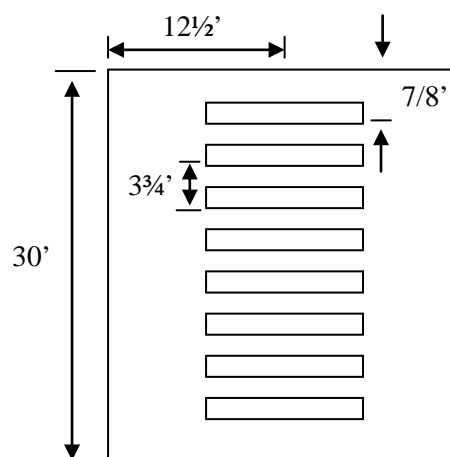
Calculating Illuminance Achieved

Illum. achieved	$= \frac{Length \times Width \times \text{Desired Illuminance}}{Lamp. per Luminaire \times Lumen Lamp \times C.O.U \times M.F \times D.F}$	[lux]
Line 22	$= \frac{Line 21 \times Line 13 \times Line 14 \times Line 15 \times Line 16 \times line 17}{line 3}$	

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3.5 Arrangement of fittings


Possibly the simplest way of arranging the 8 fitting of luminaires would be to space them equally in a line down the middle of the room.



It is clear that the illumination in the middle would be much higher than that at the sides.

3.6 Spacing for Uniform Illumination

Besides appearance design, the aim of lighting design is to have uniformity in illumination over the working plane. Complete uniformity is impossible in practice, but an acceptable standard is for the minimum to be at least 70% of the maximum (IES Recommended figure).

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3.7 Spacing / Mounting-height ratio

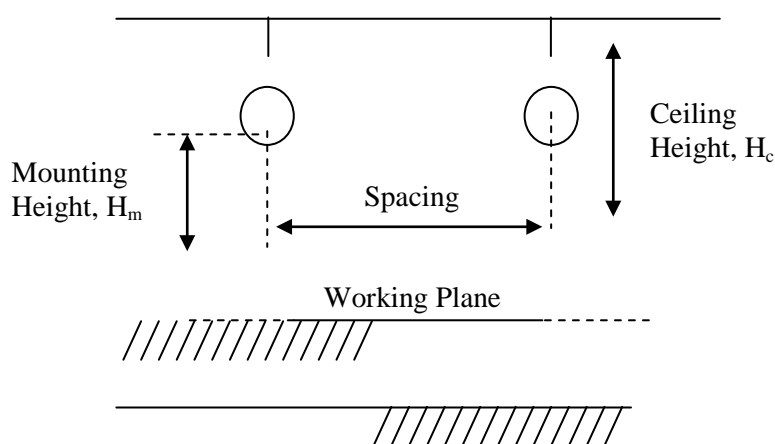



Table 3.1: Maximum Permissible Spacing/Mounting Height Ratio for The Following Type of Fittings.

No.	Fittings	Max. spacing	Max. spacing between fitting and wall. (Generally)	Working positions next to wall
1.	a) Indirect fittings b) Semi-indirect fittings (Fittings generally between $\frac{1}{4} H_c$ and $\frac{1}{3} H_c$ below ceiling).	$1\frac{1}{2} H_c$	$\frac{1}{4} H_c$	$\frac{1}{2} H_c$
2.	a) Generally diffusing fitting b) Opal (or similar) base fitting c) Open direct fittings (unlouvered) but other diffusing materials reflectors.	$1\frac{1}{2} H_m$	$\frac{1}{2} H_m$	$1 H_m$
3.	a) Optically designed prismatic control of down drop light fitting b) Louvered fittings	$1\frac{1}{4} H_m$	$\frac{3}{4} H_m$	$\frac{1}{2} H_m$
4.	a) Concentrating fittings b) Optically designed specular reflector fittings	$1 H_m$	$\frac{1}{2} H_m$	

Where: H_c = Ceiling height above the working plane
 H_m = Fitting height above the working plane

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Practical Design Example

Example Calculation on Lux Level and Quantity of Fitting.

Nowadays, the use of computer program such as Excel is widely practiced to expedite the electrical calculations. For example, in lux level calculations, the DE only need to get all the related information / data of the rooms i.e. width, length, height, etc. and insert them into the formula. The below diagram shows the example of the calculation using Excel computer program.



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Pengiraan Untuk Mencari Kuantiti Lampu

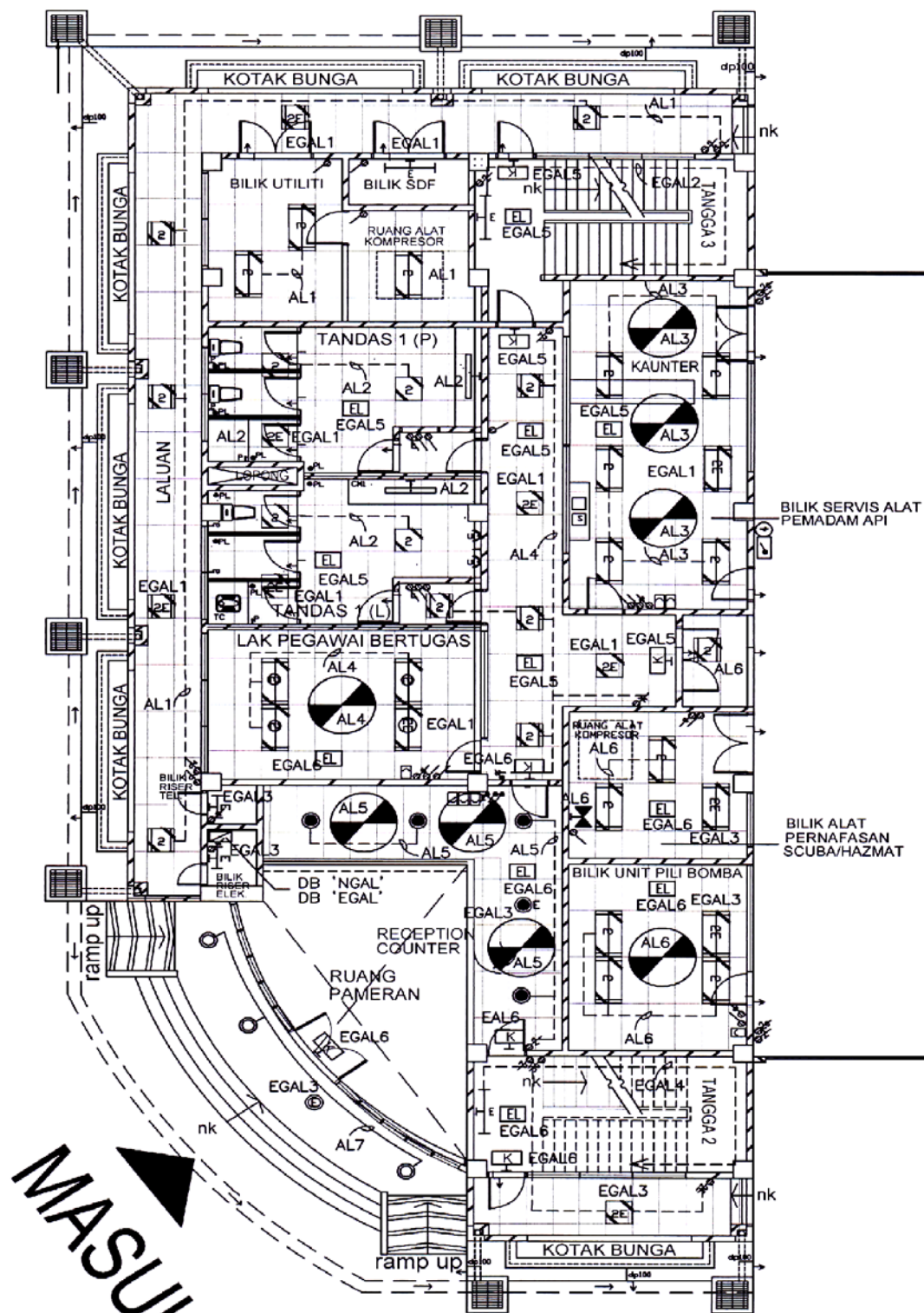
Keraja-kerja keselamatan
Unit Perunding Rekabentuk
Cawangan Elektrik
Ibu Pejabat JKR Malaysia
Jln Sultan Salahuddin, K Lumpur

Projek :Pemasangan Elektrik Untuk Pembinaan
Balai Bomba Dan Kuarters Di Kuala Kubu
Baru, Selangor

Flourescent 54

Bil.	Kod Lokasi	Periphi Bilik (meter)	Luas Bilik (meter)	Tinggi Bilik (meter)	Luas Bilik (meter ²)	Indeks Bilik Lux (lm/ft ²)	Pelaku Pengiraan (C.O.I)	Pencapaian Penyebaran (Lux)	Faktor Singgahan M.F.	Instalasi Flux Lux (lm/ft ²)	Kod Lampu	Jenis Lampu	Rekabentuk Lumen Lampu I.D.L.	Kuantiti Lampu Seleksi	Kuantiti Lampu Seleksi	Lokasi Seleksi	Lux (actual)
1	H4 Switch room	3.00	1.50	3.0	4.50	0.34	0.16	100	0.8	3555.80	F3	Pendafour 1x35w	2650	13	1	SDF Room	75
2	H5 Corridors	20.50	1.50	3.0	30.75	0.47	0.22	100	0.8	4733.53	F2	Pendafour 2x18w	2780	77	6	Laluan A	78
3	H5 Corridors	12.00	1.50	3.0	18.00	0.44	0.21	100	0.8	4048.71	F2	Pendafour 2x18w	2780	48	2	Laluan B	42
4	H4 Switch room	4.50	3.00	3.0	13.50	0.61	0.26	100	0.8	5926.34	F4	Pendafour 2x35w	5300	11	2	Utility Room	179
5	T5 Bedroom	7.50	6.50	3.0	48.75	1.18	0.39	100	0.8	15559.31	F2	Pendafour 2x18w	2780	69	6	Toilet	87
6	H1 Appliance room	4.00	6.50	2.1	26.00	1.18	0.39	300	0.8	24904.43	F4	Pendafour 2x35w	5300	47	4	Bilik Pegawai Bertugas	255
7	P1 Office general	7.00	2.00	3.0	14.00	0.53	0.25	300	0.6	21334.82	P29	FLCOP 2x18w	3600	59	3	Reception Counter	152
8	P1 Office general	4.50	2.00	3.0	9.00	0.47	0.22	300	0.6	15408.48	P28	FLCOP 2x18w	3600	43	2	Reception Counter	140
9	H1 Appliance room	8.50	4.20	2.1	35.70	1.34	0.41	300	0.8	32602.35	F4	Pendafour 2x35w	5300	62	6	Bilik Servis Alat Pemadam Api	293
10	H1 Appliance room	4.00	4.00	2.1	16.00	0.65	0.36	300	0.8	16535.43	F4	Pendafour 2x35w	5300	31	3	Bilik Alat Pemadaman	288
11	H1 Appliance room	4.50	4.00	2.1	19.50	1.05	0.38	300	0.8	19545.05	F4	Pendafour 2x35w	5300	37	4	Bilik Unit Pili Bomba	325
12	P1 Office general	6.00	5.50	2.1	33.00	1.37	0.41	300	0.8	28863.10	F4	Pendafour 2x35w	5300	56	7	Bilik KAB	372
13	H5 Corridors	11.50	1.50	3.0	18.40	0.48	0.22	100	0.8	10351.34	F2	Pendafour 2x18w	2260	46	4	Laluan Ke Tangga 3	87
17	H5 Corridors	5.00	1.50	3.0	9.00	0.41	0.19	100	0.8	5926.34	F2	Pendafour 2x18w	2260	26	1	Laluan Ke Tangga 2	38
25	H5 Corridors	10.00	1.50	3.6	16.00	0.38	0.18	100	0.8	11361.71	P29	P2-COP 2x18w	3600	31	4	Entrance	129

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




















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Diagram 1

LEGEND (NON-ESSENTIAL)

SYMBOL	DESCRIPTION
	1 X 18W (F) WALL MOUNTED CHANNEL LUMINAIRE
	1 X 36W (F) WALL MOUNTED CHANNEL LUMINAIRE
	1 X 36W (F) MIRROR LIGHT LUMINAIRE
	2 X 18W (F) SURFACE MOUNTED LUMINAIRE C/W ALUMINIUM LOUVERS (TOILET)
	2 X 18W (F) RECESSED LUMINAIRE C/W ALUMINIUM LOUVERS
	2 X 36W (F) SURFACE MOUNTED LUMINAIRE C/W LOUVERS
	2 X 36W (F) RECESSED LUMINAIRE C/W ALUMINIUM LOUVERS
	1500mm DIA. CEILING FAN
	SWITCH PANEL
	2X18W PLC SURFACE MOUNTED DOWNLIGHT
	2X18W PLC RECESSED MOUNTED DOWNLIGHT


LEGEND (ESSENTIAL)

SYMBOL	DESCRIPTION
	1 X 18W (F) ESSENTIAL WALL MOUNTED CHANNEL LUMINAIRE
	1 X 36W (F) ESSENTIAL WALL MOUNTED CHANNEL LUMINAIRE
	2 X 36W (F) ESSENTIAL RECESSED LUMINAIRE C/W ALUMINIUM LOUVERS
	2 X 18W (F) ESSENTIAL SURFACE MOUNTED LUMINAIRE C/W ALUMINIUM LOUVERS (TOILET)
	2 X 18W (F) ESSENTIAL RECESSED PLASTER LUMINAIRE C/W ALUMINIUM LOUVERS
	2 X 8W (F) KELUAR SIGN LUMINAIRE
	1 X 8W (F) EMERGENCY LIGHT LUMINAIRE
	2 X 36W (F) ESSENTIAL SURFACE MOUNTED LUMINAIRE C/W LOUVERS
	2X18W PLC SURFACE MOUNTED DOWNLIGHT
	2X18W PLC RECESSED MOUNTED DOWNLIGHT

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Appendix 1: Room Illumination Level

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
Circulation Area			
Corridors, Passageway	100	50	100
Lift	150	100	100
Stairs	150	100	100
Escalator	150	150	100
External Covered Ways	30	50	30
Entrances			
Entrance halls, lobbies, waiting rooms	150	100	100
Enquiry desk	500	300	300
Gate houses	300	200	200
Kitchens			
Food stores	150	150 - 300	100
General	500	150 - 300	300
Outdoor			
Controlled entrance halls or exit gate	150	100	150
Entrance and exit car park	30	50	30
Stores, stockyards	30	50	30
Industrial covered ways	50	50	50
Staff Restaurants			
Centre cafeterias, dining room	300	200	300
Medical and First Aids Centres			
Consultant room, treatment areas	500		400
Medical stores	100		100
Rest room	150	150	100

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
Staff Room			
Changing locker and cleaner's room, cloakrooms lavatories	150	100	150
Rest rooms	150	150	150
Store and Stock Rooms			
Telecommunication board, switchboard rooms			500
Cordless switchboard	300		300
Apparatus rooms	150		150
Teleprinter rooms	500		500
Aircraft Maintenance Hangers			
Aircraft engine testing	750		600
Inspection and repairs (hanger)	500		500
Boiler House General	150		150
Fire Stations			
Appliance room	300		300
External apron	30		30
Garages			
External apron general	50		50
Pumps	300		200
Parking areas (interior) general repairs servicing	30		30
Greasing, pits washing polishing	500		300

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
Gas Works			
Exterior walkways and platforms	50		50
Exterior stairs and ladders	100		50
Retort house, oil gas plants, water gas plant purifier, indoor coke, screening and handling plants	100		100
Booster and exhauster houses	150		150
Gauge Tools Rooms			
General	1000		600
Inspection and Testing shop			
Rough work e.g. counting rough Checking of stock parts	300		200
Medium work e.g. 'go' & 'no go' gauges sub-assemblies	500		400
Fine work e.g. radio and telecommunication equipment, calibrated scales, precision mechanism, instruments	1000		600
Very fine work e.g. gauging and inspections of small intricate parts	1500		750
Minute work e.g. very small instruments	3000		1000
Laboratories			
General	750		500
Laundries & Dry Cleaning Works			
Receiving, sorting, washing, drying, ironing (clending) dispatch, drying cleaning, bulk machine work	300		200
Hand ironing, pressing, inspection, mending, spotting			300

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
MACHINE & FITTING SHOP			
Rough bench and machine work	300		200
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing, polishing	500		400
Fine bench and machine work, ordinary automatic machines, rough grinding, medium buffing, polishing	1000		500
PHARMACEUTICAL & FINE CHEMICAL WORKS PHARMACEUTICAL MANUFACTURE			
Grinding, granulating mixing and drying, tableting, sterilizing and washing, preparation of solutions and filling, labelling capping, cartooning, warping	500		300
Inspection	750		400
Fine chemical manufacture, plant processing	300		200
Fine chemical finishing	500		400
Raw material store	300		200
Inspection	750		300
PRINTING WORKS TYPE FOUNDRIES			
Matrix making, dressing type hand and machine casting	300		300
Front assembly sorting	750		400

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
COMPOSING PRESS			
Hand composing, imposition and distribution	750		500
Machine, composition-key board	750		500
Machine, composition casting	300		200
Proof press	500		300
Illuminated tables general lighting	300		200
PRINTING MACHINE ROOM			
Presses	500		300
Premake ready	500		300
Printed-sheet inspection	1000		500
GRAPHIC REPRODUCTION			
General	500		300
Precision proofing, retouching, etching	1000		500
RUBBER PROCESSING FACTORIES			
Preparation needs, dipping molding, compounding calendaring	300		200
Tyre and tube making	500		300
SHEET METAL WORKS			
Bench work, scribing, inspection	750		400
Pressing, punching, shearing stamping, spinning, folding	500		300
SLAUGHTER HOUSE			
General	500		300
Inspection	750		400

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
WELDING & SOLDERING SHOP			
Gas and arc welding rough spot welding	300		200
Medium soldering, brazing spot welding e.g. domestic hand ware	500		300
Fine soldering, spot welding e.g. instrument	1000		500
Very fine soldering, spot welding e.g. radio valves	1500		750
WOODWORKING SHOP			
Rough sawing, bench work	300		200
Sizing, planning, rough sanding medium and bench work gluing cooperage	500		300
Fine bench and machine work fine sanding, finishing	750		400
OFFICE			
General office with mainly clerical task and typing office	500	300 - 400	500
Deep plan general offices	750	300 - 400	300
Business machine and typing	750	300 - 400	300
Filling room	300	200	300
Conference rooms	750	300 - 400	300
OFFICES & SHOP			
Executive office	500	300 - 400	300
Computer rooms	500	300 - 400	500
Punch card rooms	750	300 - 400	600
Drawing offices drawing boards	750	300 - 400	600
Reference table and general	500	300 - 400	300
Print room	300	300 - 400	300

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
SHOP			
Conventional with counters	500	200 - 750	500
Conventional with wall display	500	200 - 750	500
SHOP			
Self service	500	200 - 750	500
Supermarkets	500	200 - 750	500
Hypermarkets	500	200 - 750	500
General	500	200 - 750	500
PUBLIC AND EDUCATIONAL BUILDING ASSEMBLY AND CONCERT HALLS			
Theatre and concert halls	100		100
Cinemas	50		50
Multipurpose	500		300
FURTHER EDUCATION ESTABLISHMENT			
Lecture theatres general	500	300 -500	300
Chalkboard	500	300 -500	300
Demonstration benches	500	300 -500	300
Examination halls, seminar rooms, teaching spaces	500	300 -500	300
Laboratories	500	300 -500	300
FURTHER EDUCATION ESTABLISHMENT			
Workshop	300		300
Staff rooms, student rooms / students hostels etc			
Gymnasium			

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
LIBRARIES			
Shelves, book stack	150	300 - 500	150
Reading table	500	300 - 500	500
Reading rooms, newspaper and magazines	500	300 - 500	500
Reference libraries	500	300 - 500	500
Counters	500	300 - 500	500
Cataloging and sorting	500	300 - 500	500
Binding	500	300 - 500	500
Closed book store	100		100
MUSEUM & ART GALLERIES GENERAL			
Exhibits insensitive to light	300	300	300
Light sensitive exhibit	150		150
Specially light sensitive exhibit	50		50
SCHOOL			
Assembly hall general	special lighting	special lighting	special lighting
Platform and stage	300	300	200
Teaching spaces general	300	300	200
General where also used for further education	500	300	300
Chalkboard	500	300	300
Beedlework rooms	500	300	300
Art rooms			
Laboratories	500	300	300
Workshop	300	300	200

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
Gymnasium	300	300	200
Music practice rooms	300	300	200
TRANSPORT TERMINAL BUILDING			
Airport coach and railway station			
Reception areas (desk) customs and immigration halls	500		300
Railway stations booking offices	500		300
Railway station parcel and left luggage offices counters	300		200
Circulation area	150		100
Waiting area	300		200
HOSPITAL			
Ward unit bed heads general	30 - 50		50
General	150		local lighting
Night	0.1		
Nurse station evening	300		300
Pharmacies dispensing bench	500		300
Shelves	150		
Reception general	300		200
Enquiry desk	500		300
Laboratories	500		300
Operating theatre suits general	400		500
Operating area			
Recovery room and intensive care units	30 50		bedhead
X-ray department radio-diagnostic and rooms fluoroscopy	500		500
Dental surgeries			

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
HOMES			
Living rooms general	50		50
Casual reading	150		150
Sewing darningsrudies desk and protuged	300		300
Bedroom general	50		50
Bedlead kitchen	150		150
Kitchen working area			
Bathrooms	100		100
Halls and landings	150		150
Stairs	100		100
Workshops	300		200
Garages	50		50
INDOOR SPORTS & RECREATIONAL BUILDING			
MULTIPURPOSE SPORTS HALLS			
Athletics, basketball, bowls, judo	300		200
Hockey	700		500
BADMINTON COURTS	300		300
BILLIARD ROOMS			
General	100		150
Table	special lighting		
CARD ROOMS	300		300
GYMNASIA GENERAL	500		300

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Appendix 1: Room Illumination Level (continue)

General Building Areas	IES Standards Illumination Level	MS 1525 Recommendation	Panduan Teknik JKR
SWIMMING POOL			
Top pool	500		300
Spectator areas	150		150
Club recreational	300		200
GENERAL			
Changing rooms showers lockers rooms	150	150	150
TABLE TENNIS			
Club	300		200
Recreational	200		200

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Appendix 2: Lamp - Lumen Table

JENIS LAMPU	LUMEN (LDL)
Pendaflour 1x18w	1130
Pendaflour 2x18w	2260
Pendaflour 3x18w	3390
Pendaflour 1x36w	2650
Pendaflour 2x36w	5300
Pendaflour 3x36w	7950
Pendaflour 4x36w	10600
Tungsten Bulb 40W	325
Tungsten Bulb 60W	576
Tungsten Bulb 100W	1160
Mercury 80W	2500
Mercury 125W	4600
Mercury 250W	10400
Mercury 400W	18000
Mercury 700W	32000
Metal Halide 70W	5500
Metal Halide 150W	12500
Metal Halide 400W	22000
Metal Halide 1000W	70000
Metal Halide 250W	18000
Down Light SL16	1000
PL-L/4P 18w	1200
PL-L/4P 24w	1800
PL-L/4P 36w	2900
PL-L/4P 40w HF	3500
PL-L/4P 55w HF	4800
PL-S/2P 5w	250
PL-S/2P 7w	400
PL-S/2P 9w	600
PL-S/2P 11w	900
PL-S/4P 5w	250
PL-S/4P 7w	400
PL-S/4P 9w	600
PL-S/4P 11w	900


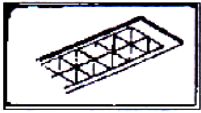
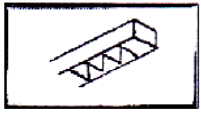

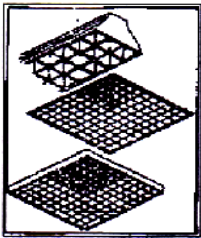
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Appendix 2: Lamp - Lumen Table (continue)

JENIS LAMPU	LUMEN (LDL)
PL-C/2P 10w	600
PL-C/2P 13w	900
PL-C/2P 18w	1200
PL-C/2P 26w	1800
PL-C/4P 10w	600
PL-C/4P 13w	900
PL-C/4P 18w	1200
PL-C/4P 26w	1800
PL-C/2P 2 x 26w	3600
PL-E/C 9w 230-240V	400
PL-E/C 11w 230-240V	600
PL-E/C 15w 230-240V	900
PL-E/C 20w 230-240V	1200
PL-E/C 23w 230-240V	5000
SL Comfort 9w	350
SL Comfort 13w	550
SL Comfort 18w	800
SL Comfort 25w	1050
SL Prisma 9w	400
SL Prisma 13w	600
SL Prisma 18w	900
SL Prisma 25w	1200
SON 50w Standard	3400
SON 70w Standard	5600
SON 1000w Standard	130000
SON PLUS 100w	10000
SON PLUS 150w	16000
SON PLUS 250w	30000
SON PLUS 400w	54000
SON COMFORT 150w	12500
SON COMFORT 250w	22000
SON COMFORT 400w	37000
QL 55w	3500
QL 85w	6000
High-Bay	150

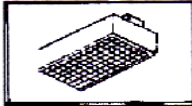
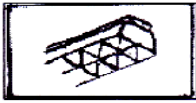




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Appendix 3: Coefficient of Utilization Table

	Description of Fitting and Typical Downward Light Output Ratio %	Typical Outline	Basic Downward L.O.R. %	Ceiling	70		
				Walls	50	30	10
				Room Index			
(M)	Aluminium industrial reflector (72-76)		70	0.6	0.39	0.36	0.33
				0.8	0.48	0.43	0.4
(T)	High-bay reflector, aluminium (72) or enamel (66)			1	0.52	0.49	0.45
				1.25	0.56	0.53	0.5
				1.5	0.6	0.57	0.54
				2	0.66	0.62	0.59
				2.5	0.67	0.64	0.62
				3	0.69	0.66	0.64
				4	0.71	0.68	0.67
				5	0.72	0.7	0.69
(F)	Recessed louvered trough with optically designed reflecting surfaces (50)		50	0.6	0.28	0.25	0.23
				0.8	0.34	0.31	0.28
				1	0.37	0.35	0.32
				1.25	0.4	0.38	0.35
				1.5	0.43	0.41	0.38
				2	0.46	0.44	0.42
				2.5	0.48	0.46	0.44
				3	0.49	0.478	0.46
				4	0.5	0.49	0.48
				5	0.51	0.5	0.49
(F)	Suspended louvered metal trough, upward and downward light, optically designed reflecting surfaces (47-54)		50	0.6	0.35	0.32	0.29
				0.8	0.41	0.38	0.35
				1	0.46	0.42	0.4
				1.25	0.49	0.46	0.43
				1.5	0.52	0.49	0.46
				2	0.56	0.53	0.51
				2.5	0.58	0.55	0.53
				3	0.59	0.57	0.55
				4	0.61	0.59	0.57
				5	0.63	0.6	0.59
(M)	Reflectorised colour-corrected mercury lamp MBFR/U (80-90)		85	0.6	0.4	0.34	0.3
				0.8	0.53	0.46	0.41
				1	0.62	0.55	0.49
				1.25	0.68	0.6	0.55
				1.5	0.72	0.65	0.59
				2	0.81	0.73	0.67
				2.5	0.85	0.78	0.72
				3	0.9	0.83	0.78
				4	0.94	0.89	0.84
				5	0.97	0.92	0.89
(F)	Enamel slotted trough, louvered (45-55) ..		50	0.6	0.27	0.24	0.22
(F)	Louvered recessed (module) fitting (40-50)			0.8	0.32	0.3	0.27
				1	0.35	0.32	0.3
(F)	Shallow ceiling-mounted louver panel (40-50)			1.25	0.38	0.35	0.32
				1.5	0.41	0.38	0.36
				2	0.45	0.42	0.4
				2.5	0.47	0.44	0.42
				3	0.48	0.45	0.44
				4	0.49	0.47	0.46
				5	0.5	0.49	0.48

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Appendix 3: Coefficient of Utilization Table (continue)

	Description of Fitting and Typical Downward Light Output Ratio %	Typical Outline	Basic Downward L.O.R. %	Ceiling	70		
				Walls	50	30	10
				Room Index			
(F)	Suspended opaquesided fitting, upward and downward light, diffuser or louver beneath (40-50) ...		45	0.6	0.28	0.24	0.2
				0.8	0.36	0.3	0.28
				1	0.41	0.36	0.32
				1.25	0.45	0.41	0.36
				1.5	0.49	0.45	0.4
				2	0.55	0.5	0.46
				2.5	0.58	0.53	0.5
				3	0.6	0.56	0.53
				4	0.63	0.59	0.57
				5	0.65	0.62	0.6
(F)	Plastic trough, louvered (45-55) ...		50	0.6	0.26	0.22	0.19
				0.8	0.34	0.29	0.26
				1	0.39	0.34	0.3
				1.25	0.43	0.38	0.34
				1.5	0.46	0.41	0.37
				2	0.5	0.46	0.43
				2.5	0.53	0.49	0.46
				3	0.55	0.51	0.49
				4	0.58	0.54	0.52
				5	0.6	0.57	0.55
(F)	Plastic trough, unlouvered (60-70) ...		70	0.6	0.33	0.28	0.25
				0.8	0.42	0.37	0.33
				1	0.48	0.43	0.38
				1.25	0.52	0.47	0.43
				1.5	0.56	0.51	0.47
				2	0.62	0.56	0.53
				2.5	0.65	0.6	0.57
				3	0.67	0.63	0.6
				4	0.7	0.66	0.64
				5	0.73	0.69	0.67
(T)	Near-spherical diffuser, open beneath (50) ...		50	0.6	0.28	0.22	0.18
				0.8	0.39	0.3	0.26
				1	0.43	0.36	0.32
				1.25	0.48	0.41	0.37
				1.5	0.52	0.46	0.41
				2	0.58	0.52	0.47
				2.5	0.62	0.56	0.52
				3	0.65	0.6	0.56
				4	0.68	0.64	0.61
				5	0.71	0.68	0.65
(F) (F)	Bare lamp on ceiling Batten fitting (60-70)		65	0.6	0.29	0.24	0.19
				0.8	0.37	0.31	0.27
				1	0.44	0.37	0.33
				1.25	0.49	0.42	0.38
				1.5	0.54	0.47	0.42
				2	0.6	0.52	0.49
				2.5	0.64	0.57	0.53
				3	0.67	0.61	0.57
				4	0.71	0.66	0.62
				5	0.74	0.7	0.66
(F)	Enclosed plastic diffuser (45-55) ...		50	0.6	0.27	0.21	0.18
				0.8	0.34	0.29	0.26
				1	0.4	0.35	0.31
				1.25	0.44	0.39	0.35
				1.5	0.47	0.42	0.38
				2	0.52	0.47	0.44
				2.5	0.55	0.51	0.48
				3	0.58	0.54	0.51
				4	0.61	0.57	0.54
				5	0.63	0.59	0.57

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4.1 Introduction

Besides the basic indoor lighting, the DE may have to design for other types such as special lighting for halls, gymnasium, or outdoor facility e.g. façade lighting, courts lighting, area/security lighting, etc.


4.2 Category of Lamps

Table 4.1: Types of Lamps

NO.	TYPE OF LAMP
1.	<u>Reflector Lamp:</u> a) Spotlight b) Floodlight
2.	<u>Incandescent Lamp</u> a) Halogen b) Parabolic Aluminized Reflector (PAR) i) PAR 16 ii) PAR 38 iii) PAR 56 iv) PAR 64
3.	<u>High Intensity Discharge Lamp:</u> a) Mercury Vapour b) Hydrargyrum Medium-arc Iodide (HMI) c) Metal Halide d) Sodium Vapour i) High Pressure Sodium (HPS/SON) ii) Low Pressure Sodium (LPS/SOX)

4.3 Indoor / Industrial lighting

Building with high ceiling such as gymnasiums, multipurpose halls, exhibition halls, etc. shall use less maintenance and high performance type of luminaire such as high-pressure discharge lamps.

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The high ceiling lighting design criteria:


CEILING HEIGHT	TYPE OF LUMINAIRES	CRITERIA
Below 5 metre	Low Bay	Uniform, good glare control and vertical illumination
Above 5 - 15 metre	High Bay	

For high bay luminaries, $S < 1.0 H_m$. Which is, S is maximum spacing between luminaries in order to ensure sufficient uniformity and H_m is Mounting height (distance between luminaries and working plane). The lighting system shall be designed by arrangement of alternating circuits, proper grouping of lighting switches, separate switching etc. so that necessary light fittings can be switched off if desired.

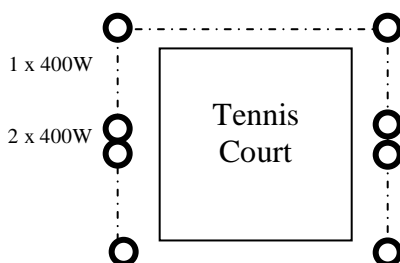
4.4 Outdoor lighting

For security lighting e.g. 125 W, 150 W or 250 W SON with 6 to 10 meter pole and 30 meter apart, single or double arm for external installation shall be taken from essential circuit.

For external courts lighting, floodlighting using SON or Metal Halide lamps shall be considered. The lighting shall be on hot dipped galvanised steel poles/concrete R.C. poles with climbing rungs or etc. for easy maintenance. If the pole height is 8 meter and above, type of mid hinge poles can also be considered. Lighting, feeder pillars, switchboards, distribution board and other equipment installed in the external areas shall be weather-proof, dust-proof and vermin-proof type to IP65 or higher. The location of these feeder pillars, distribution board shall be designed near to the courts. The feeder pillar, distribution board, etc. Shall be hot dipped galvanised or stainless steel.

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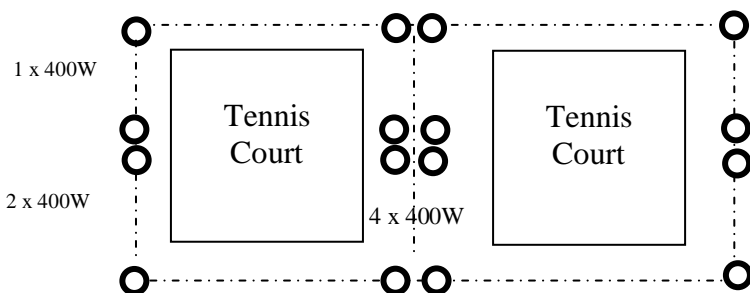
Single court



Legend:

400 W metal halide c/w 6 meter poles and Mounting bracket (3 - 5 meter offset)

Double court (side by side)



Note:

Light fitting - 2 x 400 W and 4 x 400W also can be considering to use 1 x 1000 W and 2 x 1000 W. (400 W – 16 nos, if 1000 W – 10 nos)

4.5 Architectural & Sculptural Lighting

Architectural & Sculptural lighting may consist of floodlight, directional light, etc. It may be installed to enhance the facade of the buildings or to enhance other special aspects, taking in orientation, promotion, identity, ambience and entertainment aspects (if any).



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Table 4.2: General Illuminance of Spotlight / Floodlight For Sports & Recreational Building

Area	IES Std. Service Illuminance LUX	JKR Std. Service Illuminance LUX	Suitable Luminaires	Colour Appearance Of Light	Notes
INDOOR:				Warm	Localize Lighting
Gymnasium	300	200	PAR		
Multipurpose Hall	700	500	PAR down light. (supplementary)		
Auditorium					
Indoor Sport Facilities (Squash Courts)	700	500	SON/ Metal Halide		
OUTDOOR:					Refer MS 825
Street Lighting			HPS		
Security Lighting			SON		
Facade Lighting	300	300	Floodlight		
Badminton Courts	300	200	HPS/SON/ Metal Halide		
Tennis Courts	700	500			
Volley Ball Courts					

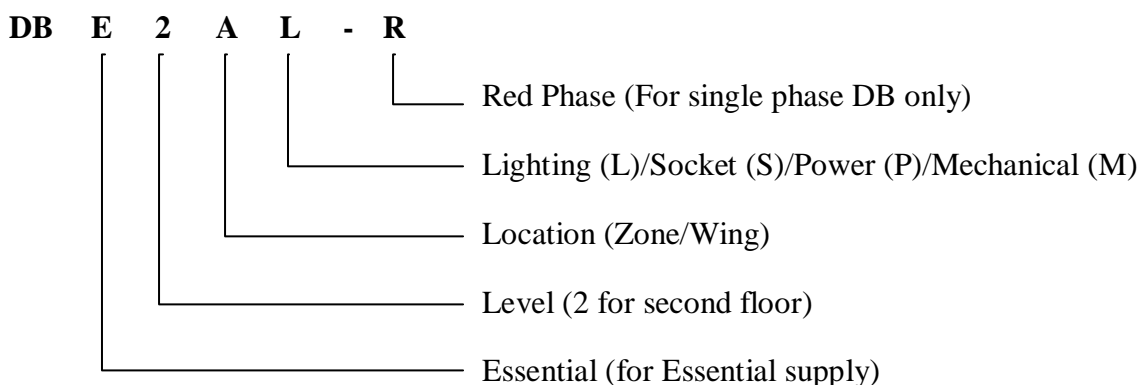
4.6 Others

There is numerous other special type of lighting such as stadium lighting, high mast lighting, utility area lighting etc. For these types of lighting, the DE shall liaise with specialist lighting manufacturers to coordinate the design.

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5.1 Labelling of Distribution Board

CKE adopted the following labelling scheme:




Example:

- a) DB Essential (Power)
 - i) Single phase DB at level 1 zone A yellow phase - DB E1AP – Y
 - ii) Three phase DB at level 2 - DB E2P
- b) DB Normal, without Essential supply (Lighting)
 - i) Single phase DB at level 1 - DB 1L – R
 - ii) Three phase DB at level 2 zone B - DB 2BL

5.2 Information Required to be Included in Schematic Drawing

A. Total Connected Load (TCL).

- Total Connected Load is the sum of all the designed electrical loads in particular installations. (Please refer to appendix 1)
- To be written in the schematic drawing as TCL Watts (Amps). e.g. 4434 W (21.74A).

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B. Diversity Factor (DF).

1. Diversity Factor (DF) is a factor between Maximum Demand and Total Connected Load.
2. Normally, DF is just a factor which is obtained from experience and past project information. It is also the possibility of how certain equipments to be used in the installations.
3. It differs according to function and the usage of the equipment in the system. (Refer to Appendix 2).
4. As a norm, DF for lamps is 0.8 and for socket outlets is 0.4. (Depend on the usage of the building)


C. Maximum Demand (MD).

1. Not all electrical appliances in an installation been used at the same time. Therefore, Maximum Demand (MD) is the total load used at that particular instant of time.
2. MD and DF must be estimated so as not to be overdesign or under design.
3. It may be less or equal to TCL.
4. To be written in the schematic drawing as MD Watts (Amps). e.g. 4,000 W (19.6A).
5. The formula to calculate the MD is :

$$MD = TCL \times DF$$

D. Protective Current Device / Incoming Switch Gears

1. Refer below to determine the size:
 - a) For DB, it is based on TCL.
 - b) For SSB and MSB there are two options depending on the technicality and economic as:
 - i) Based on MD + 30% (future)
 - ii) Based on TCL.

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5.3 Practical Example.

Design and Drawing of Distribution Board For Lightings and Fans .

Please refer to Schematic Drawing 1;

1. The load requirement for every circuit of lighting and fan must be less than 1000 watts or not more than 10 points.
2. Every lighting and fan circuit uses 6 A rated MCB. For light fitting with higher wattage, DE should size the MCB based on calculated wattage.
3. To determine the DB ways.

Add another 20% to the required ways designed, i.e.

$$\begin{aligned}
 (R) &= 8 + 20\% (1.2) = 9.2 \text{ ways} \\
 (Y) &= 8 + 20\% (1.2) = 9.2 \text{ ways} \\
 (B) &= 8 + 20\% (1.2) = 9.2 \text{ ways}
 \end{aligned}$$

Therefore the number of ways required is (3 phase, 10 way DB). Normally the selection will be an even number.

4. To determine the MCCB rating/Switch gear size.


From schematic drawing 1, it shows:

$$\text{Total TCL} = 15.49 \text{ kW (25.35 A)}$$

Therefore the MCCB rating based on TCL will be 40 A TPN 10 kA.

$$\begin{aligned}
 DF &= 0.8 \\
 MD &= \text{TCL} \times DF \\
 &= 15.49 \text{ kW} \times 0.8 \\
 &= \mathbf{12.39 \text{ kW (20.28 A)}}
 \end{aligned}$$

This MD will be used to size the SSB later.

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5. The RCCB has been standardized as 63 A with 100 mA sensitivity for lighting and fan DB.

6. To determine the cable size from MCB to final circuit.

For lighting and fan, the final circuit size will be 1.5mm² PVC cable. (Up to 80 m radius)

For lamp with higher wattage, DE should calculate the lamp wattage and thus the required cable size.

7. Name the DB according to the location of the DB.

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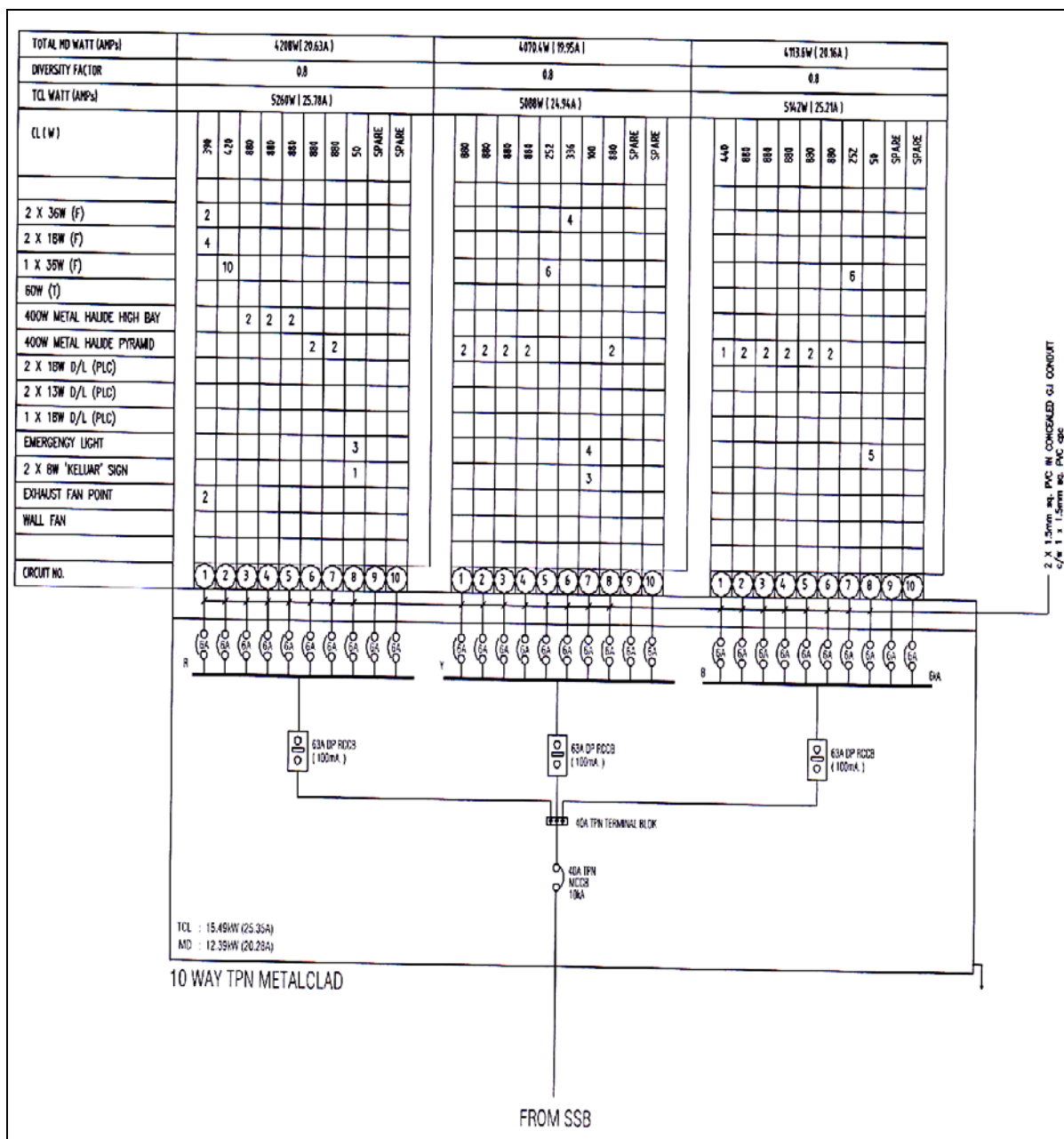



Figure 5.1: Schematic Drawing 1

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5.4 Design and Drawing of Distribution Board for Switch Socket Outlet (S/S/O).

Refer to Schematic Drawing 2;

1. Every radial circuit must not exceed 1500 watts with a maximum of 6 numbers of 13 A outlets. As a norm, each room is equipped with at least 2 numbers of S/S/O for general usage and if there are computer, additional 2 socket outlet will be allocated for each computer.

2. Sizing of MCB

Normally the MCB used are 20 A or 32 A. It will be depending on the type of circuit used:

- Ring circuit – 32 A (not more than 10 numbers of S/S/O).
- Radial circuit – 20 A (not more than 2 numbers of S/S/O).
- Radial circuit – 32 A (not more than 6 numbers of S/S/O).

3. To determine the number of ways in a DB.

Add 20% to the circuit used i.e.

$$\begin{aligned}
 (R) &= 5 + 20\% (1) = 6 \text{ ways} \\
 (Y) &= 5 + 20\% (1) = 6 \text{ ways} \\
 (B) &= 5 + 20\% (1) = 6 \text{ ways}
 \end{aligned}$$

Therefore the number of ways used will be 6 ways 3 phase. The number of ways is normally an even number.

4. To determine the MCCB rating/Switch Gear.


From schematic drawing 2, it shows that:

$$\text{Total TCL} = 19.5 \text{ kW (31.9 A)}$$

Therefore based on TCL, the MCB selected will be rated at 40 A TPN 10 kA.

$$\begin{aligned}
 DF &= 0.5 \\
 MD &= \text{TCL} \times DF \\
 &= 19.5 \text{ kW} \times 0.5 \\
 &= \mathbf{9.75 \text{ kW (16.0 A)}}
 \end{aligned}$$

This MD will be used to size the SSB later.

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5. To determine the RCCB sensitivity.

Required to have 2 different DB for S/S/O.

- a) DB used for portable equipment

DB used for portable equipment, the RCCB sensitivity used will be 30mA in accordance with Electricity Regulation 1994 – Reg. 36 (3).

- b) DB used for computer.

DB for computer load, the RCCB sensitivity chosen will be based on the number of computer used. As a rule of thumb, the leakage current for a computer (monitor + CPU + printer) is estimated to be 1.5 mA to 3 mA. In a worst case scenario, 30 mA RCCB can only cater 10 numbers of computer before it trips. Therefore DE is suppose to calculate the quantity of computer used and selects the RCCB for that particular DB. Normally the next size used will be 100 mA sensitivity instead of 30 mA. This selection is in accordance to Electricity Regulation 1994 – Reg. 36 (4).

Maximum rated current for the RCCB will be 63 A.

6. DB for computer load is required to use SPD Class II type B. Refer to Chapter 17 SPD information.
7. To determine the cable size for S/S/O circuit.
 - For radial circuit (20 A MCB), 2.5 mm² PVC cable is used.
 - For radial circuit (32 A MCB), 4 mm² PVC cable is used.
 - For ring circuit, 2.5 mm² PVC cable is used.
8. Name the DB according to the location of the DB.

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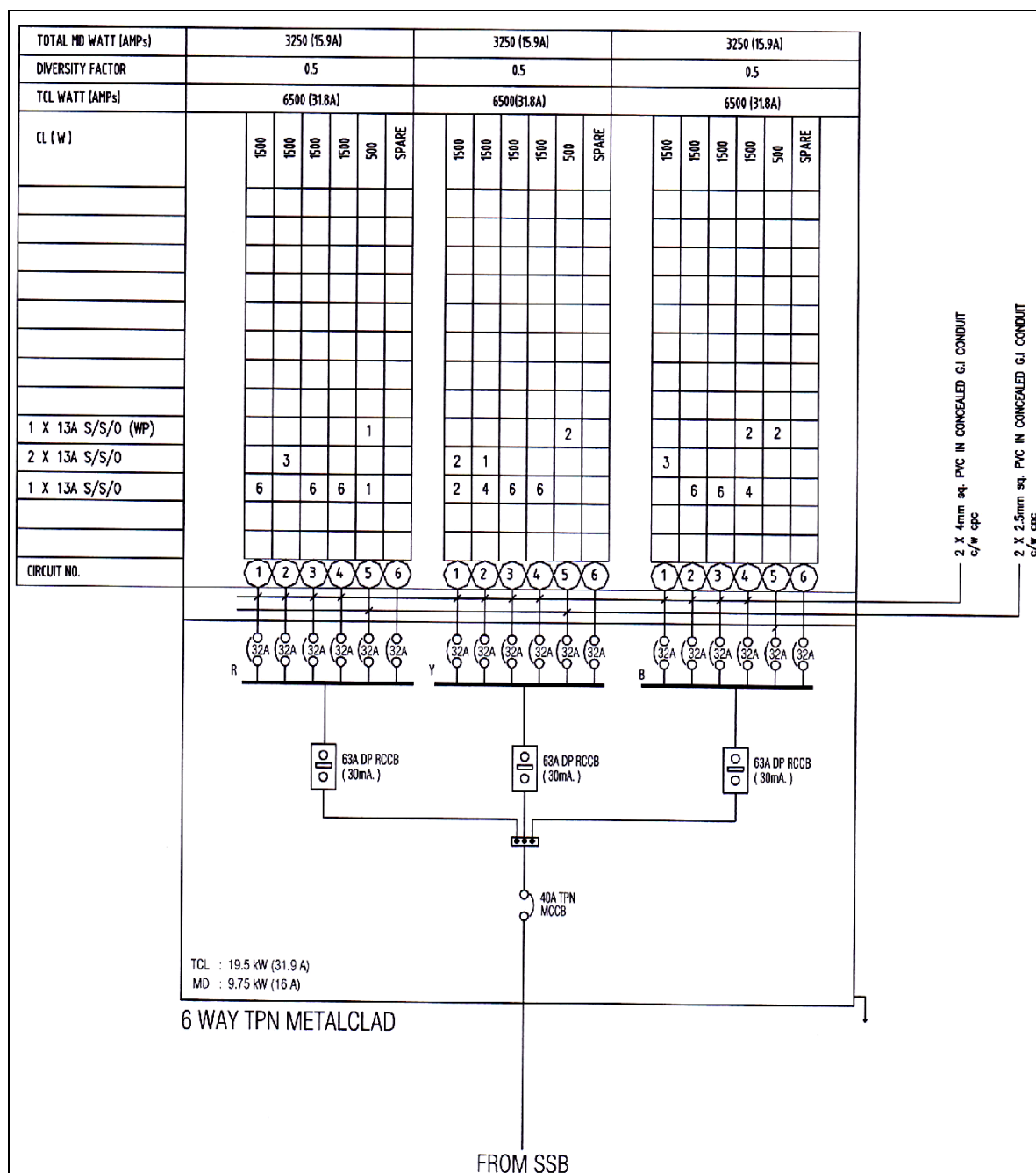



Figure 5.2: Schematic Drawing 2

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5.5 Design and Drawing of Distribution Board for other loads.

Please refer to Schematic Drawing 3;

1. Separate DB will be design for mechanical loads e.g. Air-cond, pumps etc.
2. To determine the MCB rating.
 - For air-cond (window or split unit) with compressor more than 2 h.p the MCB rating used will be 32 A.
 - Water heater also uses the same MCB rating with RCBO.
 - For other load the size is based on the actual load.
3. Usually we use $DF = 1$ for mechanical load but DE is requested to know the operation of this mechanical load before applying the DF.
4. To determine the number of ways for the DB is the same as determining DB way for lighting and S/S/O.
5. To determine the MCCB rating/Switch Gear.

From schematic drawing 3, we find that:

$$\text{Total TCL} = 40.33\text{kW (66.0 A)}$$


Therefore based on TCL MCCB rating will be 100 A TPN

$$\begin{aligned}
 DF &= 1 \\
 MD &= \text{TCL} \times DF \\
 &= 40.33 \text{ kW} \times 1 \\
 &= \mathbf{40.33 \text{ kW (66.0 A)}}
 \end{aligned}$$

This MD will be used to size the SSB later.

6. To determine the RCCB sensitivity.

For circuit which have mechanical load eq. Compressor, motor etc. the RCCB sensitivity will be 100 mA for 1 phase and Earth Leakage Relay (ELR) for 3 phase.

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For water heater the RCCB sensitivity is 10 mA.


7. To size the cable used from MCB to the final circuit.

It is required to calculate in the requirement submitted by Mechanical Engineering Branch.

For Aircond (window or split unit) with compressor not more than 2 h.p, cable used will be 4 mm² PVC and equipment used more than 3 h.p, cable used will be 6 mm² (depending on the volt drop, motor type and distance etc).

Please refer to IEE 16th. Edition Table 9D1.

8. Name the DB according to the location of the DB.

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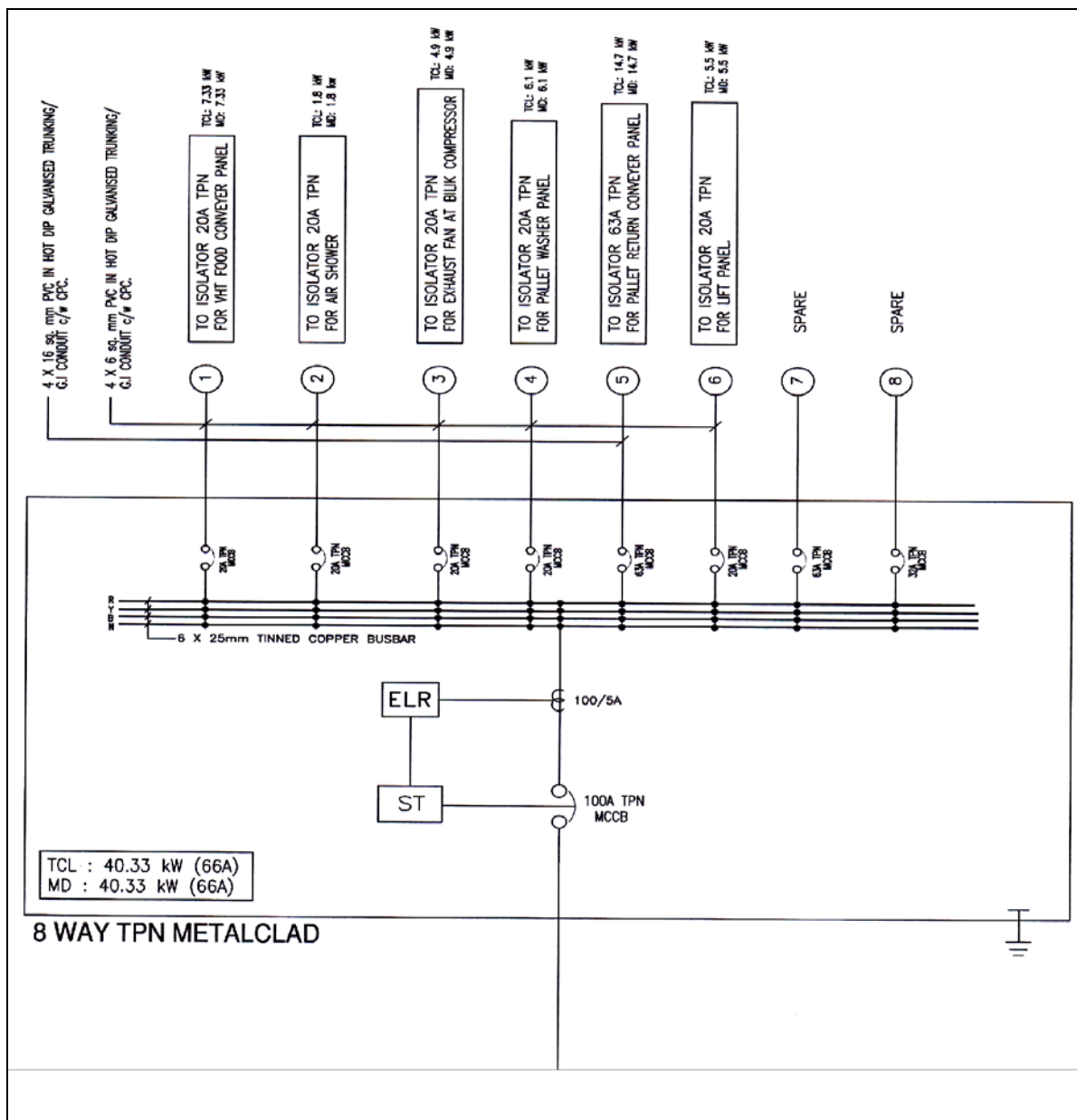




Figure 5.3: Schematic Drawing 3


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Appendix 1: TCL Guide (updated: 15.5.2006)

NO	DESCRIPTION	ESTIMATED LOAD
1	18W Fluorescent	24W
2	36W Fluorescent	42W
3	60W Tungsten	60W
4	100W Tungsten	100W
5	1 × 8W (F) EL	10W
6	2 × 8W (F) LAMPU 'K' SIGN	20W
7	9W PLC	15W
8	11W PLC	17W
9	13W PLC	19W
10	18W PLC	24W
11	9W PLCE	10W
12	11W PLCE	12W
13	13W PLCE	14W
14	18W PLCE	20W
15	50W Halogen Bulb	50W
16	70W Metal Halide/SON	80W
17	150W Metal Halide/SON	170W
18	250W Metal Halide/SON	280W
19	400W Metal Halide/SON	440W
20	Obstruction Light	100W
21	Electric Bell	Ignore
22	2 × 8W (F) Insect Killer	20W
23	1500mm Ceiling Fan	80W
24	1200mm Ceiling Fan	60W
25	400mm Wall Fan	60W
26	500mm Wall Fan	80W
27	400mm Automatic Fan	80W
28	200mm Exhaust Fan	15W
29	250mm Exhaust Fan	25W
30	300mm Exhaust Fan	40W
31	13A 3P Switched Socket Outlet	250W
32	15A Switched Socket Outlet	500W
33	15A SPN Isolator	Motor H.P. rating
34	20A SPN Isolator	Motor H.P. rating
35	30A SPN Isolator	Motor H.P. rating
36	15A TPN Isolator	Motor H.P. rating
37	20A TPN Isolator	Motor H.P. rating

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NO	DESCRIPTION	ESTIMATED LOAD
38	30A TPN Isolator	Motor H.P. rating
39	45A TPN Isolator	Motor H.P. rating
40	60A TPN Isolator	Motor H.P. rating
41	1 HP Air-Cond	746W
42	1.5 HP Air-Cond	1119W
43	2 HP Air-Cond	1492W
44	2.5 HP Air-Cond	1865W
45	3 HP Air-Cond	2238W
46	Water Heater	3Kw
47	Cooker	7.5Kw
48	Booster Pump	Motor H.P. rating
49	Fire Fighting Pump	Motor H.P. rating
50	Fire Fighting Panel	250W
51	CO2 Point	500W
52	SATS System	500W
53	HI KLEEN System	Motor H.P. rating


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Appendix 2: Diversity Factor (DF)

Updated: 21st March 2008

Building	School	Health		Mosque	Hall	Hostel		Dining Hall/ Canteen	Office	Lab		Quarters
		Essential	Non-Essential			School	Executive			Computer	Science	
Lamp/ Fan	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
13A S/S/O	0.1	0.4	0.4	0.4	0.4	0.1	0.4	0.4	0.4	0.6	0.6	0.5
15A S/S/O	1	1	1	1	1	1	1	1	1	1	1	1
AC Motor Pump	1	1	1	1	1	-	1	1	1	1	1	1
Outdoor Lighting	1	1	1	1	-	-	-	-	1	1	1	1
Water Heater	-	-	-	-	-	-	1	1	-	-	-	1
Cooker Unit	1	1	1	-	-	-	-	-	-	-	-	-
Isolator	1	1	1	1	1	1	1	1	1	-	-	-

Note: * DF may be relook based on the day and night profile usage.

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6.1 Type of Switchboards

- a) Floor Standing Front & Rear Access Switchboard.
- b) Floor Standing Front Access Switchboard.
- c) Wall Mounted Switchboards.

Normally it shall be designed to withstand fault condition of not less than 50kA of 415V for 1 second as defined in IEC 60439-1 and shall be of minimum Form 2B when the supply being supplied from the substation's transformer or otherwise stated by the DE.

6.2 Type of Incoming Switchgear

- a) Air Circuit Breaker (ACB) – normally being used.
- b) Moulded Case Circuit Breaker (MCCB).

They shall be certified for minimum rupturing capacity of 50kA at 415V for 1 second as defined in IEC 60947 or otherwise specified to have a breaking capacity of 31 MVA at 415 V with a short time rating of 1 second.


6.3 Number of TNB Incomers

In normal cases TNB will supply the main switchboard with one incomer i.e. comes from a transformer. In some cases TNB will supply the main switchboard with 2 incomers i.e. comes from 2 transformers.

This may happen when:-

- i) A single transformer is insufficient to cater for the total load of the installation, or
- ii) A more secured supply system for the installation is required.

When the main switchboard is being supplied with two incomers, a 4 pole coupler between the two sections of the main busbars should be introduced. The coupler must be mechanically interlocked with the other two incoming Circuit Breaker (CB). This is to ensure that the coupler can only to closed if either one of the two incoming CBs is opened.

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6.4 Outgoing Switchgears

Types of outgoing switchgears are:

- a) ACB
- b) MCCB
- c) Switch fuse
- d) Fuse switch

The selection of the type of switchgears above depends on the current ratings of the load.

6.5 Type of supply to switchboards

- a) Normal supply (from TNB).
- b) Essential supply (from generator set and Uninterruptible Power Supply, UPS).


6.6 Drawings and Sub Switch Board (SSB) Design

Refer to Fig. 6.2: Drawing schematic 1: SSB F;

1. There is no fixed number of outgoing from the SSB. It is determined by the number of outgoing loads supplied from the SSB and a reasonable spare ways to be considered.
2. Sizing of MCCB/Switchgear and busbar.

Sizing of MCCB/Switchgears and busbar is depends on the Maximum Demand (MD) of the outgoing (downstream) loads.

Figure 6.1 show the concept schematic for selection of switchgears and Table 6.1 shows the numbers of Distribution Boards (DB) connected to the SSB F and their sizes of switchgears.

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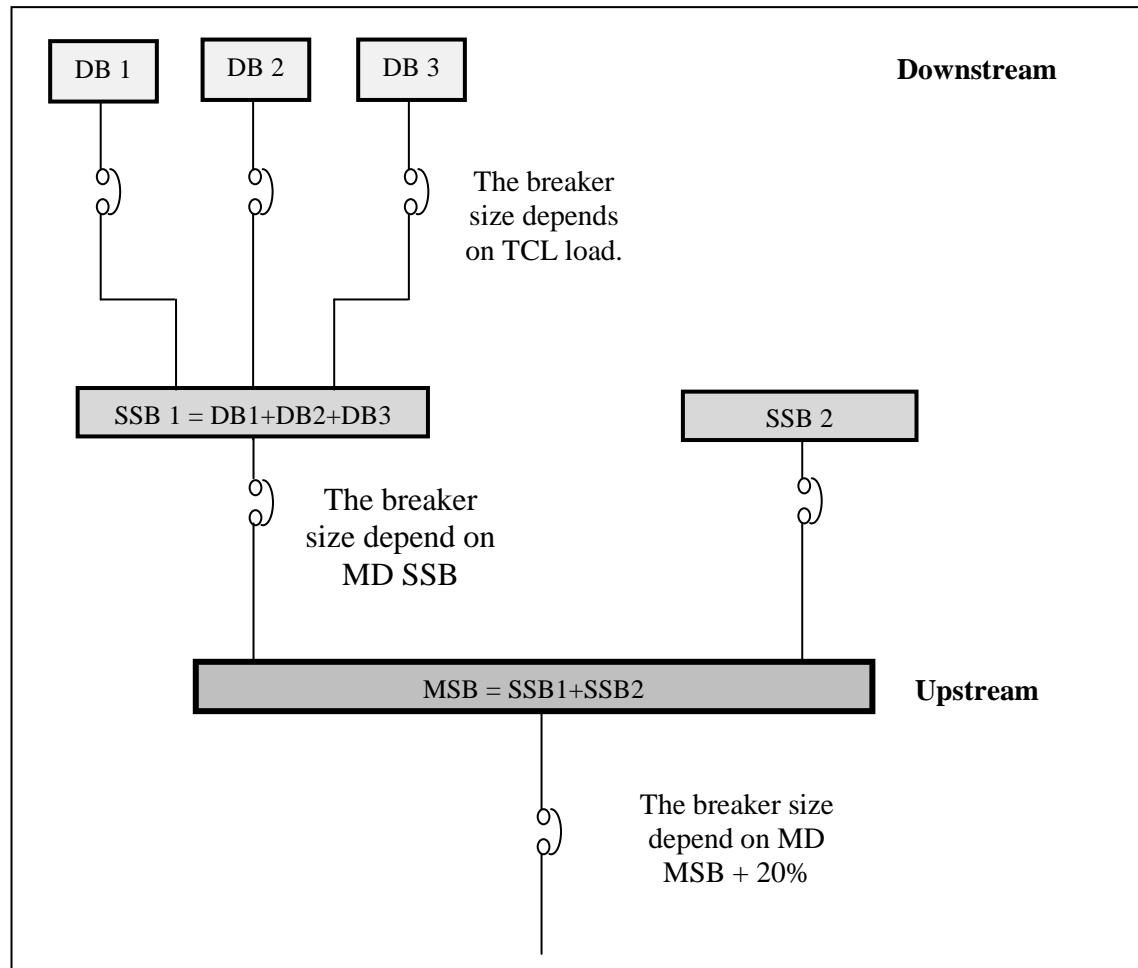


Figure 6.1: Calculation Concept for Determination of Switchgear Size.


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Table 6.1: SSB F


Level	DB Lighting	DB Power	TCL (kW)	MD (kW)	TCL (AMP)	MD (AMP)	S/Gear
G	DB GAL		15.49	12.39	25.35	20.28	40A TPN MCCB
	DB GBL		12.59	10.07	24.61	16.48	40A TPN MCCB
	DB GCL		10.20	8.16	22.69	13.36	40A TPN MCCB
		DB GAP	14.0	7.0	27.91	11.46	40A TPN MCCB
		DB GBP	19.50	9.75	31.91	15.96	40A TPN MCCB
		DB GCP	16.25	8.13	31.60	13.31	40A TPN MCCB
1	DB 1CL		12.82	10.26	20.98	16.79	40A TPN MCCB
	DB 1BL		10.40	8.32	17.02	13.62	40A TPN MCCB
		DB 1CP	4.25	2.13	20.83	10.44	40A TPN MCCB
		DB 1BP	3.50	1.75	17.16	8.58	40A TPN MCCB
		CCTV	4.0	2.0	19.61	9.80	40A SPN MCCB
	CL 1		4.76	3.80	23.33	18.63	32A SPN MCCB
Total			127.76	83.76	263.0	168.71	250A TPN MCCB

From the Table 6.1 above, the sizing MCCB for SSB F is 250 A TPN.

3. Busbar ratings shall not be less than the rating of the incoming switchgear. Busbars shall be of tinned copper type.
4. Type of leakage protection relay are:-
 - a) ELR with Z_{CT} : $20A \leq MCCB \leq 250A$ (3 phase)
 - b) OC/EF : $MCCB > 250A$

Protection relay shall be installed as follows:-

- i) Upstream: For isolators/mechanical loads.
 - ii) Downstream: Loads within the same building.
 - iii) Upstream & Downstream: Loads at different building (a underground cable)
5. The Surge Protection Device (SPD) shall be designed to requirement.
6. Cable sizing from the SSB to DBs to refer to Chapter 7. 'Reticulation Cable Size and Voltage Drop Calculation'

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7. Measuring and Monitoring Devices.

The selection of measuring and monitoring devices depend on the rating of the incoming switchgear and the usage of the panel, which shall include the followings:-

- Incoming phase indicating light – LED type c/w fuse
- Voltmeter
- Ammeter
- Kilowatt hour meter
- Items b, c and d may be replaced with a digital power meter to connect to electrical building automation system (SCADA) enabling collecting data and may be used for measurement of efficiency and improvement etc.


8. Earthing Busbar.

Busbar sizes shall be based on the fault Current Rating. Refer to Table 6.2.

Table 6.2: Dimension of Main Earthing Bars and Earthing Conductors

Prospective Earth Fault currents (I) for 1 s duration	Main Earthing Bars (mm x mm)	Earthing Conductors (No. x mm x mm)
$I \leq 20 \text{ kA}$	25 x 6	2 sets of 1 x 25 x 3
$20 \text{ kA} < I \leq 30 \text{ kA}$	31 x 6	2 sets of 2 x 25 x 3
$30 \text{ kA} < I \leq 40 \text{ kA}$	38 x 6	2 sets of 2 x 25 x 3
$40 \text{ kA} < I \leq 50 \text{ kA}$	50 x 6	2 sets of 2 x 25 x 3

9. The SSB shall be labeled to indicate its location.

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6.7 Design and Schematic Drawing for Main Switch Board (MSB)

Refer to Figure 6.3 Schematic Drawing 2.

1. MSB shall have enough outgoings to the required load and a reasonable spare ways for future consumption.
2. Sizing of MCCB / Switchgears and Busbar.

Sizing of MCCB / Switchgear and busbar depends on the total Maximum Demand (MD) of the outgoing and with additional 20% for some ways. Please refer to table 6.3.

Table 6.3 shows the total load has been connected to Non Essential MSB.


Table 6.3: MSB Non Essential

No.	MSB Non E	TCL (kW)	MD (kW)	TCL (Amp)	MD (Amp)	MCCB Rating
1	SSB G	127.76	83.76	263.0	168.71	250 A
2	Feeder Pillar	5.91	4.73	9.67	7.74	40 A
3	MSB Essential	420.00	409.00	687.40	669.39	800 A
4	MSB FAMA (Existing)	79.80	63.84	130.61	104.48	150 A
5	STP (Sewerage Treatment Plant)	10.00	10.00	16.37	16.37	40 A
Total		643.47	571.33	1107.05	966.69	1200A TPN

$$\begin{aligned}
 \text{MD} + 20\% &= 966.69 + 193.34 \\
 &= 1160.02 \text{ A}
 \end{aligned}$$

Base on calculation above, where the Maximum Demand + 20 % (future) is 1160.02 A, the sizing of switchgear for MSB Non Essential is 1200 A 4 Pole.

The sizing of busbar panel must be same rating as incoming switchgear. The busbar must be tinned copper type.

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3. The SPD must be mentioned.
4. Determination of cable size from SSB to DB.


Refer to the chapter 7, 'Reticulation Cable Size and Voltage Drop Calculation'.

5. Facility of measuring and monitoring devices.

The facility of measuring and monitoring devices at SSB is depending to the incoming switch gear rating and the usage of the panel. The itemised need to install is:-

- a) Incoming phase indicating light – LED type c/w fuse.
 - b) Voltmeter.
 - c) Ammeter.
 - d) Kilowatt hour meter.
 - e) Items b, c and d may be replaced with a digital power meter to connect to electrical building automation system (SCADA) enabling collecting data and may be used for measurement of efficiency and improvement etc.
6. Switchboard Earthing busbar - indicate the bar, its size to be referred to Table 6.2 L-S1, according to the fault current rating.
 7. The MSB shall be labeled to indicate its location.
 - a) MSB NE (Non Essential).
 - b) Supply direct from TNB.
 - c) MSB E (Essential).
 - d) Supply from Generator Set.
 - e) MSB Mechanical, etc.
 8. Block diagram.

(Refer to Figure 6.4: Schematic drawing 3)

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7.1 Introduction

The tabulated current-carrying capacity relates to a single circuit in the installation methods shown in Table 4A (Refer to IEE Wiring Regulation Sixteenth Edition page 181, 182, 183, 184 & 185), in an ambient air temperature of 30°C. The current-carrying capacities given in the tables for AC operation apply only to frequencies in the range 49 to 61 Hz.

The tabulated current-carrying capacity relates to continuous loading and is also known as the ‘full thermal current rating’ of the cable, corresponding to the conductor operating temperature indicated in the headings to the tables concerned. It is intended to provide for a satisfactory life of conductor and insulation subject to the thermal effects of carrying current for sustained periods in normal service. A cable may be seriously damaged, leading to early failure, or its service life may be significantly reduced, if it is operated for any prolonged period at a temperature higher than the indicated value.

In addition, there are other consideration affecting the choice of the cross-sectional area of a conductor, such as the requirements for protection against electric shock, protection against thermal effects, over current protection, voltage drop and the limiting temperatures for terminals of equipment to which the conductors are connected.


Other than that, the conductors will need to be sized in accordance with the relevant circuit criteria. This sizing will also have to be taken into account the type of cable and its insulation. Other requirements that will also affect the size indirectly may include: availability, type of building, environment, security, life expectancy, adaptability, aesthetics and cost.

7.2 Correction factors for current-carrying capacity

In order to determine the current-carrying capacity of the cable, it may be necessary to apply one or more correction factors to the tabulated value given in the appropriate table for the cable.

a) For ambient temperature

Tables 4C1 and 4C2 (Refer to IEE Wiring Regulation Sixteenth Edition page 188) give the correction factor to be applied to the tabulated current-carrying capacity depending upon the actual ambient temperature of the location in which the cable is to be installed.

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b) For grouping

Tables 4B1, 4B2 and 4B3 (Refer to IEE Wiring Regulation Sixteenth Edition page 186 & 187) give the correction factor to be applied to the tabulated current-carrying capacity where cables or circuits are grouped.


c) For thermal insulation

For a cable installed in a thermally insulating wall or above a thermally insulated ceiling the cable being in contact with a thermally conductive surface on one side, the rating factor to applied may, in the absence of more precise information, be taken as 0.75 times the current carrying capacity for that a cable likely to be totally surrounded by thermally insulation material. The applicable rating factor may be as low as 0.5

7.3 Relationship of current-carrying capacity to other circuit parameters

The relevant symbols used in the Regulations are as follows:

- I_z** the current-carrying capacity of a cable for continuous service, under the particular installation condition concerned
- I_t** the value of current tabulated in the Table with referring to the IEE Wiring Regulation Sixteenth Edition for the type of cable and installation method concerned, for a single circuit in an ambient temperature of 30°C
- I_b** the design current of the circuit, i.e. the current intended to be carried by the circuit in normal service
- I_n** the nominal current or current setting of the device protecting the circuit against over current

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C a correction factor to be applied where the installation conditions differ from those for which values of current-carrying capacity are tabulated in IEE Wiring Regulation Sixteenth Edition. The various correction factors are identified as follows:

- C_a for ambient temperature
- C_g for grouping
- C_i for thermal insulation
- C_t for operating temperature of conductor


In all circumstances I_z must be not less than I_b and I_n also must be not less than I_b . However CKE practice is **$I_z > I_n > I_b$**

7.4 Determination of the size of cable

As a preliminary step it is useful to identify the length of the cable run and the permissible voltage drop for the equipment being supplied. The permissible voltage drop in mV, divided by I_b and by the length of run, will give the value of voltage drop in mV/A/m which can be tolerated. A voltage drop not exceeding that value is identified in the appropriate table and the corresponding cross-sectional area of conductor needed on this account can be read off directly before any other calculation are made.

The conductor size necessary from consideration of the conditions of normal load and overload is then determined. All correction factors affecting I_z (i.e. the factors for ambient temperature, grouping and thermal insulation) can, if desired, be applied to the values of I_t as multipliers. This involves a process of trial and error until a cross-sectional area is reached which ensures that I_z is not less than I_b and not less than I_n of any protective device it is intended to select. In any event, if a correction factor for protection by a semi-enclosed fuse is necessary, this has to be applied to I_n as a divisor. It is therefore more convenient to apply all the correction factors to I_n as divisors.

Once the cable type and other characteristics have been considered, the conductor size can be determined. This size will be dependent upon the current required by the circuit load.

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The following procedure enables the designer to determine the size of cable it will be necessary to use in order to comply with the requirement for overland protection.

1. For single circuits

Divide the nominal current of the protective device (I_n) by any applicable correction factor for ambient temperature (C_a), then further divide by any applicable correction factor for thermal insulation (C_i).

The size of cable to be used is to be such that it's tabulated current-carrying capacity (I_t) is not less than the value of nominal current of the protective device adjusted as below:

$$I_t \geq \frac{I_n}{C_a C_i}$$

2. For groups

Divide the nominal current of the protective device (I_n) by the correction factor for grouping (C_g) given in Tables 4B1, 4B2 or 4B3:


$$I_t \geq \frac{I_n}{C_g}$$

Where a rewire able fuse to BS036 is to be used, an additional factor (0.725) must be included, hence

$$I_t \geq \frac{I_n}{0.725 C_a C_i C_g}$$

Thus, the factors to determining current carrying capacity of conductors will be such as:

- cross-sectional area
- type of cable or conductor
- method of installation
- number of conductors grouped together
- Environmental conditions, e.g. high ambient temperature, enclosure in thermally insulating material.

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Once the factors that apply to a particular conductor have been ascertained the value of It can be found by calculation and reference then made to the relevant table i.e. 4D1A (single core PVC insulated), to obtain the cable size.

7.5 Voltage Drop

Values of voltage drop are tabulated for a current of one ampere for a meter run i.e. for a distance of 1 m along the route taken by the cables, and then present the result of the voltage drops in the entire circuit conductor. For any given run the values need to be multiplied by length of the run in meters and by the current the cables are to carry, in amperes. The voltage drop for any particular cable run must be such that the voltage drop in the circuit of which the cable forms a part does not exceed 4% of the nominal voltage of the supply. As a guide, refer to the following diagram. Volt drop from DB to final point need not be calculated. It is assumed to be negligible since we are limiting our final circuit to not more than 80 meters from the DB.

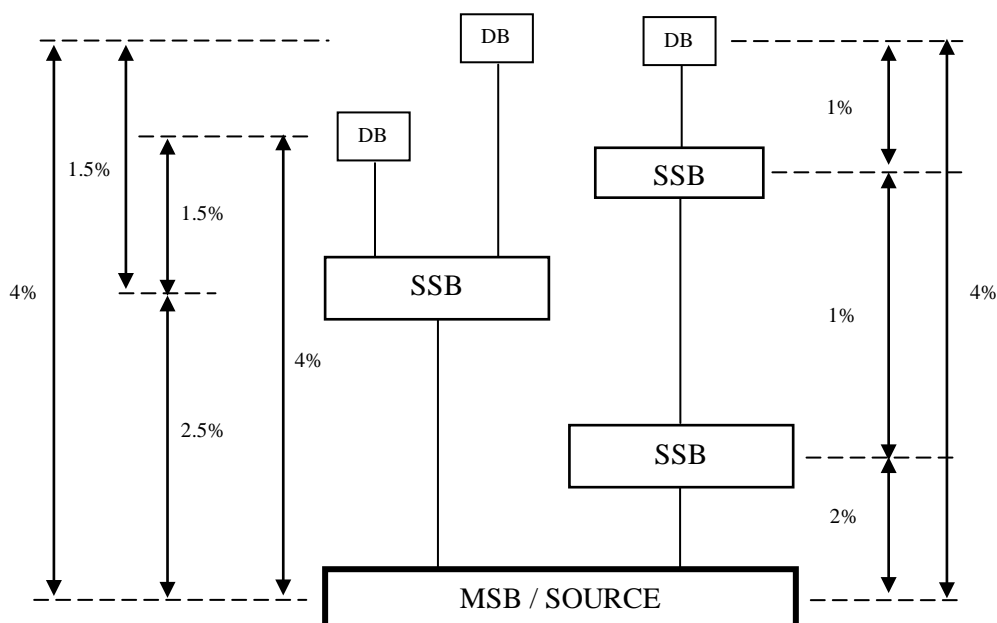



Figure 7.1

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However for external lighting the volt drop from DB to final point must be calculated. The total must not exceed 4%.

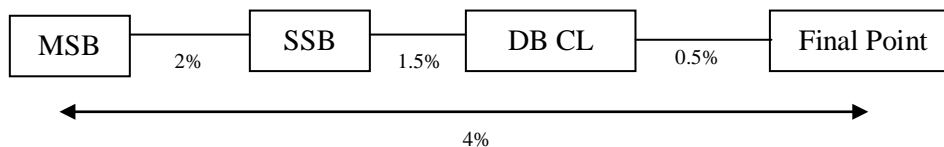


Figure 7.2

The voltage drop calculated from the formula:-

$$\text{Voltage Drop, } VD = \frac{V_d \times L \times I_n}{1000}$$


Where,

- V_d = permissible voltage drop (mV/A/m)
- I_n = the device current of the circuit (A)
- VD = volt drop (V)
- L = length of cable (m)

It is pertinent to point out that the cable rating must always be higher than (or equal to) that of the fuse or circuit breaker that is supposed to protect that part of the installation.

7.6 Type of cables commonly used

It used to be a standard practice in CKE to use PVC/PVC cables for non conduit wiring (surface and concealed). However these two (2) types of wiring are not used anymore in CKE. All wiring must now be in conduit using PVC insulated cables.

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Underground cables that are widely used:

- a) PILCDSTAS Cable (Paper Insulated, Lead Covered, Double Steel Tape Armoured and Served Cable).

This is use conjunction with cable-box termination and is available only in the 3 phase 4 core types, normally used when the 3 phase line current exceeds 40 A.


- b) PVC/SWA/PVC Cable (Polyvinyl Chloride / Steel Wire Armoured / Polyvinyl Chloride Cable).

This cable is used with cable gland terminations and is available both in the 3 phase 4 core as well as in the single phase 2 core. It is generally used when the current demand is less than 60 A.

- c) XLPE / SWA / PVC Cable. (Crosslinked Polyethylene / Steel Wire Armoured / Polyvinyl Chloride Cable)

Normally used for 35 mm² and above.

For more information on other types of cables refer to manufacturers. Unless otherwise required all cables used for JKR projects shall be copper.

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7.7 Practical Design Example

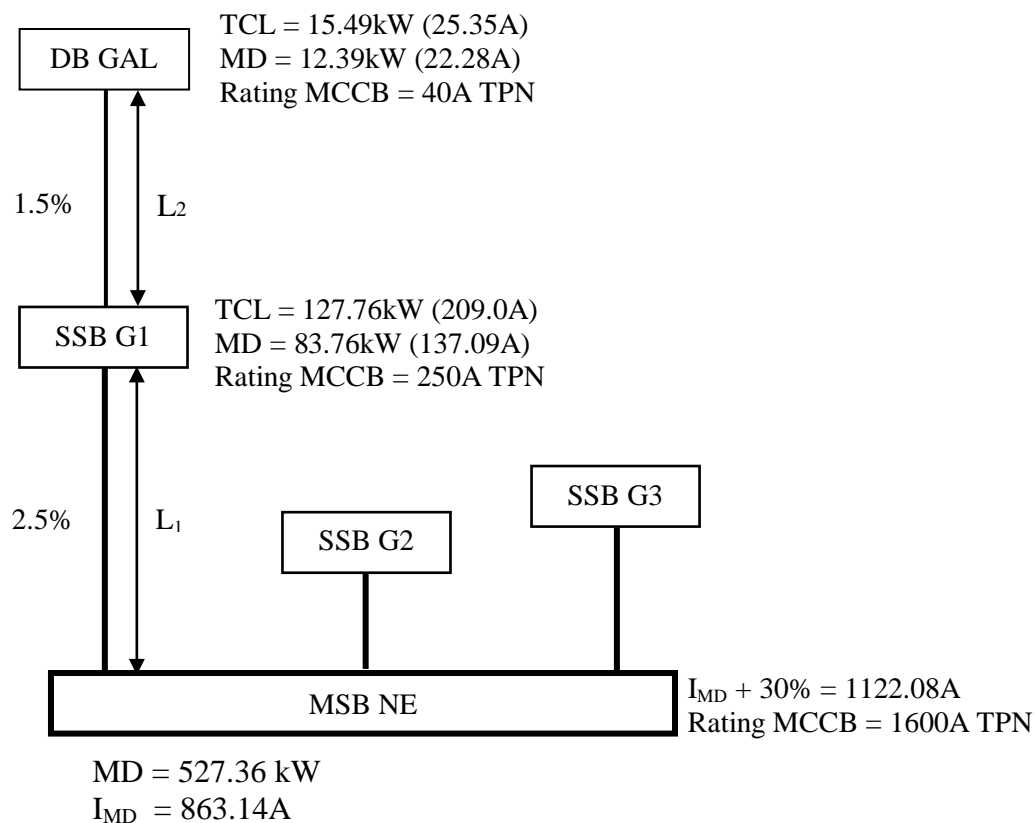



Figure 7.3

Allowable voltage drop:

$$\left. \begin{array}{l} 2.5\% = 10.375 \text{ V} \\ 1.5\% = 6.225 \text{ V} \end{array} \right\} 3 \text{ phase}$$

$$I_z > I_n > I_b$$

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i) **Calculate cable size used and voltage drop from SSB G to DB GAL**

- a) Consider copper conductor used e.g. single core PVC insulated cable and installation method is enclosed in conduit on a wall where $L_2 = 60$ metre.

$$I_z > I_n > I_b$$

Refer to table 4D1A from IEE Wiring Regulation Sixteenth Edition, $I_z = 50$ A

$$\begin{aligned} I_z &> 40 > 22.28 \\ 50 &> 40 > 22.28 \end{aligned}$$

From value of I_z we get cable size of 10 mm².

From table 4D1B voltage drop (per ampere per metre), $V_d = 4.4$ mV/A/m

$$\begin{aligned} \text{Voltage drop (V}_D\text{)} &= V_d \times L_2 \times I_n / 1000 \\ &= 4.4 \times 60 \times 40 / 1000 \\ &= 10.56\text{V} \end{aligned}$$

Therefore cable to be used is 4 x 10 mm² PVC in conduit.

- b) Say L_2 is longer i.e. $L_2 = 80$ metre

$$\begin{aligned} \text{Voltage drop (V}_D\text{)} &= V_d \times L_2 \times I_n / 1000 \\ &= 4.4 \times 80 \times 40 / 1000 \\ &= 7.84 \text{ V} \end{aligned}$$

(exceeding allowable voltage drop of 6.225 V)


Thus, 4 x 10 mm² PVC in conduit cannot be used.

Check again the I_z value.

Refer to table 4D1A from IEE Wiring Regulation Sixteenth Edition, $I_z = 68$ A

$$\begin{aligned} I_z &> 40 > 22.28 \\ 68 &> 40 > 22.28 \end{aligned}$$

From value of I_z we get cable size of 16 mm².

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From table 4D1B voltage drop (per ampere per metre), $V_d = 2.8 \text{ mV/A/m}$

$$\begin{aligned}
 \text{Voltage drop (V}_D) &= V_d \times L_2 \times I_n / 1000 \\
 &= 2.8 \times 80 \times 22.28 / 1000 \\
 &= 4.99 \text{ V}
 \end{aligned}$$

Therefore cable to be used is 4 x 16 mm² PVC in conduit.

ii) **Calculate cable size used and voltage drop from MSB NE to SSB G**

- a) Consider copper conductor XLPE/SWA/PVC cable, installed underground where $L_1 = 110 \text{ metre}$

$$I_z > I_n > I_b$$

Refer to table 4E4A from IEE Wiring Regulation Sixteenth Edition, $I_z = 251 \text{ A}$

$$\begin{aligned}
 I_z &> 250 > 137.09 \\
 251 &> 250 > 137.09
 \end{aligned}$$

From value of I_z we get cable size of 70 mm².

From table 4E4B voltage drop (per ampere per metre), $V_d = 0.60 \text{ mV/A/m}$

$$\begin{aligned}
 \text{Voltage drop (V}_D) &= V_d \times L_1 \times I_n / 1000 \\
 &= 0.60 \times 110 \times 137.09 / 1000 \\
 &= 9.05 \text{ V}
 \end{aligned}$$


Therefore cable to be used is 4 core 70 mm² XLPE/SWA/PVC laid in the ground.

- b) Say L_1 is longer i.e. $L_1 = 155 \text{ metre}$

$$\begin{aligned}
 \text{Voltage drop (V}_D) &= V_d \times L_1 \times I_n / 1000 \\
 &= 0.60 \times 155 \times 137.09 / 1000 \\
 &= 12.75 \text{ V}
 \end{aligned}$$

(exceeding allowable voltage drop of 10.375 V)

Thus, 4 core 70 mm² XLPE/SWA/PVC cannot be used.

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Check again the I_z value.

Refer to table 4E4A from IEE Wiring Regulation Sixteenth Edition, $I_z = 304$ A

$$I_z > 250 > 137.09$$

$$304 > 250 > 137.09$$

From value of I_z we get cable size of 95 mm².

From table 4E4B voltage drop (per ampere per metre), $V_d = 0.45$ mV/A/m

$$\begin{aligned} \text{Voltage drop (V}_D\text{)} &= V_d \times L_1 \times I_n / 1000 \\ &= 0.45 \times 155 \times 137.09 / 1000 \\ &= 9.56\text{V} \end{aligned}$$

Therefore cable to be used is 4 core 95mm² XLPE/SWA/PVC laid in the ground.

c) Say L_1 is longer i.e. $L_1 = 250$ metre

$$\begin{aligned} \text{Voltage drop (V}_D\text{)} &= V_d \times L_1 \times I_n / 1000 \\ &= 0.60 \times 250 \times 137.09 / 1000 \\ &= 20.56 \text{ V} \end{aligned}$$

(exceeding allowable voltage drop of 10.375 V)

Thus, 4 core 70 mm² XLPE/SWA/PVC cannot be used.

Check again the I_z value.


Refer to table 4E4A from IEE Wiring Regulation Sixteenth Edition.

Refer next value of I_z and calculate the volt drop until the acceptable volt drop is achieved. In this case the I_z that result in an acceptable volt drop is $I_z = 406$ A

$$I_z > 250 > 137.09$$

$$406 > 250 > 137.09$$

Therefore cable to be used is 4 core 150 mm² XLPE/SWA/PVC laid in the ground.

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8.1 Introduction

The effects of a low power factor in an installation are well known. These include:-

- i) A penalty charge in the electricity bill
- ii) Extra losses in the feeder cable
- iii) A significant voltage drop in the cables
- iv) A reduction of the effective capacity of the cables
- v) A reduction in the power available at the transformer
- vi) A significant voltage drop at the secondary of the transformer
- vii) Significant losses in the transformer

There are basically two types of equipment for improving the power factor of an installation:-

- a) By rotary phase advancers, synchronous condensers or synchronous motors
- b) Static capacitors.

For normal installations, the capital cost of rotating machinery, both synchronous and phase advancing, makes its use uneconomical and, in addition, the wear and tear inherent in all rotary machine involves additional expenses for upkeep and maintenance.


Capacitors, on the other hand, have a very low initial cost, have minimal upkeep costs and can be used with high efficiencies on all sizes of installations. They are compact, reliable and convenient to install and thus is the more satisfactory equipment for power factor improvement.

The sitting of the capacitors in an installation depends on whether each piece of equipment, example a motor, is being individually corrected or the plant/installation as a whole is being corrected as a block (bulk or central correction).

As a rule of thumb, switchboards exceeding 200 A shall be installed with power factor correction board.

8.2 Individual Correction

This is used in small installations on motors constantly in operation or, in the case of kVA maximum demand tariffs, on certain motors known to be in operation at the time of maximum demand. It should not be applied where the motors are used for haulage, cranes, and colliery winders of where “inching” or “plugging” and direct reversal takes

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place. Individual correction of tandem (or two speed motors) should be avoided. If correction is necessary, the capacitors should never be connected directly to the low speed component but a contactor arrangement installed using one capacitor for both windings.

In general, this method is not profitable for motors less than 10 kW.

8.2.1 Advantages of Individual Correction


This method reduces the current loading on the distribution system with consequent improvement in the voltage regulation. Also no additional switchgear is required as the capacitor is connected directly across the motor terminals and, therefore, switched with the load by the motor starter.

8.2.2 Disadvantages of Individual Correction

Several small capacitors installed at various individual loads may cost more than a single capacitor of total equivalent rating centrally installed. Also the capacitors have a low utilization factor as the capacitor operates only when the particular load is used.

8.2.3 General Considerations

- One size of capacitor will give constant value of power factor over the normal low range since variations in motor kVAr are comparatively small.
- Since connection of the capacitor directly across the motor results in a lower load current, the overload setting on the starter should be reduced in order to obtain the same degree of protection.
- When star delta starting is used, a standard three terminal, delta connected capacitor should be employed, which gives maximum power factor correction at the start when the power factor of the motor is low.
- To prevent auto-excitation (i.e. Self excitation of the motor by the stored capacitor charge – when the motor supply is switched off); ensure that the capacitor current is equal to or smaller than the motor magnetizing current. A commonly used value is 90% of the motor no load current.

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- e) The capacitor rating required is calculated as follows:-

$$kVar = \frac{H_p \times 0.746 \times \% \text{ of full load} \times (\tan \cos^{-1} \phi_1 - \tan \cos^{-1} \phi_2)}{\text{efficiency (at the above \% of full load)}}$$

where:

$\cos \phi_1$ is the original power factor

$\cos \phi_2$ is the required power factor.

- f) Motors are usually corrected to a power factor of 0.98 at 75% load.
- g) Welding equipment generally have a power factor of about 0.35 lagging but since welding loads are intermittent and consequently have a low load factor, they are usually corrected to about 0.6 to 0.8 based on its continuous kVA rating.
- h) Figure 8.1 below shows the method of connection for individual power factor correction of motors.

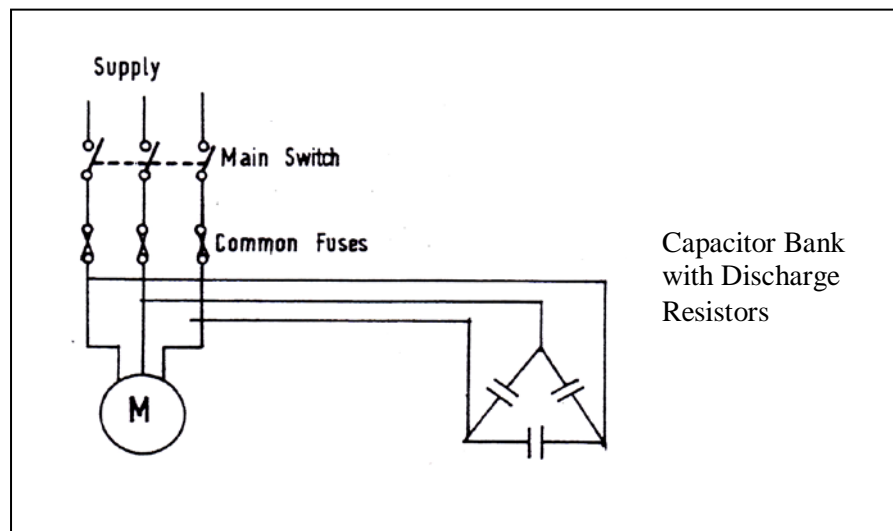


Figure 8.1: Connections for Individual Motor Power Factor Correction


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Table 8.1: Typical Uncompensated PF for Building/Plant

Category	Typical uncompensated PF
Hospitals	0.7,..0.8
Machinery- big sized	0.5,..0.6
Machinery-small sized	0.4,..0.5
Office Building-General	0.7,..0.8
Water pumps	0.8,..0.85
Compressor	0.7,..0.8
Vocational School (Welding Transformer)	0.5,..0.7
School (normal Laboratory)	0.7,..0.8
Factory (Steel)	0.6,..0.7
Breweries / sawmill / factory	0.6,..0.7

8.3 Bulk or Central Correction

The method is used when the total reactive load varies during the day, but is too small to be compensated individually because of cost reasons. Also, it may sometimes be impossible to connect capacitors at the individual load locations due to uncertainty of loads, high ambient temperatures, restricted space or presence of explosive gases.

8.3.1 Advantages of Central Correction


This is ideal method of obtaining the full electrical and financial benefits of a capacitor installation. The central location makes supervision easier and with automatic control, the resulting economics and convenience may outweigh the initial cost.

8.3.2 Disadvantages of Central Correction

Here the loads in the distribution lines are not lightened. The capacitors must also be provided with protective and isolating gear. This was previously done manually but manual switching requires surveillance which may not be convenient to provide. Therefore it is now to be done automatically (but at a higher cost).

8.3.3 General Considerations for central automatic power factor correction

- The equipment consists of a capacitor bank subdivided into two or more steps, each step or capacitor being controlled by a contactor.

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- b) In turn the contactors are controlled by a reactive relay. The reactive relay consists of a potential coil connected across 2 phases of the supply load and a current coil taken from a current transformer on the third phase – so as to obtain a 90° phase displacement at unity power factor. The utilization category of contactor for the switching of capacitor banks is AC-6b.
- c) The number of stages installed is usually a compromise between the technical requirement and cost. The aim is to have each contactor switching its maximum rated capacitance and, at the same time, have the capacitor bank divided into the most economic subsections, so that all variations in load can be corrected.
- d) To determine the rating of the capacitor needed, the following formula is used:-

$$Q = P (\tan \phi_1 - \tan \phi_2)$$

Where: Q is the rating of the capacitor required in kVAr
P is the installation load in kW
Cos ϕ_1 is the initial power factor, and
Cos ϕ_2 is the required power factor.

The above formula is derived from the Figure 8.2 which shows the effect of correction.

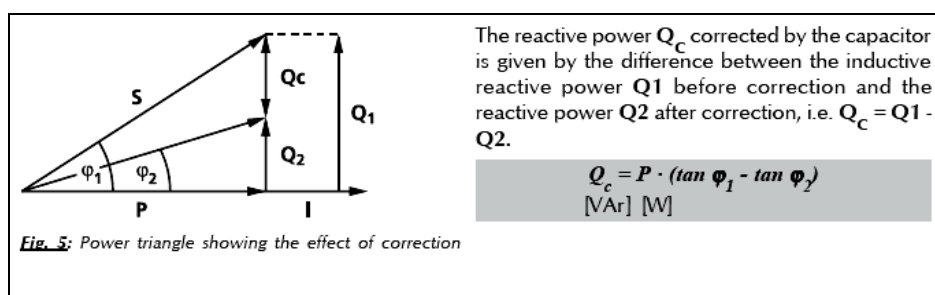



Figure 8.2: The Effect of Correction

Alternatively, the required rating can be obtained from tables which give the required values of $(\tan \phi_1 - \tan \phi_2)$. This is given by 'k Value' in Table 8.2

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- e) It is necessary to set the relay to operate with the particular current transformer used. On most relays, this is usually achieved by means of a C/K setting, where

C = size of capacitor being switched (in kVAr), and
K = ratio of current transformer primary to secondary.

Example: For C = 100 kVAr and K = 2000/5 = 400

$$C/K = 100/400 = 0.25$$

- f) To prevent “hunting” i.e. continuous switching in and out of a capacitor step, the sensitivity limit of the regulator is set such that it is greater than the current of one capacitor step. In practice the regulator is usually set to react to changes corresponding to about 2/3 of the current of one capacitor step.
- g) A typical connection of an automatic relay is as shown:-

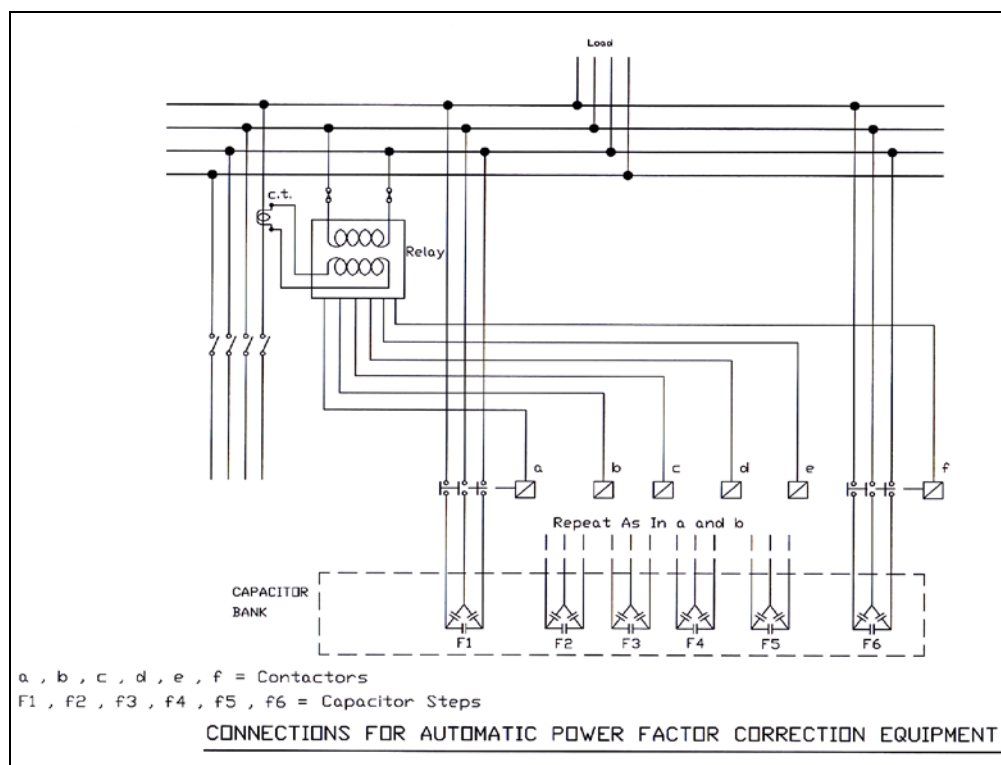


Figure 8.3: Typical Connection of An Automatic Relay



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Table 8.2: 'k Value'

Power factor of load before applying capacitor	SIZE OF CAPACITOR IN KVA PER KW OF LOAD FOR RAISING THE POWER FACTOR (K VALUE)												
	0.80	0.85	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	Unity
0.40	1.537	1.668	1.805	1.832	1.861	1.895	1.924	1.959	1.998	2.037	2.085	2.144	2.288
0.41	1.474	1.605	1.742	1.769	1.798	1.831	1.860	1.896	1.935	1.973	2.021	2.082	2.225
0.42	1.413	1.544	1.681	1.709	1.738	1.771	1.800	1.836	1.874	1.913	1.961	2.022	2.164
0.43	1.356	1.487	1.624	1.651	1.680	1.713	1.742	1.778	1.816	1.855	1.903	1.964	2.107
0.44	1.290	1.421	1.558	1.585	1.614	1.647	1.677	1.712	1.751	1.790	1.837	1.899	2.048
0.45	1.230	1.360	1.501	1.522	1.561	1.592	1.626	1.659	1.698	1.737	1.784	1.846	1.988
0.46	1.179	1.309	1.446	1.473	1.502	1.533	1.567	1.600	1.636	1.677	1.725	1.786	1.929
0.47	1.130	1.260	1.397	1.425	1.454	1.485	1.518	1.552	1.588	1.629	1.677	1.758	1.881
0.48	1.076	1.206	1.343	1.370	1.400	1.430	1.464	1.497	1.534	1.575	1.623	1.684	1.826
0.49	1.030	1.160	1.297	1.326	1.355	1.386	1.428	1.453	1.489	1.530	1.578	1.639	1.782
0.50	0.982	1.112	1.248	1.276	1.303	1.327	1.368	1.403	1.441	1.481	1.528	1.598	1.752
0.51	0.936	1.066	1.202	1.230	1.257	1.291	1.323	1.357	1.395	1.435	1.483	1.544	1.686
0.52	0.894	1.024	1.160	1.188	1.213	1.249	1.281	1.315	1.353	1.393	1.441	1.502	1.644
0.53	0.850	0.980	1.116	1.144	1.171	1.205	1.237	1.271	1.309	1.349	1.397	1.458	1.600
0.54	0.809	0.939	1.075	1.103	1.130	1.164	1.196	1.230	1.268	1.308	1.356	1.417	1.559
0.55	0.769	0.899	1.035	1.063	1.080	1.124	1.156	1.190	1.228	1.268	1.316	1.377	1.519
0.56	0.730	0.860	0.996	1.024	1.051	1.085	1.117	1.151	1.189	1.229	1.277	1.338	1.400
0.57	0.692	0.822	0.958	0.986	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1.300	1.442
0.58	0.655	0.785	0.921	0.949	0.976	1.010	1.042	1.076	1.114	1.154	1.202	1.263	1.405
0.59	0.618	0.748	0.884	0.912	0.939	0.973	1.005	1.039	1.077	1.117	1.165	1.226	1.368
0.60	0.584	0.714	0.848	0.878	0.905	0.939	0.971	1.005	1.043	1.083	1.131	1.192	1.334
0.61	0.549	0.679	0.815	0.843	0.870	0.904	0.936	0.970	1.008	1.048	1.096	1.157	1.299
0.62	0.515	0.645	0.785	0.809	0.836	0.870	0.902	0.936	0.974	1.014	1.062	1.123	1.265
0.63	0.483	0.613	0.749	0.777	0.804	0.838	0.870	0.904	0.942	0.982	1.030	1.091	1.233
0.64	0.450	0.580	0.716	0.744	0.771	0.805	0.837	0.871	0.909	0.949	0.997	1.058	1.200
0.65	0.419	0.549	0.685	0.713	0.748	0.774	0.806	0.848	0.876	0.918	0.966	1.027	1.169
0.66	0.388	0.518	0.654	0.682	0.709	0.743	0.775	0.809	0.847	0.887	0.935	0.996	1.138
0.67	0.358	0.488	0.624	0.652	0.679	0.713	0.745	0.779	0.817	0.857	0.905	0.966	1.108
0.68	0.329	0.459	0.595	0.623	0.650	0.684	0.716	0.750	0.788	0.828	0.876	0.937	1.079
0.69	0.299	0.429	0.565	0.593	0.620	0.654	0.686	0.728	0.758	0.798	0.848	0.907	1.049
0.70	0.270	0.400	0.534	0.544	0.591	0.625	0.657	0.691	0.729	0.769	0.811	0.878	1.028
0.71	0.242	0.372	0.508	0.536	0.563	0.597	0.629	0.663	0.701	0.741	0.783	0.850	0.992
0.72	0.213	0.343	0.479	0.507	0.534	0.568	0.600	0.634	0.672	0.712	0.754	0.821	0.963
0.73	0.186	0.316	0.452	0.480	0.507	0.541	0.573	0.607	0.645	0.685	0.727	0.794	0.936
0.74	0.159	0.289	0.425	0.453	0.480	0.514	0.546	0.580	0.618	0.658	0.700	0.767	0.909
0.75	0.132	0.262	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673	0.740	0.882
0.76	0.105	0.235	0.371	0.399	0.426	0.460	0.492	0.526	0.564	0.604	0.652	0.713	0.855
0.77	0.079	0.209	0.345	0.373	0.400	0.434	0.466	0.500	0.538	0.578	0.620	0.687	0.829
0.78	0.053	0.183	0.319	0.347	0.374	0.408	0.448	0.474	0.512	0.552	0.594	0.661	0.803
0.79	0.026	0.156	0.292	0.320	0.347	0.381	0.413	0.447	0.485	0.525	0.567	0.634	0.776
0.80	-	0.138	0.266	0.294	0.321	0.355	0.387	0.421	0.459	0.499	0.541	0.608	0.730
0.81	-	0.104	0.240	0.268	0.295	0.329	0.351	0.395	0.433	0.473	0.515	0.582	0.724
0.82	-	0.078	0.214	0.242	0.269	0.303	0.335	0.369	0.407	0.447	0.489	0.556	0.698
0.83	-	0.052	0.188	0.216	0.243	0.277	0.309	0.343	0.381	0.421	0.463	0.530	0.672
0.84	-	0.026	0.162	0.190	0.217	0.251	0.283	0.317	0.355	0.395	0.437	0.504	0.645
0.85	-	-	0.136	0.164	0.191	0.225	0.257	0.291	0.329	0.369	0.417	0.478	0.620
0.86	-	-	0.109	0.140	0.167	0.198	0.230	0.264	0.301	0.343	0.390	0.450	0.593
0.87	-	-	0.083	0.114	0.141	0.172	0.204	0.238	0.275	0.317	0.364	0.424	0.567
0.88	-	-	0.054	0.085	0.112	0.143	0.175	0.209	0.246	0.288	0.335	0.395	0.530
0.89	-	-	0.028	0.059	0.086	0.117	0.149	0.183	0.238	0.262	0.309	0.369	0.512
0.90	-	-	-	0.031	0.058	0.089	0.121	0.155	0.192	0.234	0.281	0.341	0.484
0.91	-	-	-	-	0.027	0.058	0.090	0.124	0.161	0.203	0.250	0.310	0.453
0.92	-	-	-	-	-	0.031	0.063	0.097	0.134	0.176	0.223	0.283	0.426
0.93	-	-	-	-	-	-	0.032	0.066	0.103	0.145	0.192	0.252	0.395
0.94	-	-	-	-	-	-	-	0.034	0.071	0.113	0.160	0.220	0.363
0.95	-	-	-	-	-	-	-	-	0.037	0.079	0.126	0.186	0.329
0.96	-	-	-	-	-	-	-	-	-	0.012	0.089	0.149	0.292
0.97	-	-	-	-	-	-	-	-	-	-	0.047	0.107	0.250
0.98	-	-	-	-	-	-	-	-	-	-	-	0.060	0.203
0.99	-	-	-	-	-	-	-	-	-	-	-	-	0.143

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8.4 General


- i) Selection of Current Transformers for power factor relays.
 - a) The primary rating of the CT is based on the line current of the system at its original power factor.
 - b) The secondary rating depends on the current rating of the power factor relay used and is usually 5 amps.
 - c) The burden of the CT depends on the Volt-Ampere consumption of the relay and is usually less than 5 VA. If the CT is far from the battery, a 10 VA CT may have to be used to take into account of the I^2R losses in the cables.
 - d) In some cases, it may be necessary to summate the currents in more than one circuit. A suitable auxiliary summation CT can be used.

ii) Rating of Switchgear

The duty imposed on switchgear and fuse gear used with capacitors is heavier than that in normal circumstances due to:-

- a) At the instant of switching, a large transient current will flow.
- b) High overvoltage transients can occur when capacitors are disconnected by switching devices which allow restricting of the arc.
- c) The switchgear has to carry continuously the full rated current of the capacitor at all times the capacitor is in circuit.
- d) At light loads when the voltage may be higher than normal, the capacitor currents will be increased accordingly.
- e) If harmonics are present in the supply voltage, the capacitor current will be increased.

In view of this, it is normal to have switchgear of ratings higher than the rated current of the capacitor. Often a factor of 1.5 times the rated current is used.


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iii) General Considerations in the Installation of Capacitors

- a) For capacitors directly connected to motor terminals, all capacitor banks should have a switching device equipped with an appropriate automatic trip.
- b) A discharge device should be provided for every capacitor equipment unless it is connected directly to other electrical equipment providing a discharge path without a disconnecting switch, fuses cut-out, or series capacitor interposed.
- c) Self healing dry type capacitors should normally be specified for all installation due to their superior qualities and ease of maintenance.
- d) To reduce the current loading in the distribution system, the power factor correction should be done as close as possible to the load.
- e) Apart from the individual and the bulk central corrections methods, other methods are possible. These are in effect variations and combinations of the above mentioned two methods. They are:-
 - Group compensation e.g. One capacitor bank for a group of motors.
 - Fixed central compensation.
 - Combined compensation - a combination of fixed, automatic group and individual compensations.
- f) Very often at the time of installing the power factor correction system, the load has not built up yet. The power factor correction system should thus either be designed to cater for future loads or provisions be made in switchgears, cables, accessories, space, etc. for easy extension of the system in the future.

iv) Maintenance of power factor correction capacitors.

- a) Capacitors being static equipment, do not generally require the same degree of care as rotary machinery, but nevertheless, require regular maintenance.
- b) Capacitors should normally be inspected every 12 months – preferably 6 months. Inspection time intervals are governed mainly by conditions on site. Humid atmospheres or those subjected to chemical fumes, dirt or dust requires more frequent attention.


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- c) Before examination the apparatus should be switched off and time allowed for complete discharge as stated on the rating plates. Current transformers must never operate with the secondary circuit open. If it is not being used, the secondary terminals must be short-circuited.
- d) Conditions of exterior finish and protective paint should be in good condition. If necessary, it should be repainted.
- e) The terminal box cover should be removed and inspected for abnormalities. Special care should be taken of:
 - i) Condition of cable
 - ii) Condition of interior paint work (repainting if necessary)
 - iii) Tightness of nuts and bolts – especially of earth connections
 - iv) Removal of dust and other foreign matter
 - v) Cleanliness – particularly of insulators and terminals

8.5 Series Blocking Reactors

Where series blocking reactors (hereafter referred as 'reactors') are specified in the Drawings and/or Bill of Quantities, they shall be of dry type copper windings rated at 440 volts, 50 Hz and class H insulation connected in series with the capacitors suitable to operate in ambient temperature up to 40°C. Unless otherwise specified in the Drawings and/or Bill of Quantities, the kVAr rating (reactance) of the reactor shall be 7% to the kVAr rating (reactance) of the capacitor to where the reactor will be connected.

The reactors shall be securely fastened and installed in a separate compartment of the power factor correction board. If necessary, rubber pad shall be used to reduce noise.

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8.6 Switching Sequence

The regulator shall incorporate minimum following automatic switching sequence modes, viz. cyclic switching sequence and multi-step switching sequence allowing minimum following combinations of switching programme of capacitors stages:


- a) 1:1:1:1:1:....
- b) 1:1:2:2:2:....
- c) 1:1:2:2:4:4:....
- d) 1:2:2:2:2:2:....
- e) 1:2:4:4:4:4:....
- f) 1:2:4:8:8:8:....

The first three control output may be allowed to be set as fixed steps which are not included in the normal control cycle but are switched on immediately after the regulator is switched on and always remain switched on.

8.7 Comparison Method of Installation

Table 8.3: Different Method of Power Factor Correction

METHOD	ADVANTAGES	DISADVANTAGES
Individual Capacitors	Most technically efficient, most flexible	Higher installation and maintenance cost
Fixed Bank	Most economical, fewer installations	Less flexible, requires switches and/or circuit breakers
Automatic Bank	Best for variable loads, prevents over voltages, low installation cost	Higher equipment cost
Combination	Most practical for larger numbers of motors	Least flexible

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8.8 Practical Design Example

Given maximum demand (MD) = 685.60 kW

Assume Power Factor to be corrected is from 0.75 to 0.9. Calculate capacitor step for power factor correction and MCCB size at MSB where the power factor correction board will be locate.

- 1) Make assumption:

$$\text{Power Factor Correction} = 0.75 \text{ to } 0.9$$

- 2) Refer table 1, k value = 0.398

$$\begin{aligned} Q \text{ (kVAr) pf correction at } 3\Phi_{415} &= MD \times k \\ &= 685.6 \times 0.398 \\ &= 272.87 \text{ kVAr } 415 \end{aligned}$$

$$\begin{aligned} Q \text{ (kVAr) pf correction at } 3\Phi_{525} &= Q \text{ (kVAr) } 415 \times (525/415)^2 \\ &= 272.87 \times 1.6 \\ &= 436.59 \text{ kVAr} \end{aligned}$$


$$\begin{aligned} Q \text{ (kVAr)}_{525} \text{ with 7\% reactance} &= Q \text{ (kVAr) } 525 \times 0.93 \\ \text{(Industry practice)} &= 436.59 \times 0.93 \\ &= 406.03 \text{ kVAr} \\ &\approx 400 \text{ kVAr} \end{aligned}$$

- 3) Capacitor step:

$$\begin{aligned} \text{Step 1} &= 10\% \text{ of } Q \text{ (kVAr) } 525 \text{ with 7\% reactance} \\ &= 40 \text{ kVAr} \\ &\approx 50 \text{ kVAr} \end{aligned}$$

$$\begin{aligned} \text{If use step } 1:1:1:1:1:1:1:1 &= 50+50+50+50+50+50+50+50 \\ &= 400 \\ &= 8 \text{ step} \end{aligned}$$

$$\begin{aligned} \text{If use step } 1:1:2:2:2:2:2 &= 50+50+100+100+100 \\ &= 400 \\ &= 5 \text{ step} \end{aligned}$$

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4) MCCB size at MSB

$$I_{415} = \frac{Q \text{ (kVAr)}_{525} \text{ with reactance} / (525/415)^2}{\sqrt{3} \times 415}$$

$$= \frac{400 / 1.6}{\sqrt{3} \times 415}$$

$$= 347.80 \text{ A}$$

$$I_{415} \text{ (50\% higher)} = 347.8 + 50\%$$

$$= 521.7 \text{ A}$$

$$\text{MCCB size} = 600 \text{ A}$$

Therefore main incomer is 600 A.

- 5) However we need to ensure that the capacitor in the first step must not be more than 5% of the incomer size, otherwise the system may not be initiated.

To verify, 5% of 600 A = 30 A equivalent to 21 kVAr.

Therefore in this case the first step should be 20 kVAr instead of 50 kVAr.

- 6) Therefore the possible options for the steps may be as follow:

- 1) 1:1:1:1:1:.... (not possible, to many step to reach 400 kVAr)
- 2) 1:1:2:2:2:.... (not possible, to many step to reach 400 kVAr)


Possible step to use:

$$1:1:2:2:2:4:4:4 \quad = 20:20:40:40:40:80:80:80$$

$$= 400$$

$$= 8 \text{ step}$$

- 7) According to the market, maximum step = 14

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9.1 Generating Set

There are occasions when the TNB electricity supply fails and a building is left without electricity. In some buildings the risk of being totally without electricity is unacceptable and some provision must be made for an alternative supply to be used in such an emergency. Many consumers have installed standby generating sets in their building to maintain a supply for their essential loads.

The majority of small standby sets installed will be powered by diesel engines, as these are the most readily available prime movers, and most economic in capital costs, operation and maintenance. Most emergency sets can be started either manually or automatically. A manual start is simple, but it involves a substantial delay during which the building is without power. This delay can be minimized to about 10seconds by automatic starting, initiated by a sensing unit which detects a drop in the mains voltage.

The location of a generator room and the layout of generator set are important as they affect the performance of the equipment. Generator rooms should have as many external walls as possible. In any case, it is not advisable to have less than 2 external walls. Additionally the location of the room also affects the surrounding environment and persons. Therefore the DE shall apply noise reduction / acoustic treatment so that noise level is not more than 65dB(A) measured at receptor. This is in line with the requirements of Seksyen 23, Akta Kualiti Alam Sekeliling 1974. According to Peraturan 36 Peraturan Kualiti Alam Sekeliling (Udara Bersih) 1978, the approval from Jabatan Alam Sekitar (DOE) has to be obtained for generator sets that burn fuel at ≥ 15 kg/hr (which has been equated to ≥ 60 kVA).

The minimum clearance height of the generator set room should be given careful consideration during planning stage. If the minimum clearance height is insufficient, the exhaust system may not be able to be properly installed resulting in high back pressure. This effects the performance of the generator set and increase the noise level as well. Generator set should be so installed such that the radiator can discharge the hot air through an external wall away from occupied areas. Air intake should preferably be from the opposite side of the wall through which the radiator discharges the hot air. If the construction of the room is such that the volume of intake air is insufficient, then forced air intake by means of electric blower fan has to be installed.

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Some common terminologies associated with backup systems:

- Emergency load – back up supply from generator set only.
- Essential load – critical loads which cannot afford any break in power supply hence will normally be backed up with supply from UPS equipment which in turn may or may not be connected to a generator.
- Uninterrupted Power Supply, UPS.

9.2 Load Assessment and Sizing the Generator


Designing a generator set installation requires consideration of equipments and installation requirements for various reasons and intended use. These are usually driven by mandatory installations to meet requirements of building codes (legally required) and/or risk of economic loss due to loss of electric power (generally associated with power availability or reliability).

Safety to human life or to health hazards are typically the paramount requirements of the code referenced from the regulations of federal, state, local or any other governmental authority. These type of applications typically involve facilities such as health care (hospitals, nursing care, clinics), high rise construction, and places of assembly (theaters, assembly halls, sporting facilities, hotels).

Requirements due to economic reasons are typically justified by a mitigation of the risks of loss of services, data or other valuable assets. This type of system has become more frequent as power availability has become more critical. These genset system back up power facilities like industrial and commercial buildings and serve loads such as data processing, communications, heating, refrigerations and critical processes. Generators are often justifiable where loss of utility power could cause discomfort or interruption of critical process threatening products or process equipment.

Some common needs are outlined below:

- Lighting : Egress lighting for evacuation, illuminated exit signs, security lighting, warning lights, operating room lighting, elevator car lighting, generator room lighting etc..
- Control Power : Control power for boilers, air compressors, and other equipment with critical functions.
- Transportation : Elevators for fire department use.

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- Mechanical Systems : Waste water treatments etc.
- Heating : Critical process boilers
- Refrigeration : Blood banks etc..
- Production : Critical power for laboratory, pharmacies etc..
- Space conditioning : Cooling for computer rooms equipments, ventilation for hazardous atmospheres etc..
- Life support : Hospitals, nursing homes ,other health care facilities
- Communication systems : Police, fire stations, high rise public address systems etc..
- Data processing : UPS etc..
- Signal systems : Air traffic control etc..

Therefore, it is necessary to determine to which loads one proposes to maintain a supply under emergency conditions. As above example, these loads may consist those of static loads and motor loads.

The generator is sized with the main loads plus 20% on other power requirements such as lightings, small motors, etc.


Static load consist of lamps, communication equipment, etc. – items which do not involve rotating machinery. Static loads are expressed in kW.

Motor loads are those electrical motors which power such things as fireman lifts, pressurization fans and fire fighting equipment. These motor loads are also expressed in kW, but they also place an additional demand on the electric supply. This demand is the starting kVA (skVA). The starting kVA for a motor of 5 kW or more is 5.5 to 6 times the rated kVA and it is 8 to 10 times approximately in the case of one of 5 kW or lower.

At starting, the motor normally apply a fairly large load to the generator. Under the rated full load, most motors require about 1.4 kVA per kW. It is therefore easy to find out kVA values on the basis of output kW.

Thus to determine the total load,

- a) Add up the static loads in kW to establish the total static load.
- b) Identify the individual motor loads and compute their total kW value.
- c) Then individually calculate the starting kVA of each motor.

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9.2.1 Some Notes on European Design Motors

The essential data is on the nameplate of European design motors. The motor capacity (output) may be expressed in horse-power (hp), or in kW; and there will be no code letters as in American Design Motors. If the name-plate includes hp, multiply this figure by 0.85 to determine the kW requirement (same process as with American design motors, refer 1.1.2). If the nameplate lists motor capacities in kW, multiply this mechanical kW figure by 1.15 to determine the electrical kW requirement from the generator set (1.15 is derived from the reciprocal of typical electric motor efficiency of 88% of 0.88:- $1/0.88 = 1.15$).

The nameplate may list the starting kVA (skVA) or may list a figure, LRA, which means 'Locked Rotor Amperes'. To arrive at the skVA, the following formula should be applied,

$$\text{skVA} = \frac{\text{LRA} \times \text{rated voltage} \times 1.732}{1000}$$

Establish the total kW demand: The static load kW should be added to the motor load kW. When this exercise is completed for all static and motor loads, the total figure is the minimum generator set capacity of the selected generator set.

9.2.2 Some Notes on American Design Motors

The motor hp and NEMA (National Electric Manufacturer's Association) code letter will be shown. These two items allow you to determine quickly the motor power requirement in kW and the starting requirement in kVA.

For kW requirement, multiply the nameplate hp by 0.85 (0.85 is derived from the conversion of 0.716 kW /hp divided by a typical motor efficiency of 0.88). The result closely approximates the motor kW demand at full load. For skVA – refer to the NEMA code letter in Table 9.1. Multiply the related skVA /hp figure by the motor nameplate hp.

E.g.: A 100 hp Code F motor has a skVA of $100 \times 5.5 = 550$ kVA.


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Table 9.1: Identification of Code Letters on Typical US Design 3 Phase Induction Motors

NEMA Code letter	skVA per horsepower (multiplier)
Motors with these code letters are usually Three Phase	
A	3.1
B	3.5
C	4.0
D	4.5
E	5.0
F	5.5
G	6.2
H	7.0
J	8.0
Motors with these code letters are usually Single Phase	
K	9.0
L	10.0
M	11.0
N	12.5
P	14.0
R	16.0
S	18.0
T	20.0
U	22.0
V	25.0

NOTE: Wound rotor motors have no code letters.


9.3 Check for Voltage Dip

The next step is to establish if the generator set with the required kW capacity will be adequate to cope with the motor skVA needs. Manufacturers usually provide tables listing voltage dip versus skVA. Each motor is checked against the generator set skVA capacity for the probable voltage dip. This figure is compared with the acceptable voltage dip. If the expected dip exceeds the acceptable dip, the generator size will have to be increased or the starting requirement of motors will have to be reduced.

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Some notes on generator set performance to voltage dip:

- Transient performance depends on turbo charging system (turbo lag effect), Brake mean effective pressure of engine (pme), Speed governor characteristics, Alternator excitation system characteristics, Voltage regulator behavior, Rotational inertia of the genset
- ISO8528 & ISO3046 provide guide values for step loads as a function of brake mean effective pressure (pme) .They provides a common standard to compare transient performance and categorizes the engine/genset performance into 4 classes viz. G1, G2, G3 and G4. The guidelines are set to determine the level of step loading that can be applied based on the bmep of the engine.
- Recovery characteristics can be determined to meet the following values stated in the respective category as below :

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Operating limit values

Parameter	Performance class			
	ISO 8528 G1	ISO 3046 A2	ISO 8528 G2	ISO 3046 A1
Frequency droop	≤ 8%	≤ 8%	≤ 5%	≤ 5%
Steady state frequency band	≤ 2,5%	≤ 1,0% 1,5%	≤ 1,5%	≤ 0,8% 1,0%
Transient frequency difference from initial frequency 100% Sudden power decrease	≤ +18%	≤ 15%	≤ +12%	≤ 10%
Sudden power increase	≤ – (15% + droop)	≤ 15%	≤ – (10% + droop)	≤ 10%
Frequency recovery time	≤ 10s	≤ 15s	≤ 5s	≤ 8s

Parameter	Performance class			
	ISO 8528 G3	ISO 3046 –	ISO 8528 G4	ISO 3046 A0
Frequency droop	≤ 3%	–	AMC	AMC
Steady state frequency band	≤ 0,5%	–	AMC	AMC
Transient frequency difference from initial frequency 100% Sudden power decrease	≤ +10%	–	AMC	AMC
Sudden power increase	≤ – (7% + droop)	–	AMC	AMC
Frequency recovery time	≤ 3s	–	AMC	AMC

AMC = by agreement between manufacturer and customer

Figure 1 Comparison of Selected Limit Values of Table 3 ISO 8528-5: 1993 and ISO 3046-4: 1978

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9.4 Dimension Guideline for Generator Set Installation

Table 9.2 shows some guideline of generator plinth size, room size and other requirement for the installation. When installing the generating set and components in the restricted confines of a genset room, care must be taken that easy access is provided for carrying out routine servicing.



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Table 9.2 : Recommendation For Generator Room And Plinth Sizes

Generator Rated		Generator Physical Size (mm)			Generator Weight	Oil Tank Size	Generator Plinth Size	AIS Size (mm)	ADS Size (mm)	Recommended Room Size			Door Size
kW	kVA	L	W	H	KG	L x W x H (mm)	L x W x H (mm)	W x H x T	W x H x T	L	W	H	W x H x T
20	25	1408	556	900	600	1000 x 500 x 350	1400 x 550	900 x 600 x 900	900 x 600 x 900	3400	4000	4000	1800 x 2100 x 75
32	40	2149	710	1341	820	1000 x 500 x 350	2100 x 700	900 x 600 x 900	900 x 600 x 900	3900	4000	4000	1800 x 2100 x 75
35.2	44	2149	710	1341	820	1000 x 500 x 350	2100 x 700	900 x 600 x 900	900 x 600 x 900	3900	4000	4000	1800 x 2100 x 75
40	50	2149	710	1341	820	1000 x 500 x 350	2100 x 700	900 x 600 x 900	900 x 600 x 900	3900	4000	4000	1800 x 2100 x 75
48	60	2149	710	1341	905	1000 x 500 x 350	2100 x 700	900 x 600 x 900	900 x 600 x 900	3900	4000	4000	1800 x 2100 x 75
52	65	2149	710	1341	905	1000 x 500 x 350	2100 x 700	900 x 600 x 900	900 x 600 x 900	3900	4000	4000	1800 x 2100 x 75
60	75	2149	710	1341	945	1000 x 500 x 350	2100 x 700	900 x 600 x 900	900 x 600 x 900	3900	4000	4000	1800 x 2100 x 75
66	82.5	2149	710	1341	945	1000 x 500 x 350	2100 x 700	900 x 600 x 900	900 x 600 x 900	3900	4000	4000	1800 x 2100 x 75
80	100	2515	845	1545	1222	1000 x 500 x 500	2500 x 850	900 x 600 x 900	900 x 600 x 900	4400	4200	4000	1800 x 2100 x 75
88	110	2515	845	1545	1222	1000 x 500 x 500	2500 x 850	900 x 600 x 900	900 x 600 x 900	4400	4200	4000	1800 x 2100 x 75
108	135	2700	900	1545	1417	1000 x 500 x 600	2500 x 850	900 x 600 x 900	900 x 600 x 900	4400	4200	4000	1800 x 2100 x 75
120	150	2700	900	1545	1417	1000 x 500 x 600	2500 x 850	900 x 600 x 900	900 x 600 x 900	4400	4200	4000	1800 x 2100 x 75
128	160	2953	990	1717	2001	1000 x 600 x 600	3600 x 1500 x 510	900 x 600 x 900	900 x 600 x 900	5600	5000	4000	1800 x 2100 x 75
140	175	2953	990	1717	2001	1000 x 600 x 600	3600 x 1500 x 510	900 x 600 x 900	900 x 600 x 900	5600	5000	4000	1800 x 2100 x 75
144	180	2953	1020	1717	2001	1000 x 600 x 600	3600 x 1700 x 510	900 x 600 x 900	900 x 600 x 900	5600	5200	4000	1800 x 2100 x 75
160	200	2967	1020	1717	2043	1000 x 600 x 600	3600 x 1700 x 510	900 x 900 x 1200	900 x 900 x 1200	6200	5200	4000	1800 x 2100 x 75
176	220	2967	1020	1717	2043	1000 x 600 x 600	3600 x 1700 x 510	900 x 900 x 1200	900 x 900 x 1200	6200	5200	4000	1800 x 2100 x 75
184	230	2967	1020	1717	2107	1000 x 600 x 600	3600 x 1700 x 510	900 x 900 x 1200	900 x 900 x 1200	6200	5200	4000	1800 x 2100 x 75
200	250	2967	1020	1717	2107	1000 x 600 x 600	3600 x 1700 x 510	900 x 900 x 1200	900 x 900 x 1200	6200	5200	4000	1800 x 2100 x 75
220	275	3077	1020	1717	2150	1000 x 600 x 600	3600 x 1700 x 510	975 x 900 x 1200	900 x 900 x 1200	6200	5200	4000	1800 x 2100 x 75


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Generator Rated		Generator Physical Size (mm)			Generator Weight	Oil Tank Size	Generator Plinth Size	AIS Size (mm)	ADS Size (mm)	Recommended Room Size			Door Size
kW	kVA	L	W	H	KG	L x W x H (mm)	L x W x H (mm)	W x H x T	W x H x T	L	W	H	W x H x T
240	300	3500	1219	1813	3090	1000 x 800 x 600	4000 x 1800 x 510	1500 x 1200 x 1200	1300 x 1300 x 1200	6600	5200	4000	1800 x 2100 x 75
280	350	3500	1219	1813	3180	1000 x 800 x 600	4000 x 1800 x 510	1500 x 1200 x 1200	1300 x 1300 x 1200	6600	5200	4000	1800 x 2100 x 75
300	375	3500	1219	1662	2350	1000 x 1000 x 1000	4000 x 1800 x 510	1500 x 1200 x 1200	1300 x 1300 x 1200	6600	5200	4000	1800 x 2100 x 75
320	400	3560	1430	2000	2350	1000 x 1000 x 1000	4200 x 1900 x 510	1500 x 1200 x 1200	1300 x 1300 x 1200	6800	5300	4500	1800 x 2100 x 75
360	450	3560	1430	2000	2530	1200 x 1000 x 1000	4200 x 1900 x 510			6800	5300	4500	1800 x 2100 x 75
400	500	3585	1520	2108	4738	1200 x 1000 x 1000	4200 x 1900 x 510	1950 x 1200 x 1500	1300 x 1300 x 1500	7200	5300	4500	1800 x 2100 x 75
440	550	3689	1520	2108	5100	1200 x 1000 x 1000	4200 x 1900 x 510	1950 x 1200 x 1500	1300 x 1300 x 1500	7200	5300	4500	1800 x 2100 x 75
520	650	4200	1800	2108	5200	1200 x 1000 x 1000	4600 x 2100 x 510	1950 x 1200 x 1500	1625 x 1625 x 1500	7600	5500	4500	1800 x 2100 x 75
600	750	4485	1800	2500	5700	1200 x 1200 x 1000	4800 x 2100 x 510	2275 x 1500 x 1500	1950 x 1950 x 1500	7800	5500	4500	1800 x 2100 x 75
680	850	4800	2000	2550	7000	1200 x 1200 x 1000	5000 x 2400 x 510			8300	5800	4500	1800 x 2100 x 75
728	910	4800	2100	2550	7500	1200 x 1200 x 1000	5000 x 2500 x 510			8300	5900	4500	1800 x 2100 x 75
800	1000	4800	2100	2800	9700	1200 x 1200 x 1200	5000 x 2500 x 510	3250 x 1500 x 1500	2100 x 2100 x 1800	8300	5900	5000	2400 x 2400 x 75
1000	1250	5306	2100	2800	10670	1500 x 1500 x 1200	5400 x 2500 x 510	3900 x 1500 x 1500	2400 x 2400 x 1800	8800	5900	5000	2400 x 2400 x 75
1080	1350	5306	2100	2800	10000	1500 x 1500 x 1200	5400 x 2500 x 510	3900 x 1500 x 1500	2400 x 2400 x 1800	8800	5900	5000	2400 x 2400 x 75
1200	1500	5500	2222	2800	11450	1500 x 1500 x 1200	5500 x 2600 x 510	3900 x 1500 x 1500	2400 x 2400 x 1800	9000	6000	5000	2400 x 2400 x 75
1400	1750	6500	2530	2920	14000	1500 x 1500 x 1500	5970 x 2700 x 510			10000	6200	5000	2400 x 2400 x 75
1460	1825	6500	2530	2920	15000	1500 x 1500 x 1500	5970 x 2700 x 510			10000	6200	5000	2400 x 2400 x 75
1600	2000	6500	2530	2920	15000	1500 x 1500 x 1500	5970 x 2700 x 510	4500 x 1800 x 1800	3000 x 3000 x 2100	10000	6200	5000	2400 x 2400 x 75
1800	2250	6500	2530	2920	15000	2000 x 1500 x 1200	5970 x 2700 x 510	4500 x 1800 x 2100	3000 x 3000 x 2100	10000	6200	5000	2400 x 2400 x 75

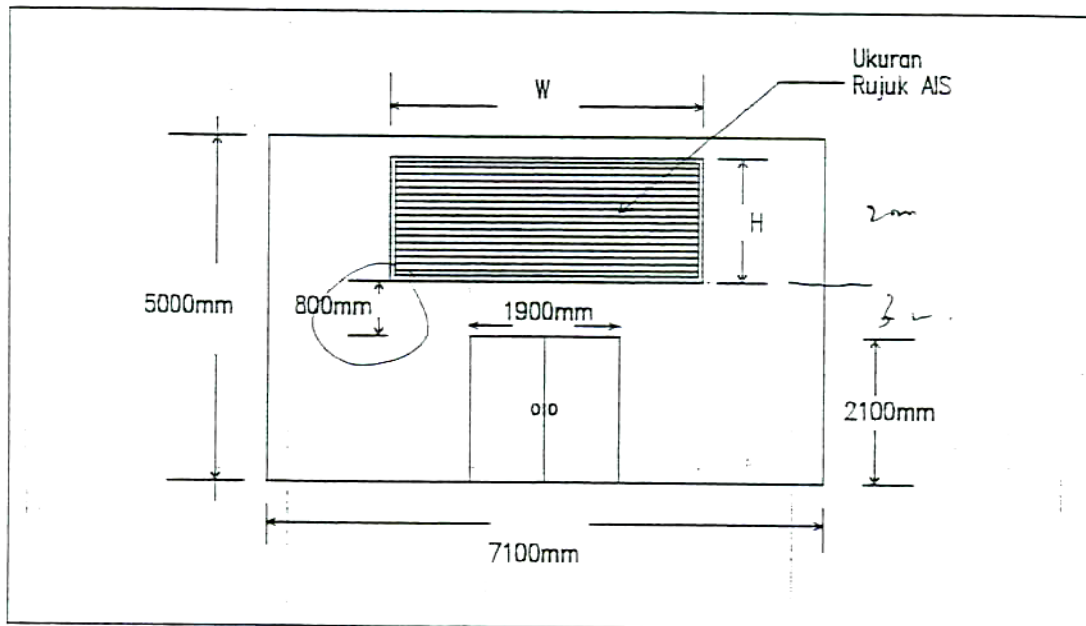
Notes: 1. Data reference from Perkins and Caterpillar Engine Model
2. AIS – Air Intake Silancer, ADS – Air Discharge Silancer
3. L – Length, W – Width, H – Height, T - Thickness

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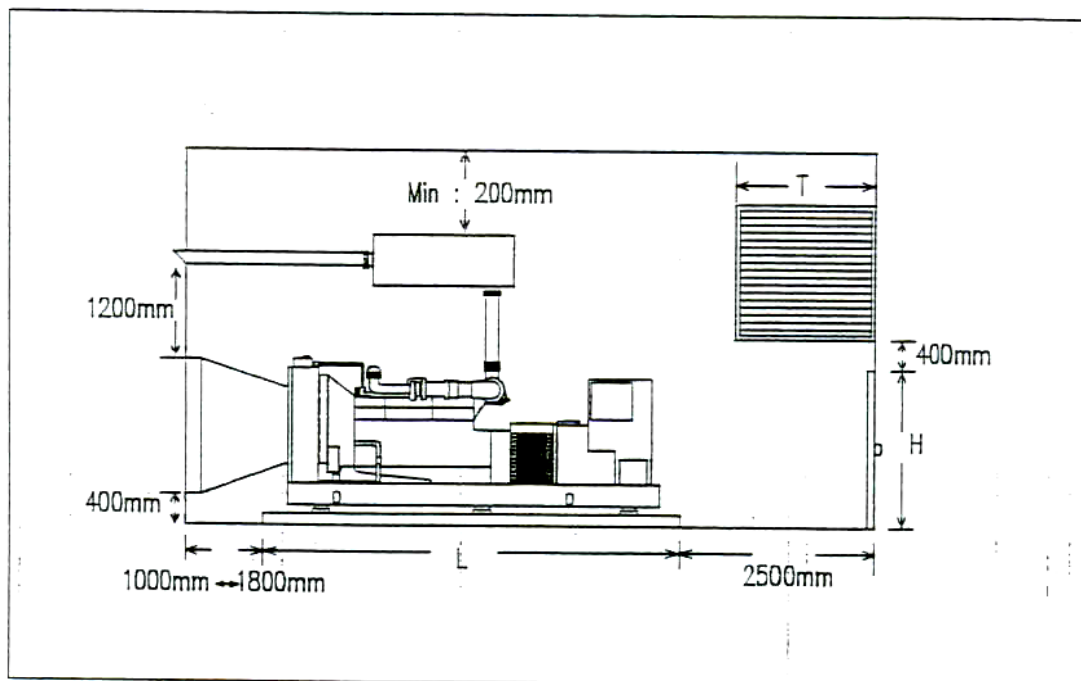
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a) Side view of a typical layout of the standby generator.



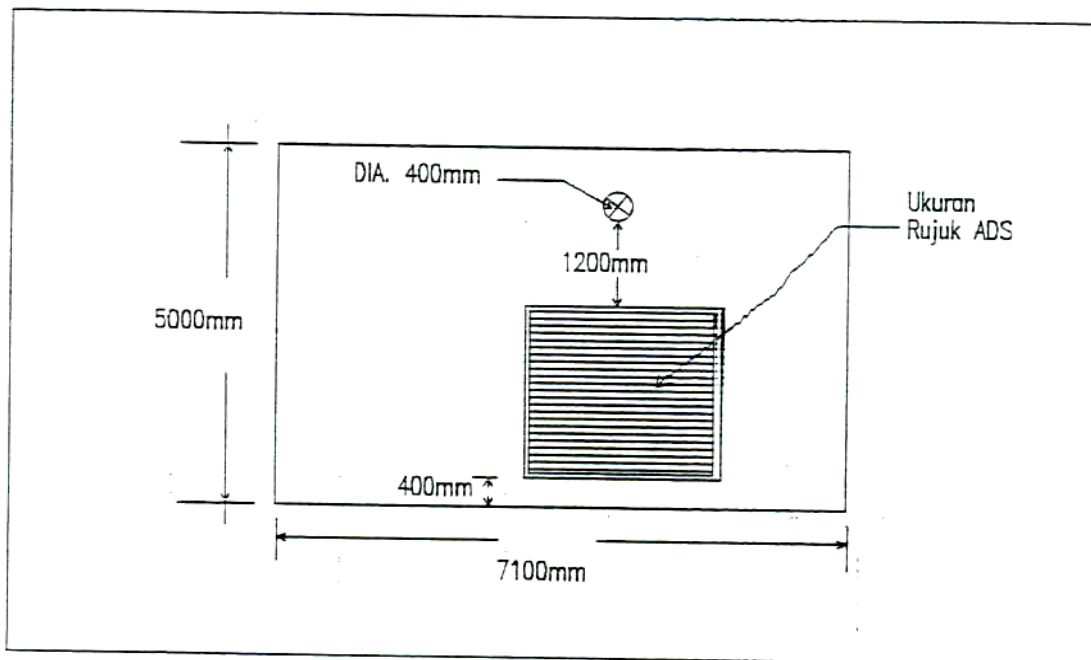
b) Typical layout Front for the standby generator.



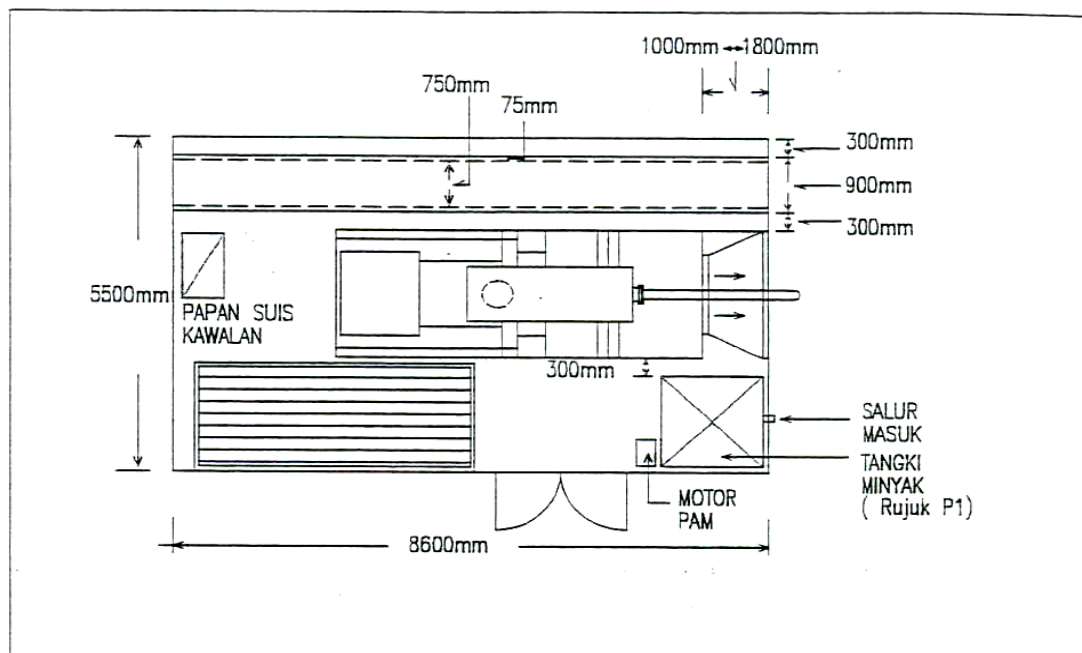
NOTE: Dimensions are based on the Power 1250kVA

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c) Rear view of a typical layout of the standby generator.



d) Diagram Layout Alternatives for standby generator



NOTE: Dimensions are based on the Power 1250kVA

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9.5 Uninterruptible Power Supply

Uninterruptible power supply equipment (UPS) shall be installed to provide emergency power supply to critical services. The UPS shall be of rotary/ dynamic type or static type:


- a) For the rotary/dynamic type UPS system with flywheel energy storage/kinetic machine energy storage module shall be of sufficient capacity for the present loads and with 20% spare capacity future extension.
- b) For the static type UPS system shall be complete with static bypass switch, minimum 12 pulse rectifier/charger, maintenance bypass switch, harmonic reduction facilities such as input harmonic filter trap, input transformer/choke etc. so as to reduce the harmonics generated in both the input circuit and output circuit.

The UPS equipment shall be completed with all necessary control, indication and alarm facilities, both local and remote. The status of the UPS equipment shall be continuously monitored by the plant monitoring system.

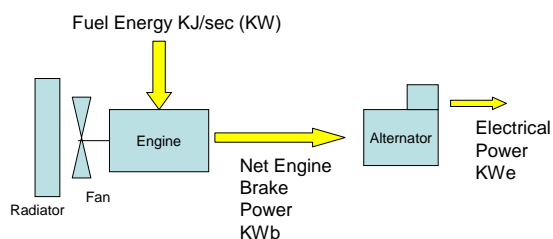
The static type UPS, including the battery, shall be of sufficient capacity for the present loads and with 20% spare capacity future extension. The battery capacity shall be **not less than 15 minutes** at the capacity of the UPS, including future extension. The battery shall be vented nickel cadmium type installed in a separate room adjacent to the UPS equipment.

The UPS shall be of the combination system whereby the UPS generator shall be in parallel with the standby generator set. The UPS rooms shall be 24 hours air-conditioned and the battery rooms shall be well ventilated.

In some cases of UPS installation, Isolation Transformer may be required to be installed for a purpose of avoiding high 'floating voltage' and relay tripping during changeover period.

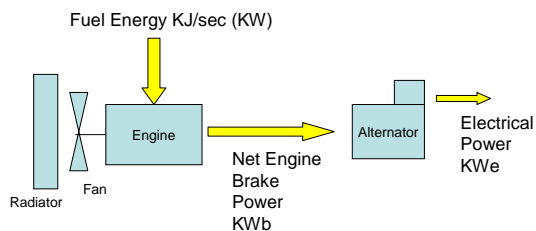
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DEFINITION OF TERMS




$$\text{Net Engine KWb} = \text{Gross Engine KWb} - \text{Fan KW}$$

DEFINITION OF TERMS

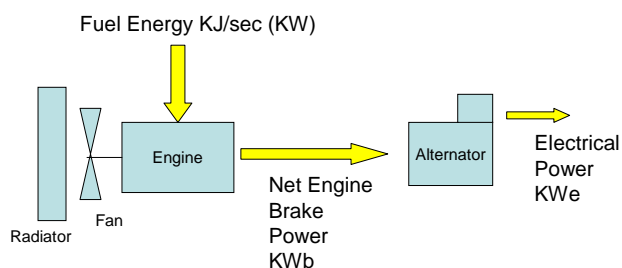


$$\text{Specific fuel consumption} = \text{grams} / \text{KWH}$$

Note : Most SFC data is based on KWb. For SFC data based on KWe, divide by alternator efficiency

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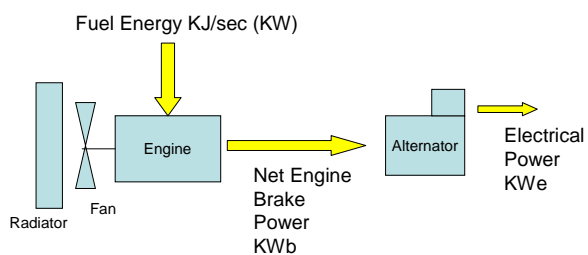
DEFINITION OF TERMS




$$\text{Fuel consumption in liter/hour} = \frac{\text{SFC} \times \text{KWb}}{840}$$

** Based on diesel fuel density of 840gram per liter*

DEFINITION OF TERMS

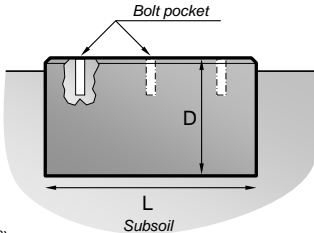


$$\text{Alternator Output KWe} = \text{KWb} \times \text{Alternator Efficiency}$$

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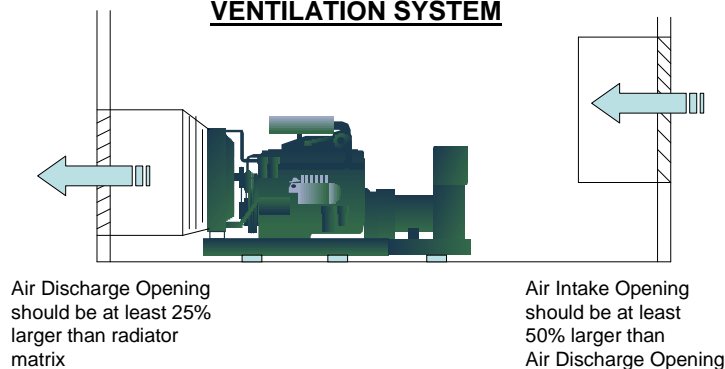
Fixed concrete block


The fixed concrete block is a proven method and preferred in some installations. In these cases the Gen.Set base frame is tightly bolted to the concrete block. The recommended concrete block size should allow app. 400-500 mm surround on all sides of the complete Gen.Set. The depth of the concrete block is calculated as follows:

$$D = \frac{\text{Weight of complete Gen.Set}}{d \times W \times L}$$


D = Depth of concrete block in metre.
d = Density of concrete in kg/m³ (use 2400 kg/m³)
W = Width of concrete block in metre.
L = Length of concrete block in metre

VENTILATION SYSTEM



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Engine Mountings and Engine Room Layout

Calculation of required engine room ventilation

When calculating the engine room ventilation, the following important parameters must be observed:

- Max. intake air temperature to the engine is 40 °C.
- Max. air temperature in engine room, providing the combustion air is taken from outside of engine room, is 60 °C.
- The entire exhaust pipe and silencer in the engine room should preferably be lagged.
- The exhaust manifold and turbocharger **must not** be lagged.
- Max. air on temperature for the radiator cooling system. See *Engine Sales Handbook*.

The large quantity of air moved by the engine mounted cooling fan is usually sufficient to ventilate the engine room. When a remote mounted radiator water cooled heat exchanger is installed, the ventilation of the engine room must be considered.

The quantity of air required to give a pre-determined temperature rise in the engine room, can be calculated from the following:

$$\text{Air flow required} = \frac{\text{Total heat rejection to air}}{\text{Air density} \times T_{\text{rise}} \times \text{Constant}} + \text{Combustion air required}$$

Total heat rejection to air: Heat rejection from engine + alternator and other heat generating equipment in engine room (kW).

Air density: Density of air at various temperatures as per table below, in kg/m³.

T_{rise}: Max. air temperature rise in engine room above ambient temp. in °C.


Constant: = 0.0167

Combustion air required: Engine air consumption in m³/min as stated in the *Engines Sales Handbook*.

Air Density

°C	0	5	10	15	20	25	30	35	40	45	50	55
kg/m ³	1.30	1.27	1.25	1.22	1.20	1.19	1.17	1.16	1.14	1.12	1.09	1.08

A Microsoft Excel based calculation program for both "Engine Room Ventilation" and "Exhaust System Back Pressure" on the same disk is available from **AB Volvo Penta, Application & Engineering**.

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9.6 Cabling


Power cables must be adequately supported throughout their length but at the alternator end, provision must be made to allow for movement of the generator set which occurs when starting and stopping.

The specific requirement of the current carrying capacity of the power cables must be adequately sized to suit the genset output rating (including the 10% overload capacity where applicable).

The nominal amperage of a three phase generator set can be calculated as follows:

$$\text{Nominal amperage (A)} = \frac{\text{Nominal KVA rating of genset} \times 1000}{\text{Gen set Nominal voltage} \times 1.73}$$

The cable manufacturers tables should then be consulted to establish the size of the cable required. The genset must also be adequately earthed. Allowance for the type of cable used, voltage drop, ambient temperature, installation method and insulation material must be made and not to be forgotten.

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10.1 Introduction

Power supply to a new development can be taken in from TNB at 415 V Low Voltage (LV) or 11 kV High Voltage/Tension (HT) or 33 kV HT depending on the estimated maximum demand and the acreage of the project concerned. Hence the determination of the MD is important for the long term planning of incoming supply.

10.2 11 kV Intake

10.2.1 Criteria


Previously, 11 kV intake is generally required for loads with estimated MD exceeding 1 MVA. Since March 2007 referring to TNB's Electricity Supply Application Handbook (ESAH) second edition, it clearly states that customers with MD approaching 1 MVA have the option of taking supply at 11 kV, if so desired. However, for MD ranging between 1000kVA to 5000 kVA, the supply voltage must be at 11 kV that is directly fed through TNB's 11 kV switching station.

10.2.2 System

The 11 kV distribution system consists of an 11 kV main intake substation and a number of distribution substations belonging to the consumer. In the past, these consumer substations were known as JKR distribution substations because JKR was the party who designed, operated and maintained the substations and its LV switchboards. Nowadays, many consumers outsource the design, operation and maintenance to a third party. However for clarity, these distribution substations will be called JKR substations.

In its simplest terms the 11 kV system involves selection of transformers, HT switchgears, cabling, protection system and making up the associated circuiting of schematic wiring diagrams showing how they are connected to the incoming supply and also how they are interconnected.

The DE shall also decide whether to have a single feeder or double feeder and whether to have a connection as a ring circuit or radial circuit. The decision made depend on the importance of the building function which cannot afford down time. The DE shall also limit the transformer to a maximum of 2000 kVA only. It is recommended to use more than 1 transformer in this case. Mechanical loads should be supplied from a separate transformer than the other electrical loads. This is to safe guard the ICT load. However this consideration should take into account the constraints on site, loads, operational costs and overall budget.

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A simple 11 kV distribution system is shown in Figure 10.1 where it consists of the following:

- Radial circuit - Substation 1
- Ring circuit - Substation 2, Substation 3, Substation 4
- Spur circuit - Substation 5

In the 11 kV distribution system, ring circuits are preferred for the following reasons:

- When the 11 kV distribution network is connected as a ring circuit, it improves the reliability of the power supply. In the event of a cable fault, the fault can be isolated and supply can be restored as shown in Figure 10.2.
- Easier to cater for any increase in loads. Additional loads can be tapped from the ring circuit as a spur circuit such as substation 5 in Figure 10.1. Alternatively, additional loads can be tapped by adding more substations in the ring circuit. In each case, it is subjected to the design maximum demand of the system.

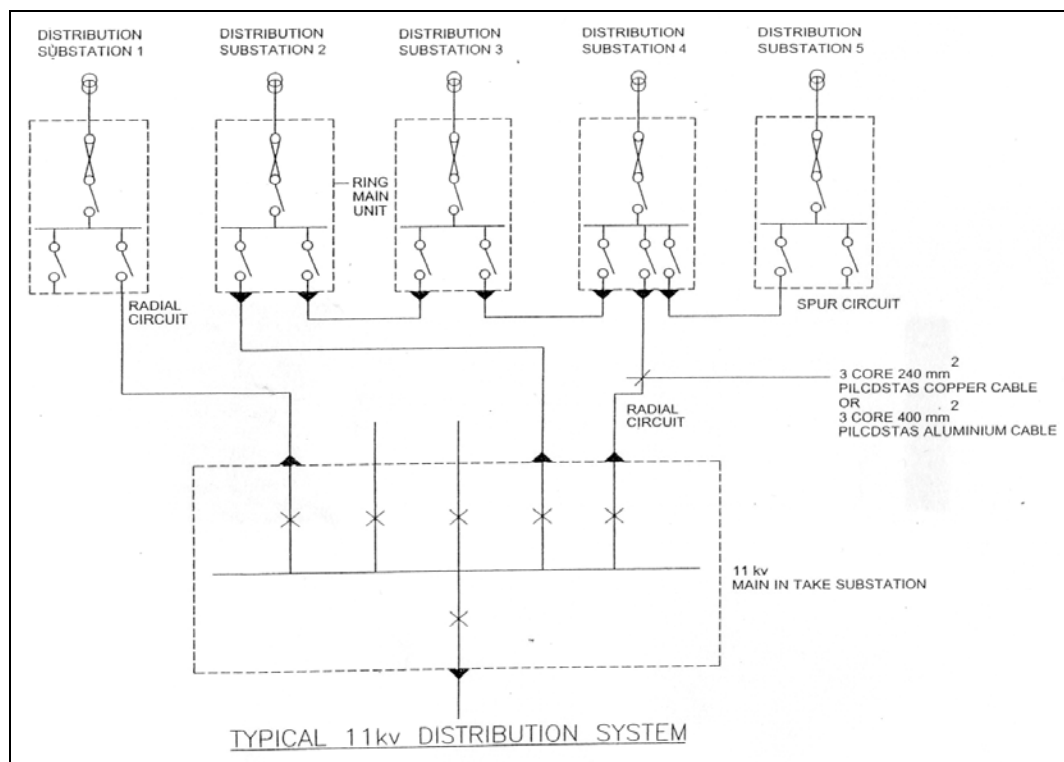



Figure 10.1: A Simple 11 kV Distribution System

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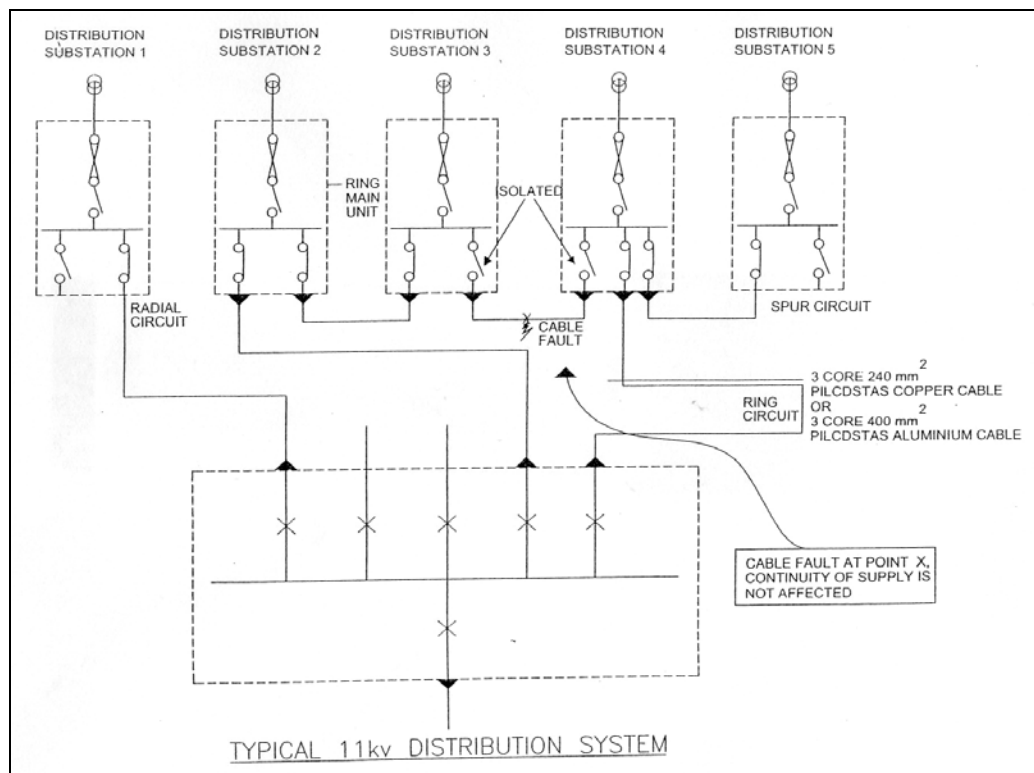



Figure 10.2: Fault at 11 kV Distribution System

As far as possible taking supply at 11 kV is avoided due to the difficulty in getting Competent Personnel (charge man holding high pressure certificate issued by the Energy Commission) for the 11 kV operation and maintenance. When the intake is at 11 kV, the following practice is generally acceptable to TNB viz:

- i) Supply authority gives 11 kV supply up to the JKR 11 kV main switchgear
- ii) HT bulk metering at either the JKR 11 kV switchgear or the TNB's 11 kV switch room
- iii) The 11 kV distribution is done by JKR.

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10.2.3 The Main Intake Substation

10.2.3.1 The standard design of the 11kV main intake substation

The standard design is usually a two chamber type i.e. one chamber houses the TNB 11 kV switchgear and the other chamber houses the JKR 11 kV switchgear as shown in Figure 10.3.

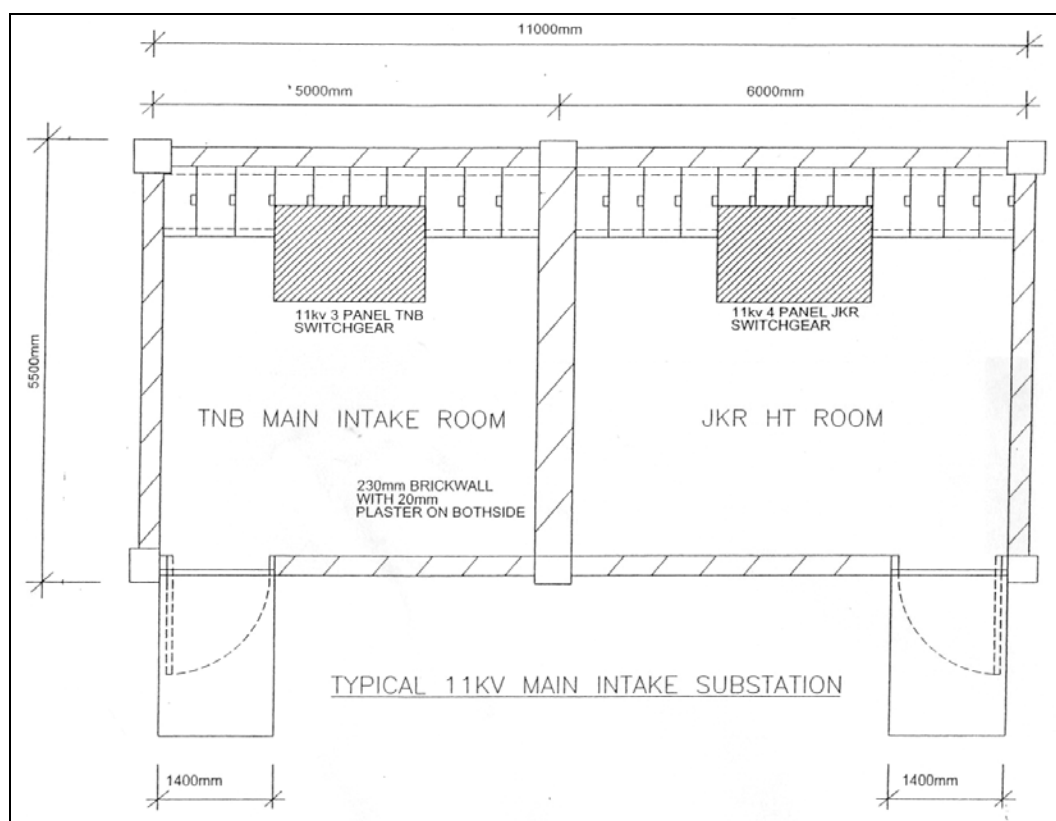



Figure 10.3: Typical 11 kV Main Intake Substation

10.2.3.2 The 11kV Circuit Breaker (CB) Switchgear.


- The CB is to perform very arduous duties under different circumstances.
- The performance is to the large extent dependent on the nature of the circuits in which it is connected.

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- c) The ratings refer to the characteristic values that define the working conditions for which the CB is designed and built.
- d) The CB must be capable of carrying continuously the full load (FL) current without excessive temperature rise and should be able to withstand the electrodynamic forces.
- e) CB should also be in a position to interrupt fault current safely.
- f) The standard ratings of different classes of CB are given in various International Standards e.g. BS 116 and IEC 56.
- g) According to IEC Specifications 56-1(1954), an AC Circuit Breaker has the following ratings:
 - 1) **RATED VOLTAGE** – is the highest RMS voltage above nominal system voltage for which the CB is designed and is the upper limit for operation.
 - 2) **RATED CURRENT** – is the RMS value of current in Amperes which the CB is capable of carrying continuously without exceeding the limit of observable temperature rise.
 - 3) **RATED FREQUENCY** – is the frequency in Hertz (c/s) at which it is designed to operate.
 - 4) **RATED BREAKING CAPACITY:**
 - a) **Symmetrical Breaking Capacity** is the value of symmetrical breaking current which the CB is capable of breaking.
 - b) **Asymmetrical Breaking Capacity** is the value of asymmetrical breaking current which the CB is capable of breaking.

Conventionally, the Breaking Capacity (BC) is given by:

$$MVA = \sqrt{3} \times \text{Rated Voltage} \times \text{Breaking Current (kA)}$$

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5) **RATED MAKING CURRENT CAPACITIES:** This value characterizes the capability of the CB to close the contact against short-circuit currents

- a) Making current is the RMS value of total current (AC + DC) which are measured from the envelope of the current wave at the time of the major peak.
- b) It may also be expressed in terms of instantaneous value of current which is measured at the first major peak of current wave (I_{pk}).
- c) The making capacity of CB is the current that the CB is capable of making.
- d) The absence of any indication to the contrary on the name-plate ratings implies that each rated capacity is the value given by:


Rated Making Capacity = $1.8 \times \sqrt{2} \times \text{Symmetrical Breaking Capacity}$.

(Factor 1.8 is employed to account for the asymmetry present in the short circuit current).

6) **RATED SHORT TIME CURRENT** – is the RMS value of current that a CB can carry in a fully closed position without damage for the specified short time interval under prescribed conditions. It is normally expressed in term of kA.

Generally there are three types of 11kV CB Switchgears:-

- a) SF6 Circuit Breaker
- b) Vacuum Circuit Breaker (VCB)
- c) Oil Circuit Breaker (OCB)

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Example:

Data Given on Nameplate Rating of VCB:

Rate Voltage	:	12 kV
Rated Insulation Level	:	75 kV Impulse
Rated frequency	:	50 Hz
Normal Current	:	630 A
Breaking Current	:	20 kA
Short Time Current (IEC 56)	:	20 kA, 3 second


$$\begin{aligned}
 \text{Making Current} &= 1.8 \times \sqrt{2} \times 20 \\
 &= 51 \text{ kA}
 \end{aligned}$$

$$\begin{aligned}
 \text{Breaking Capacity} &= \sqrt{3} \times 12 \times 20 \\
 &= 416 \text{ MVA}
 \end{aligned}$$

10.2.4 The JKR Distribution Substation

10.2.4.1 Standard design of distribution substation.

The standard design of the JKR distribution substation is shown Figure 10.4. The distribution substation is usually a three chamber type i.e. one chamber houses the 11 kV switchgears, the second chamber houses the transformer and the third chamber house the LV main switchboard.

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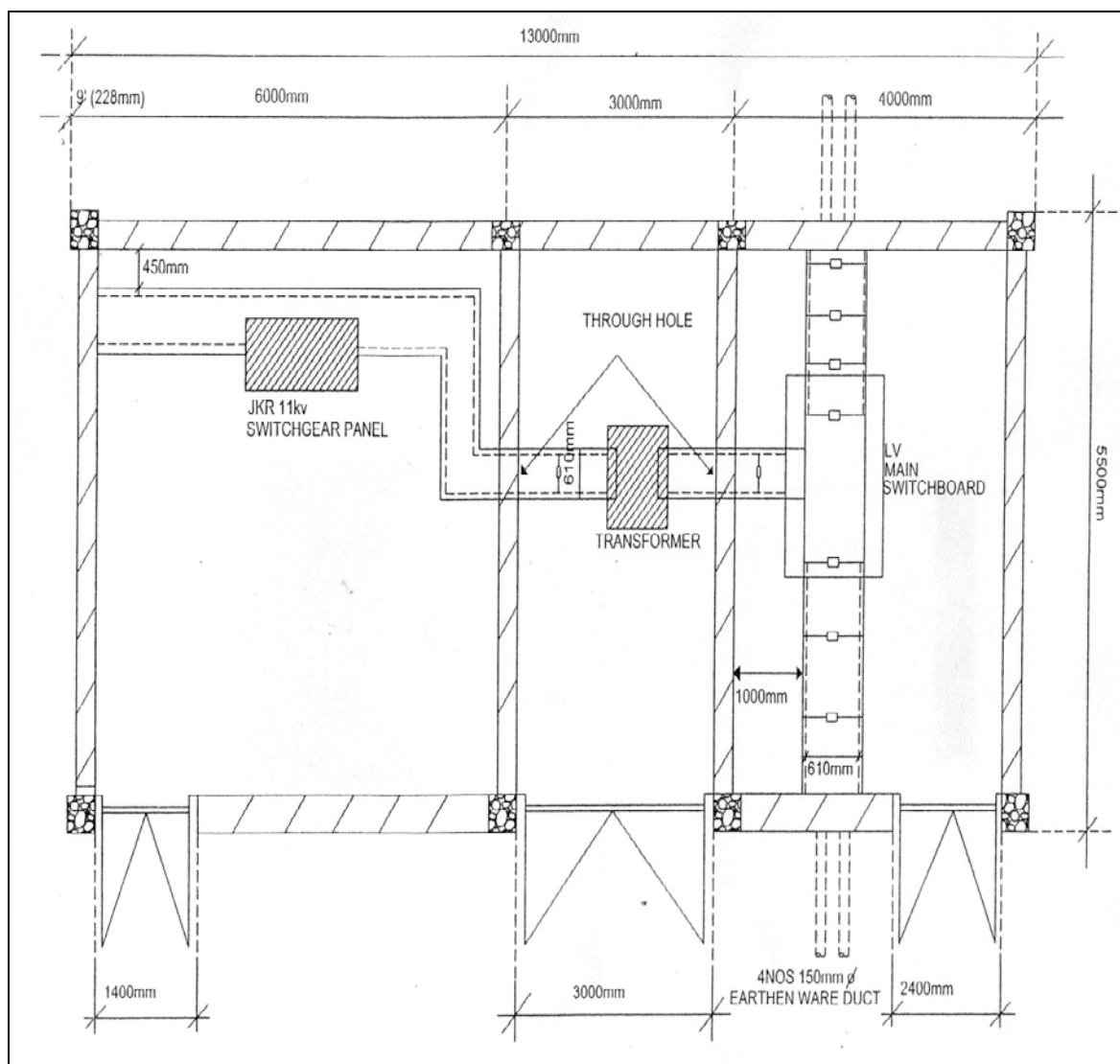



Figure 10.4: Standard Design of Distribution Substation

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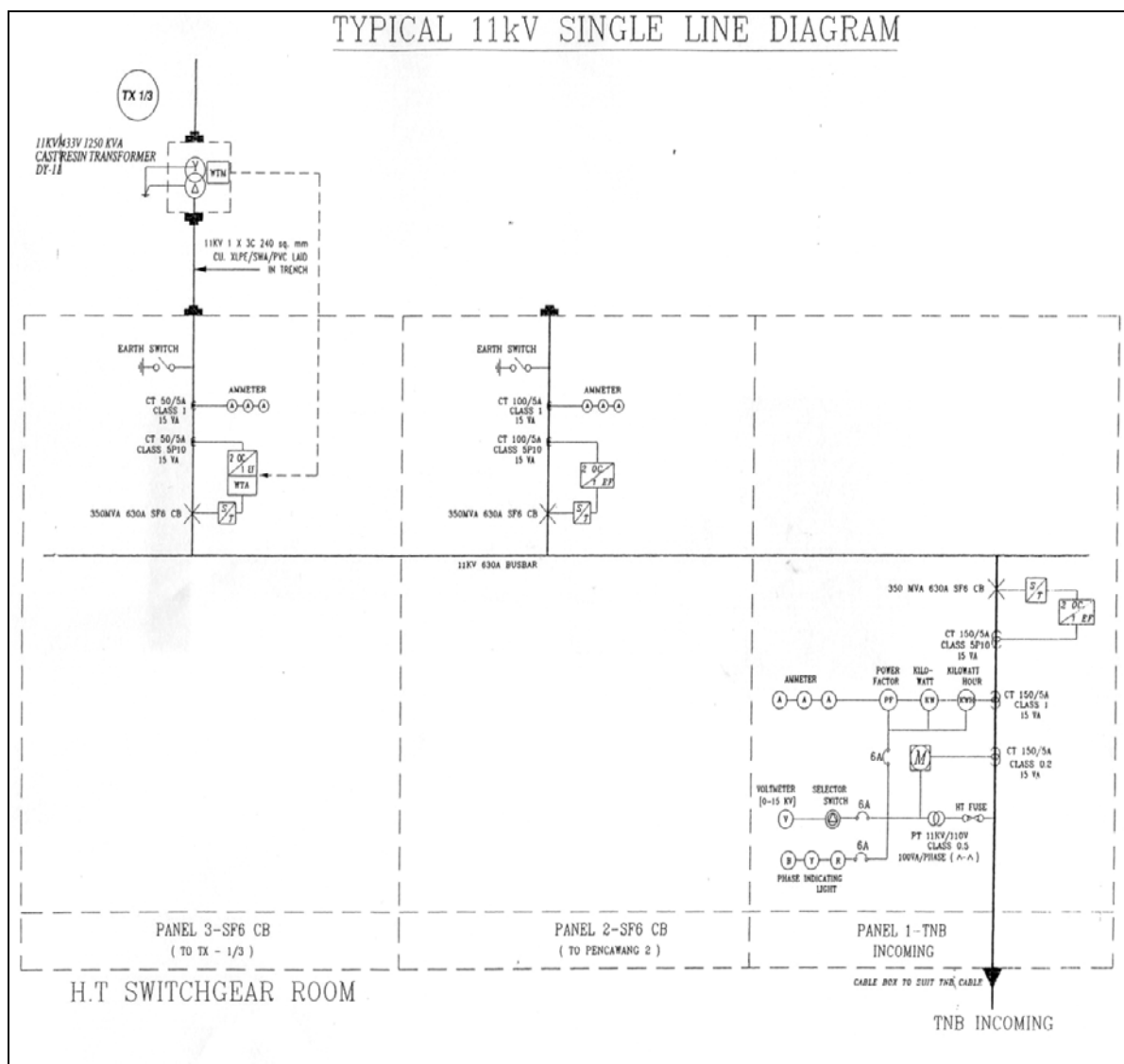



Figure 10.5: Typical 11 kV Single Line Diagram

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10.2.4.2 Types of 11kV Switchgears

a) Circuit Breakers

Similar to the Main Intake 11 kV CB Switchgear.

b) Ring Main Units, RMU

The range includes extensible and non-extensible RMU suitable for outdoor or indoor Installations. Various switchboard configurations can be built up

- 2 x ring switch + 1 x circuit breaker
- 2 x ring switch + 2 x circuit breaker
- 2 x ring oil switch + 1 x oil switch fuse unit
- 2 x ring oil switch + 2 x oil switch fuse unit

Rated Voltage	:	12 kV
Frequency	:	50 Hz
Normal current, Ring Switch	:	630 A
Circuit Breaker	:	630 A
Short Circuit breaking current, CB	:	20k A
Short time withstands current	:	20 kA, 3 seconds.

10.2.4.3 Transformer

a) Selection of Transformer

Size of transformer is chosen based on its capacity to meet the Maximum Demand on the LV side. It is a usual practice to size-up the transformer 10 to 25% more for future load growth. Power transformers used are usually of the oil-immersed type although cast-resin type is also specified. The vector group of the transformer is DYN. Commonly encountered 11 kV/433 kV transformer ratings are:-


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Table 10.1: Selection of Transformer

Size (kVA)	H.T Current (A)	L.V Current (A)
100	5	139
200	10	278
300	16	417
500	26	696
750	39	1043
1000	52	1391
1250	66	1739
1500	79	2087


b) Example:

What is the size of transformer suitable to cater for MD = 350 kW with 20% future load increase.

$$\begin{aligned}
 \text{Now, total load} &= 350 \times 1.2 \\
 &= 420 \text{ kW} \\
 &= 494 \text{ kVA}
 \end{aligned}$$

Transformer size (11 kV/433 kV) is 500 kVA.

- c) The JKR practice is for the DE to limit the transformer size to a maximum rating of 2000 kVA only. If bigger sizes are required it is recommended to install more than one transformer e.g. It is a good practice that mechanical loads be supplied from a separate transformer than the other electrical loads. This safe guards the ICT load. However these considerations should take into account the constraints on site, loads, operational costs and overall budget.

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10.2.5 Protection System and Practice

10.2.5.1 The Protection of Distribution Feeders

- Pilot wire Protection System
- Inverse Time over current and Earth Fault Protection
- Factors affecting the choice of distribution feeder protection.

10.2.5.2 The Protection of Transformer

The various forms of protection schemes for transformers are as follows:

1) Electrical Detection Scheme

- Differential Protection
- Restricted Earth Fault Protection
- Over current and Earth Fault Protection

2) Non-Electrical Detection Scheme

- Bucholz Gas & Oil Detection
- Winding Temperature Alarm

10.2.5.3 Earthing

A common earth bar 25mm x 6mm is run along the walls of the transformer room. Earthing of non-current carrying metal parts are connected to the common bar with same sized copper tape. The neutral earth of the transformer secondary is to be by insulated earthing conductor. A common practice to ensure extra bonding is to solder the steel tape of HT cable with bare copper conductor, 50 mm². The latter is bolted to be earth bar at the cable box. Earthing value is limited to 1 ohm max in order not to effect the grading on earth fault. Refer BS 162:1961.

10.2.5.4 Current and Voltage Transformer

The choice of a class of accuracy higher than is necessary is not economical and can result in transformer being excessively large requiring considerable space in the switchgear for its accommodation. The accuracy class and guidance on selection is given in the relevant British Standards which are reproduced for easy reference in Table 10.2, 10.3, 10.4, 10.5, 10.6 and 10.7. The commonly used class is marked with an asterisk.


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Table 10.2: Voltage Transformer: BS 3941:1975
Accuracy Class Designation

Accuracy Class	Percentage Voltage (Ratio)Error	Phase Displacement	
		Minutes	Centiradians
0.1	+ 0.1	+ 5	+ 0.15
0.2	+ 0.2	+ 10	+ 0.3
0.5	+ 0.5	+ 20	+ 0.6
1.0*	+ 1.0	+ 40	+ 1.2
3.0	+ 3.0	not specified	not specified

Table 10.3: Voltage Transformer: BS 3941:1975
Guidance on the Application

Application	Class of Accuracy
Precision testing or as a standard for testing of Voltage Transformer.	0.1
Metering of precision grade in accordance with BS 37.	0.5
Meters of commercial grade in accordance with BS 37.	1.0
Precision measurements (indicating instruments, recorders And electronic integrating meters).	0.2 or 0.5
General Industrial measurements (indicating instruments & Recorders).	1 or 3
Approximate measurements	3

Table 10.4: Current Transformers: BS 3938:1973
Limits of error for Accuracy Class 0.1 to 1.0

Class	± percentage current (ratio) error at percentage of rated current shown below			± phase displacement at percentage of rated current shown below					
	10 up to but not incl 20	20 up to but not incl 100	100 up to 120	Minutes			Centiradians		
				10 up to but not incl 20	10 up to but not incl 20	100 Up to 120	10 up to but not incl 20	20 up to but not incl 100	100 up to 120
0.1	0.25	0.2	0.1	10	8	5	0.3	0.24	0.15
0.2	0.5	0.35	0.2	20	15	10	0.6	0.45	0.3
0.5*	1.0	0.75	0.5	60	45	30	1.8	1.35	0.9
1*	2.0	1.5	1.0	120	90	60	3.6	2.7	1.8


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Table 10.5: Current Transformers: BS 3938:1973
Limits of error for Accuracy Class 3 and Class 5


Class	± percentage current (ratio) error at percentage of rated current shown below	
	50	120
3	3	3
5	5	5

Table 10.6: Current Transformers: BS 3938: 1973
Limits of error for Accuracy Protective Class 5P and Class 10P

Accuracy Class	Current error at rated primary current %	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current %
		minutes	centiradians	
5P	± 1			5
10P*	± 3	± 60	± 1.8	10

Table 10.7: Selection of Class of Accuracy of measuring Current Transformers

Application	Class of accuracy
(1) Precision testing, or as a standard for testing other current transformer	0.1
(2) Meters of precision grade in accordance with BS 37	0.2
(3) Meters of commercial grade in accordance with BS 37	0.5 or 1.0
(4) Precision measurement (indicating instruments and recorders)	0.1 or 0.2
(5) General industrial measurements (indicating instruments and recorders)	1 or 3
(6) Approximate measurements	5

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10.2.6 The 11 kV Underground Cable

For high voltage, the size of the cable is usually based on the SHORT CIRCUIT RATING of cable rather than the current carrying capacity.

At 11 kV, the SHORT CIRCUIT RATING of the switchgear as required by the supply authority is 350 MVA for 3 seconds. Therefore the cable chosen shall be able to withstand short circuit current of 18.4 kA for 3 second. Refer Figure 10.6 and Figure 10.7.

10.3 415 V Intake

10.3.1 415 V Intake with TNB Substation

a) Criteria

In the case of 415 V intake, TNB generally would request for a substation if the estimated maximum demand of the load exceeds 200 kVA.


b) System

In this system, supply authority will give 415 V supply up to the JKR Main Switchboard in the JKR main switch room which is usually annexed to the supply authority substation as shown in Figure 10.4.

It is a standard supply authority practice that consumer main switch room is annexed to the supply authority substation. The reasons for the above practice are:

- 1) To avoid excessive voltage drops
- 2) Supply authority use Single Core PVC cable for connection between transformer and consumer main switchboard.

For project with large acreage and loading between 500 kVA to 1.5 MVA, supply authority has given approval to give supply with more than one 415V intake. Each 415 V intake would be separately bulk metered at the consumer Main switch room. LV distribution is done by JKR. This approval is given on a case by case basis.

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A typical project example is the Kuala Lipis Infantry Battalion Complex where the estimated maximum demand is 1.5 MVA and supply authority agreed to give 2 substations. The LV distribution in the complex is done by JKR using overhead lines.

- c) Standard design of supply authority substation with JKR switch room

The standard design of supply authority substation with JKR switch room annexed is shown in Figure 10.4.

10.3.2 415 V Intake without TNB Substation

415 V intake with no supply authority substation i.e. direct from the existing supply authority services usually is meant for small load an estimated maximum demand of less than 200 kVA.

10.4 Bulk Metering


In large complexes, the common practice is to take in bulk supply from TNB. TNB's bulk meter is installed in the JKR main switch room while the individual sub-meters are installed by JKR for every unit of the quarters, canteen, etc. These sub meters are read by the staff of the clients and the charges are recouped from the occupants.

For the armed forces projects, this bulk metering and sub-metering policy had been agreed and approved since 1980 by the following parties:

- 1) The Chief Electrical Inspector (via letter KPL.8/1/83 bhg. 1/95 dated 18.1.1980)
- 2) The Commercial Manager LLN (via letter CMD 14/15/44.5/159 dated 15.1.1980)
- 3) The Ministry of Defence
- 4) The Public Works Department

This request for the bulk metering and JKR sub-metering is from the Ministry of Defence for reasons as follows:

- 1) Armed forces personnel are always on the move such as transfer. Therefore, matters such as signing of the supply authority contracts, the paying of deposits would cause tremendous administrative problems to the supply authority as well as to the armed forces.


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- 2) Armed forces personnel are always on temporary move such as operations. These operations may last a few months. Since the supply authority bill will not be paid for that few months, very often they may return and find that the electricity supply has been disconnected.
- 3) In the case of the married quarters, the Ministry of Defence provides free lighting for common areas such as staircase, entrance lobby, etc.

For other large complexes such as institutions of higher learning, the same practice / arrangement may not necessarily be acceptable to all parties. The DE shall be responsible to ascertain the metering arrangements required by the client and finalise them before the design can be completed.

10.5 33 kV Intake

For loads greater than 5000 kVA TNB normally requires a 33 kV Pencawang Pembahagian Utama, PPU. This PPU is known as Pencawang Masuk Utama, PMU to the consumer. However the DE should approach 33 kV PMU with caution. The DE must discuss/query whether the 33 kV PMU belongs to TNB or to the client because there are many other operational maintenance aspects that have to be taken into account e.g. the availability of the required competent person in the market to operate the PMU. In addition if it belongs to the TNB then decision/conditions should be made that the PPU shall cater only for that client and not for TNB to supply to other clients. The consumer may be metered at 11 kV tariff or 33 kV tariff. This must be discussed and finalized with TNB and made clear to the consumer.

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Short Circuit Ratings Conductors

The following graphs show the short circuit capability of XLPE insulated cables for working voltages up to and including 19000/33000V.

The graphs are based on the following conditions:-

- a) Cables are fully loaded at the start of the short circuit (Conductor temperature 90°C)
- b) Conductor temperature at the end of the short circuit is 250°C.

STRANDED COPPER CONDUCTORS

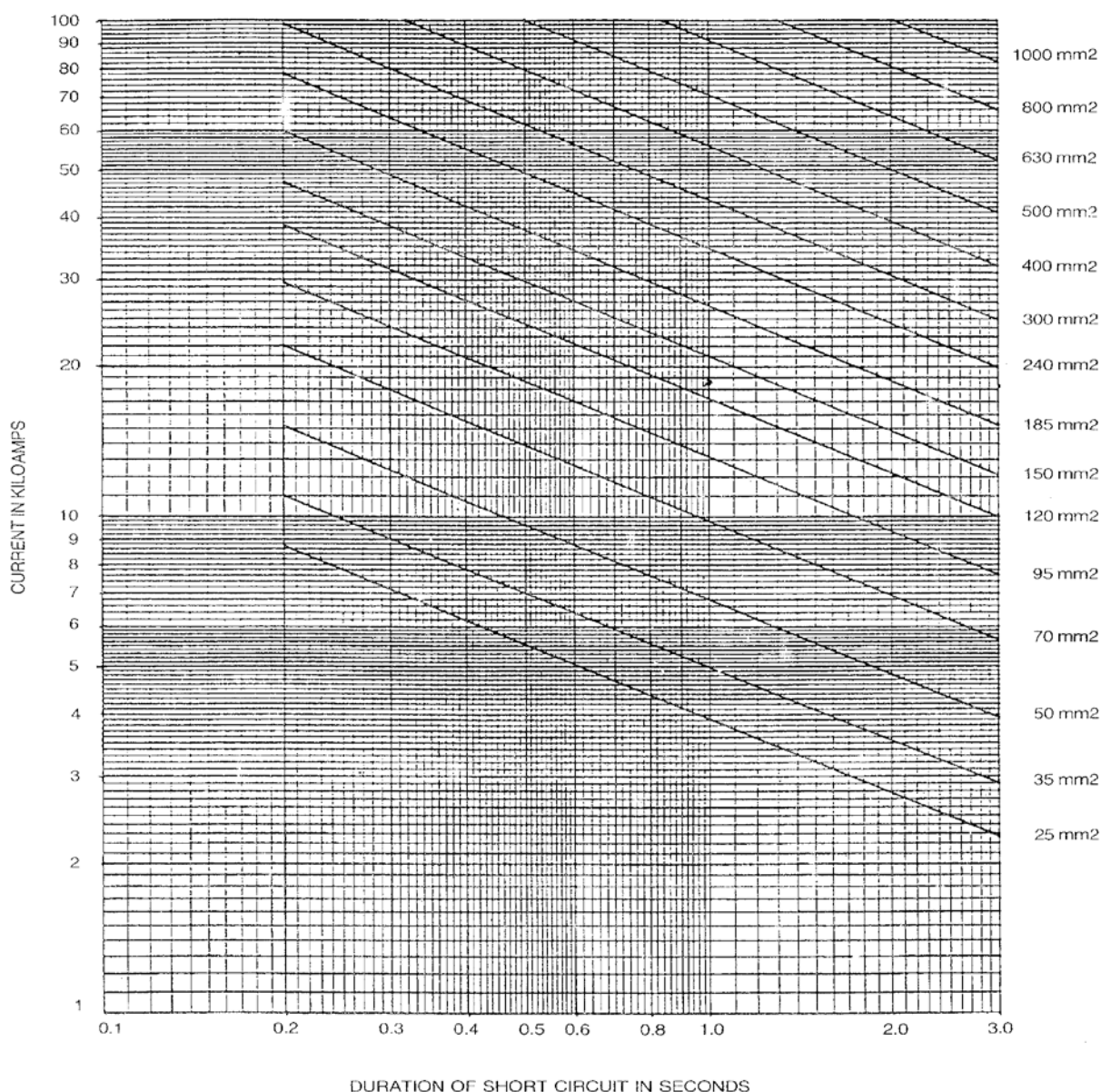

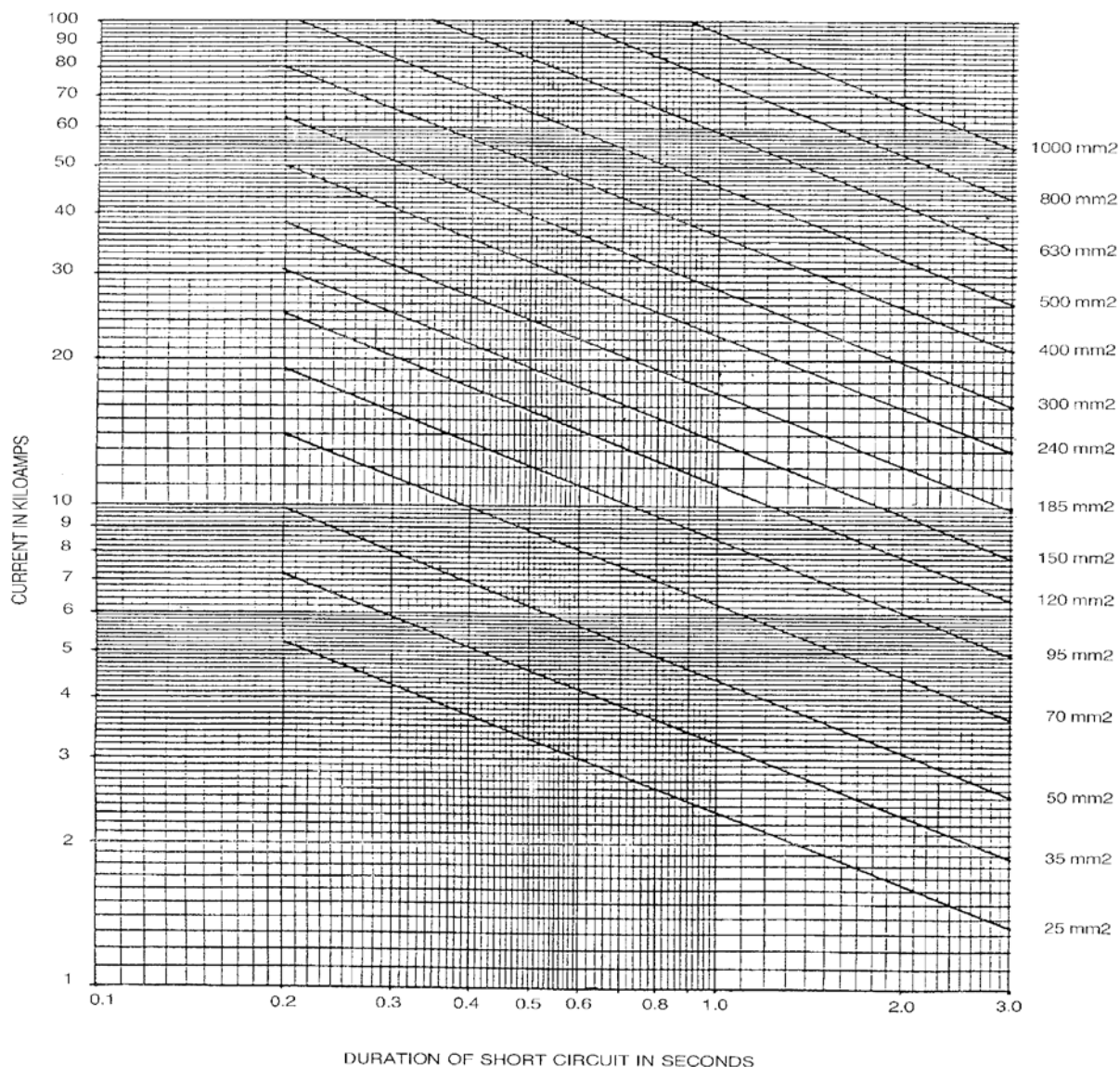


Figure 10.6: Short Circuit Rating for Stranded Copper Conductors

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STRANDED ALUMINIUM CONDUCTORS



NOTE


It should be ensured that the accessories associated with the cable are also capable of operation at these values of fault current and temperature.

The use of soldered type connectors in cable accessories (instead of compression type) would limit the final conductor temperature to 160°C and consequently reduce the fault current capacity by approximately 30%.

The asymmetrical fault rating of the smaller cables may be decided by the short circuit capacity of the conductor rather than the armour rating. It is therefore necessary to compare the two ratings.

The short circuit capacity of steel tape armouring is much lower than steel wire armouring for a cable of equivalent dimensions. Consequently, BICC normally recommend steel wire armouring in preference to steel tape armour on three core cables.

Figure 10.7: Short Circuit Rating for Stranded Aluminium Conductors

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11.1 System Design Procedure

Public address systems of various scales are used in all fields of today's world for various purposes at various locations. A system engineer designs a system suitable to a specific application. In all cases, he starts it with preparing a system plan for the customer, involving the purpose of use, budget, and specifications.

Toward achieving an appropriate system design within the budget of the system plan, it is important to clarify the main purpose of acoustic devices to be used and to decide whether to select or not to select incidental functions (such as additional functions which may be of help if provided). It is also necessary in selecting system components to carefully study not only their performance but the ease of operation and the use of PA system as well as reliability (i.e., capability of performing the intended function whenever required). A general system design procedure is shown in the flow chart for system design at Appendix A.


11.2 Acoustic Design Basics

The first problem raised in designing a public address system concerns the noise and acoustic characteristics of the place where the system will be installed.

Noise can be generally classified into two kinds, that is, noise inside the building, and noise outside. Noise inside the building includes, for example, the noises produced by the elevators and air conditioners, talking people, machines at work, and the goods carried on the floor. Outside noise may be such that produced by traffic, construction work, waves of the sea, or running water in a river. It generally varies much depending on the kind of its source, its distribution, the topography, and the buildings in the neighbourhood. It can also vary greatly from time to time.

The acoustic characteristics can pose a problem particularly when a public address system is installed indoors. The main factors involved are reverberation and echo.

A room that has walls of a heavy and hard material with small acoustic absorptive (for example, concrete, slate, or plywood walls) generally has a long reverberation time. Specifically, slate covered factories in the shape of a dome, parking areas in buildings, and gymnasiums have a long reverberation time. Reverberation lowers sound clarity, and is detrimental to acoustics at low frequencies, particularly in rooms which are not acoustically well designed.

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Echo is a reflection of the original sound heard later. Reflected sounds reaching the ear within 1/20 second (50 ms) from the direct sound reinforce the original sound so that they sound like a signal sound with reverberation. If reflected sounds reach the ear later than that, the reflected sounds are heard as an echo because they sound separate from the direct sound. The echo so seriously affects sound clarity that it makes a music performance impossible. It is the most harmful of all acoustic ill effects.

Outdoor echoes, such as caused by winds, mountains, buildings, and topographical features, also pose a problem. Therefore, when selecting speaker locations, high places where the speakers can take best advantage of fair winds, and places less likely to be troubled by echoes are chosen. Another way of coping with this problem is to locate small-powered speakers at many points.

11.2.1 Noise and Speaker Sound Pressure


If noise level is higher than the level of the sound coming out of the speaker, the speaker sound cannot be heard. No matter how close the speaker may be its sound cannot be heard if noise level is too high. The required difference between speaker sound and noise levels varies depending on the kind and degree of noise, but at least a sound pressure difference of 6 to 10 dB (2 to 3 times) is necessary for making announcements, or at least about 3 dB (about 1.5 times) for background music or other music programs.

For reference, noise levels at various locations are shown in the table 11.1 below.

Table 11.1: Noise Levels

Near jet aircraft engine	120 dB
Under railway girder	100 dB
Road intersection	80 dB
Noisy office	60 dB
Suburban housing area	40 dB
Tree leaves rustling in breeze	20 dB
Minimum audible sound	0 dB

Note: Generally, noise level is high at low frequencies, and low at high frequencies. Noise level is measured with a noise meter, and measured noise levels in WRMS are used.

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11.2.2 Speaker Output Sound Pressure and Sound Attenuation

- Output sound pressure

Speaker specifications include output sound pressure, which represents the sound volume that can be produced by the speaker, measured by applying a 1-watt input to the speaker and measuring the sound one meter away from it.

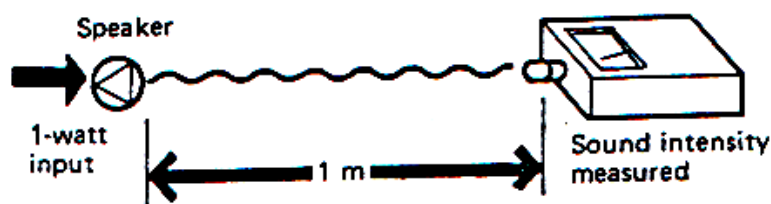



Figure 11.1: Speaker Sound Pressure

Output sound pressure is expressed in decibels (dB), which is equal to phons used to express noise. Thus, dB and phons are generally used to express the same in noise calculations. Output sound pressure also represents the speaker capacity (or efficiency) of converting electrical signals into sound, which varies from 85 dB to 110 dB with the type kinds of speakers.

Table 11.2: Difference In Output Sound Pressure With Type Kinds Of Speakers

Speaker	Output sound pressure
Ceiling / wall mount speaker	85 to 93 dB
Column gymnasium speaker	90 to 106 dB
Horn speaker	95 to 110 dB

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What will be the output sound pressure level if a higher input of 2 watts and more is applied to the speaker? The output sound pressure increases as shown in the Table 11.3 below.

Table 11.3: Loudspeaker Input Versus Increased Sound Pressure

Loudspeaker Input (W)	Increased Sound Pressure (dB)	Loudspeaker Input (W)	Increased Sound Pressure (dB)
1	0	16	12
2	3	20	13
3	5	25	14
4	6	30	14.8
5	7	32	15
6	8	40	16
7	8.5	50	17
8	9	60	17.8
9	9.5	70	18.5
10	10	80	19
13	11	90	19.5
15	11.8	100	20


Note: A double input gives an increase of 3 dB

Output sound pressure (dB), when an input of a certain watts is applied to the loudspeaker = (Output sound pressure in dB in the loudspeaker specifications) + (Increased sound pressure in dB).

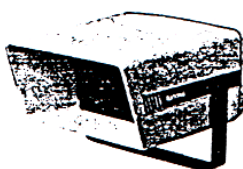
Example 1: A 3-watt input is applied to speaker below



The output sound pressure of the speaker is 92 dB (1 m, 1W). If a 3-watt input is applied, the sound pressure increases by 5 dB. Thus, 92 dB + 5 dB = 97 dB (1 m).

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Example 2: A 15-watt input is applied to speaker below



The speaker is a horn type speaker, which features a high output sound pressure of 101 dB (1 m, 1 W). If a 15-watt input is applied to it, $101 \text{ dB} + 11.8 \text{ dB} = 112.8 \text{ dB}$ (1 m).

As is clear from the two examples above, the higher the output sound pressure, the higher sound can the loudspeaker produce more efficiently.

In terms of amplifiers, the same sound pressure can be obtained from a smaller powered amplifier if the loudspeaker has a high output sound pressure. Assume that we now have a 87 dB loudspeaker and a 90 dB loudspeaker here, for example;

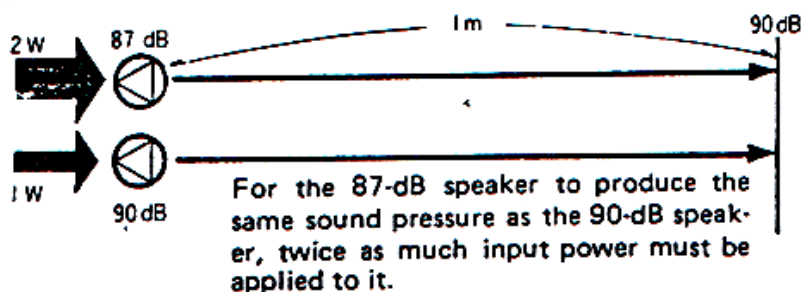



Figure 11.2: Output Sound Pressure and Required Input Power

To produce a sound pressure of 90 dB from the 87 dB loudspeaker, its output sound pressure must be increased by 3 dB. This means that a 2-watt input must be applied to the 87 dB loudspeaker.

Thus, if loudspeakers that have a difference of 3 dB in sound pressure are used, an amplifier with twice the output of the other must be used. If the difference is 6 dB, an

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amplifier with four times the output power must be used. If the difference is 9 dB, an amplifier eight times as powerful is required.

What will be the total output sound pressure in dB if two or more loudspeakers, each with an output sound pressure of X dB, are installed in the same place in the same direction?

If a 1 watt input is applied to two 90 dB loudspeakers, their total output sound pressure increases by 3 dB to 93 dB, which is the same as when a 2 watt input is applied to one of them.

If a 1 watt input is applied to three 90 dB loudspeakers, the result will be same as when a 3 watt input is applied to one of them. That is, the total output pressure increases by 5 dB to 95 dB.


Table 11.4: Increased Sound Pressure Where Two Or More Loudspeakers Of The Same Capacity Are Installed In The Same Place

Number of loudspeakers	Increased sound pressure
1	0 dB
2	+ 3 dB
3	+ 5 dB
4	+ 6 dB

Incidentally, the rated output sound pressure of a loudspeaker applies where a certain specified sound source, not a speech or music, is used. In the past, the required sound pressure was often calculated from the rated output sound pressure. This, however, does not have a peak factor (allowance for speeches or music) so that sound becomes distorted at peak level

Therefore, we calculate the required sound pressure by adding the peak factor for the peak of the program source to the required sound pressure difference, which is the difference between noise level and the average sound pressure of the program source.

Sound clarity increases as the required sound pressure difference increases. A difference of about 6 to 10 dB between noise and the average sound pressure of the program source is normally sufficient.

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The peak factor (the difference between the average sound pressure and peak sound pressure of a program source) varies from one program source to another, but it is 10 dB for speeches and background music, or 20 dB for music.

This can be summarized as follows:

$$\text{Required sound pressure} = \text{Noise level} + \text{Required sound pressure difference} + \text{Peak factor}$$

Speeches and Background Music

$$\begin{aligned} \text{Required sound pressure} &= \text{Noise level} + (6 \text{ to } 10 \text{ dB}) + 10 \text{ dB} \\ &= \text{Noise level} + (16 \text{ to } 20 \text{ dB}) \end{aligned}$$

Music

$$\begin{aligned} \text{Required sound pressure} &= \text{Noise level} + (6 \text{ to } 10 \text{ dB}) + 20 \text{ dB} \\ &= \text{Noise level} + (26 \text{ to } 30 \text{ dB}) \end{aligned}$$

Table 11.5 below shows the required sound pressures at various locations


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Table 11.5: Noise Levels and Required Sound Pressures

Noise effect	Noise level (dB)	Description	Required sound pressure		
Conversation inaudible	120 110 100 90	<ul style="list-style-type: none">Near aircraft engineSiren, automobile hornUnder railway girder, inside electric trainMachine shop	If noise level is 100 dB or more, a sound pressure of more than 120 dB (maximum audible sound level) may be necessary (varying depending on noise frequency) so that announcements will be hardly audible.		
Conversation hardly audible	80	<ul style="list-style-type: none">Road intersection, printing shop	100 dB or more		
Must speak aloud	70	<ul style="list-style-type: none">Department store, noisy office			
Normal conversation possible	60	<ul style="list-style-type: none">Restaurant, hotel lobby, office, urban housing area	70 to 90 dB	Where music is the primary sound source, 80 to 100 dB	
	50	<ul style="list-style-type: none">.....			
	40	<ul style="list-style-type: none">Suburban housing area, hospital, hotel	70 dB or more (Noise can be nearly ignored)		
	30	<ul style="list-style-type: none">Broadcasting studio			
	20	<ul style="list-style-type: none">Tree leaves rustling in breeze			
	10	<ul style="list-style-type: none">Whisper			
	0	<ul style="list-style-type: none">Minimum audible sound			

11.2.3 Sound Attenuation

Speaker output sound decreases in volume as the distance from the speaker increases. Sound volume (sound pressure) decreases in inverse proportion to the square of distance.

Table 11.6 below shows sound attenuation outdoors (wherein air density difference, temperature difference, wind direction, reflection from obstacles, refraction, etc. are ignored).



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Table 11.6: Distance from Speaker and Sound Attenuation in Free Space

Distance	Attenuation	Distance	Attenuation
1 m	0 dB	28 m	29 dB
2 m	6 dB	30 m	29.5 dB
3 m	9.5 dB	32 m	30 dB
4 m	12 dB	36 m	31 dB
5 m	14 dB	40 m	32 dB
6 m	15.5 dB	45 m	33 dB
7 m	17 dB	50 m	34 dB
8 m	18 dB	56 m	35 dB
9 m	19 dB	60 m	35.5 dB
10 m	20 dB	64 m	36 dB
11 m	21 dB	70 m	37 dB
13 m	22 dB	80 m	38 dB
14 m	23 dB	90 m	39 dB
15 m	23.5 dB	100 m	40 dB
18 m	25 dB	150 m	43.5 dB
20 m	26 dB	200 m	46 dB
22 m	27 dB	300 m	49.5 dB
25 m	28 dB	400 m	52 dB

Sound attenuation indoors is less than that in free space, varying depending on the acoustic characteristics of the room. Generally, public address systems are designed with sound attenuation in free space as reference, using the above as peak factor.

Sound attenuation also varies with frequency. That is, a high-frequency sound attenuates more than a low-frequency sound.

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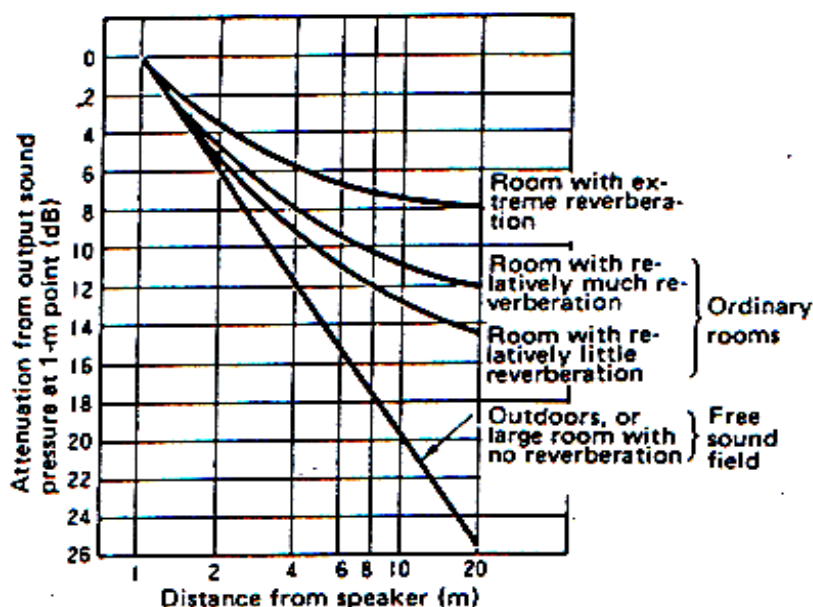



Figure 11.3: Sound Pressure Attenuation Indoors Versus Distance

The sound pressure at a point a certain distance away from the speaker is calculated as follows:

**[Output sound pressure (dB) where an input of a certain wattage is applied] —
 (Attenuation by distance (dB)).**

Suppose that the rearmost seats in an auditorium are 25 meters away from the speakers. The speaker output sound pressure required to reach them at 80 dB level is, by compensating for attenuation of the original sound pressure:

$$80 \text{ dB} + 28 \text{ dB} = 108 \text{ dB}.$$

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Example 1:

What wattage of input must be applied to the speakers of a PA system in an office?

Step 1

Suppose that the noise level indoors is 60 dB. If the required sound pressure difference is 6 dB, the required sound pressure will be, by adding a peak factor of 10 dB:

$$\begin{aligned}
 \text{Required sound pressure} &= \text{Noise level} + \text{Peak factor} + \text{Required sound pressure difference} \\
 &= 60 \text{ dB} + 10 \text{ dB} + 6 \text{ dB} \\
 &= 76 \text{ dB.}
 \end{aligned}$$

Step 2

A sound pressure of 76 dB is required at the listening points, which are 1.7 meters away from the speakers.

This means an attenuation of about 5 dB.


$$\begin{aligned}
 \text{Speaker sound pressure} &= \text{Required sound pressure} + \text{Attenuation by distance} \\
 &= 76 \text{ dB} + 5 \text{ dB} \\
 &= 81 \text{ dB.}
 \end{aligned}$$

Step 3

To achieve a uniform sound pressure, the speakers are so arranged that their directional angles cross at the listening points on condition that their service area is 90° each.

$$\text{Speaker to speaker distance} = 2 \times (2.7 \text{ m} - 1 \text{ m}) = 3.4 = 3 \text{ m}$$

Thus, the speakers are installed on the ceiling 3 meters apart.

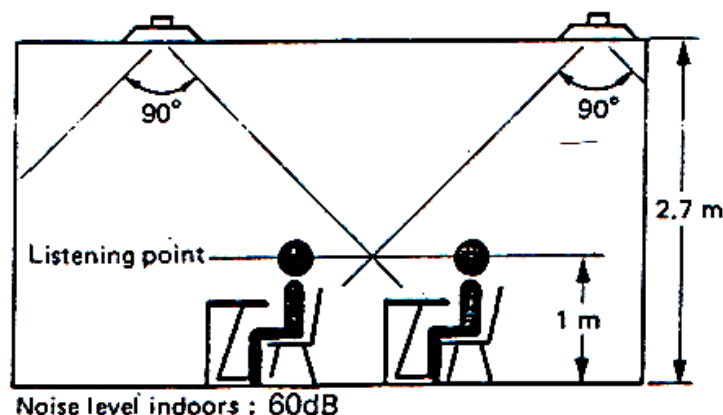
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Step 4

Selecting a speaker:

A ceiling speaker was selected. This speaker has an output sound pressure of 92 dB (1 m, 1 W) so that enough sound volume can be obtained even if an input of about 0.1 watt is applied to it.

Actually, the total input wattage is the input wattage per speaker multiplied by the number of speakers.




Example 2:

What wattage of input must be applied to the speakers of a sound reinforcement system in, for example, a gymnasium or auditorium?

Step 1

Suppose that the noise level at the audience seats is 60 dB. If the required sound pressure difference is 6 dB, the required sound pressure will be, by adding a peak factor of 20 dB:

$$\begin{aligned}
 \text{Required sound pressure} &= \text{Noise level} + \text{Peak factor} + \text{Required sound pressure Difference} \\
 &= 60\text{dB} + 20\text{dB} + 6\text{Db} \\
 &= 86\text{dB}.
 \end{aligned}$$

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Step 2

Even the rearmost row of seats must have a sound pressure of 86 dB. Because it is 14 meters away from the speakers, the original sound pressure will be attenuated by 23 dB.

$$\begin{aligned}
 \text{Speaker sound pressure} &= \text{Required sound pressure} + \text{Attenuation by distance} \\
 &= 86 \text{ dB} + 23 \text{ dB} \\
 &= 109 \text{ dB.}
 \end{aligned}$$

Step 3

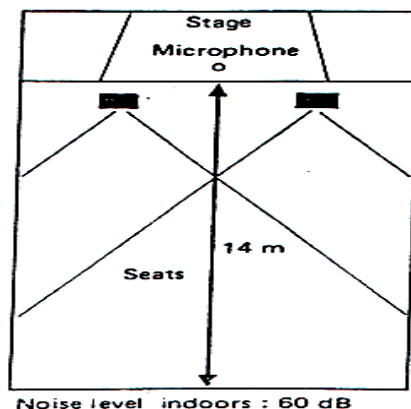
As shown, a speaker sound pressure of 109 dB is necessary. Because two speakers are used here, the required sound pressure per speaker is 109 dB minus 3 dB, that is, 106 dB.


Step 4

Next is the selection of a speaker model. A column speaker was selected. The speaker has excellent directivity and provides satisfactory performance for music as well. The output sound pressure of the speaker is 95 dB (1 m, 1 w).

$$\begin{aligned}
 \text{Increased sound pressure} &= \text{Speaker sound pressure} - \text{Output sound pressure} \\
 &= 106 \text{ dB} - 95 \text{ dB} \\
 &= 11 \text{ dB.}
 \end{aligned}$$

This can be obtained by applying a 13 watt input. The selection of the column speaker is correct because its rated input is 15 watts.



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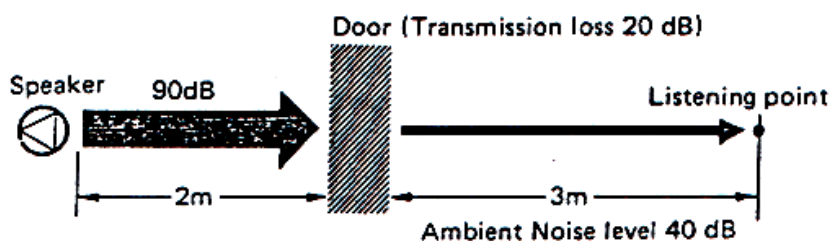
11.2.4 Sound Insulation and Transmission

Sound insulation and transmission have two meanings. One is to shutting out the sounds or announcements that originate in the next room, and the other is to transmit sounds or announcements through a door, for example.

These are calculated as follows:

$$\begin{aligned} &\text{Transmitted Sound Pressure (dB)} \\ &= \text{Incident Sound Pressure (dB)} - \text{Transmission Loss (dB)} \end{aligned}$$

Example 1:



Sound pressure (dB) at the listening point


$$= 90 \text{ dB} - (\text{Loss at 2 m: 6 dB}) - (\text{Transmission loss: 20 dB}) - (\text{Loss at 3 m: 9.5 dB})$$

$$= 54.5 \text{ dB.}$$

Under this condition, the sound from the speaker is louder than the noise level at the listening point, and can be heard through the door.

Transmission Losses

Glass window (3mm thick)	Approx. 10 dB
Wooden door (9mm thick)	Approx. 25 dB
Concrete block (100mm thick)	Approx. 45 dB
Concrete (100mm thick)	Approx. 50 dB

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11.2.5 Frequency Characteristics (Effect of a graphic equalizer)


The human ear is sensitive to sounds of 2,000 Hz to 6,000 Hz. In other words, one of the conditions for good audibility is to produce aloud sounds of 2,000 Hz to 6,000 Hz.

Each building or room has its own reverberation time frequency characteristic, which means the reverberation time characteristic of that building or room against sounds from low to high.

Generally, gymnasiums and auditoriums have such a structure and interior materials that bass sound can hardly be absorbed. That is, bass sound lingers on and thus is emphasized.

Suppose an acoustic system having a very flat characteristic is used in a gymnasium.

The actual sound in a gymnasium having a reverberation time frequency characteristic such as shown in Fig. 1 will be as shown in Fig. 2. If bass sound is emphasized, the sounds within the range of 2,000 Hz to 6,000 Hz that is necessary for, clarity fall, resulting in less clear sounds.

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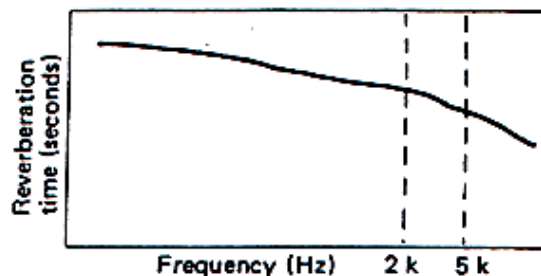


Fig. 1. Reverberation Time Frequency Characteristic

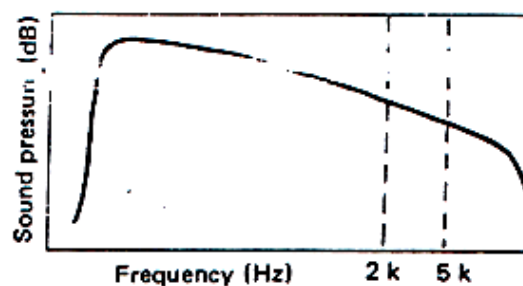


Fig. 2. Transmitting Frequency Characteristic

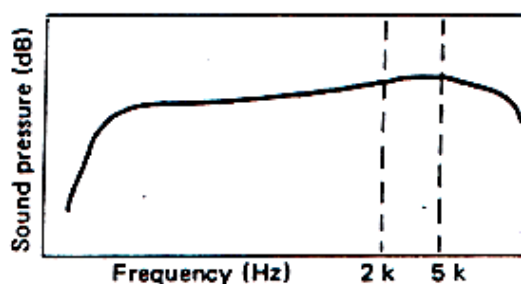



Fig. 3. Transmitting Frequency Characteristic after Correction

A graphic equalizer for sound field correction electrically corrects this phenomenon.

The graphic equalizer can vary sound level at every certain frequency. If the power response is as shown in Fig. 2, the graphic equalizer suppresses the sounds of up to 1,000 Hz, and slightly raises treble sounds of 2,000 Hz and upward.

Clarity can be raised as described above.

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11.3 Speaker Selection

Speaker selection and arrangement is so important that the performance of an acoustic system depends mostly on it. Such troubles as poor clarity and lack of volume are often caused by the wrong selection or arrangement of speakers.

11.3.1 Type Kinds of Speakers

Speakers can be roughly classified into indoor and outdoor types, which can be further broken down by place of use and purpose of use as shown in the Table 11.7 below.

Table 11.7: Type Kinds of Speakers

Kind of Speaker		Use		
		Public Address	Background Music	Music
Indoor	Ceiling Mount	√	√	
	Wall Mount	√	√	
	Column	√		√
	Horn	√		
	CLEARHORN	√		√
Outdoor	Column (Weatherproof)	√	√	√
	Horn	√	√	
	CLEARHORN	√	√	√


The required reproducing frequency bandwidths of speakers by use are explained.

▪ Public address

Generally, a frequency band of about 200 to 6,000 Hz can achieve the purpose. In the worst case, the required frequency band is from about 250 to 4,000 Hz, which corresponds to the voice frequency band of man.

▪ Background music

Background music, including music in a light sense of the word, requires a frequency band of about 100 to 8,000 Hz.

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▪ Music

In a hall primarily designed for amplifying music, a frequency band of about 40 to 15,000 Hz is necessary. Therefore, conditions for music reproduction are stricter than in the other cases, and special care must be taken in selecting speakers for it.

11.3.2 Speaker Arrangement

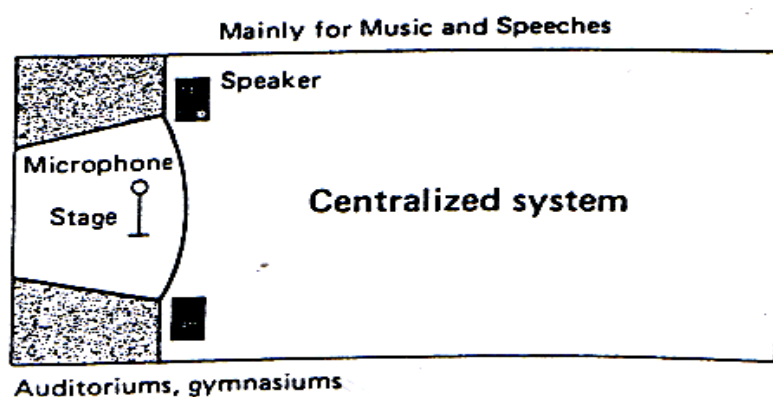
Speaker arrangement varies with the electrical input to be applied and speaker efficiency as mentioned before. Where speakers are used indoors, the purpose of use, acoustic characteristics (reverberation, echo, and sound insulation), and speaker directivity must also be taken into account. Where speakers are used outdoors, weather resistance to winds and rains must be additionally considered.


Generally, there are three types of speaker arrangement normally applied in sound system design:-

11.3.2.1 Centralized system

This system places speakers in a centralized position to operate in a single direction; and has the advantages of providing a directional sense and low installation cost. The former is particularly effective for lectures, speeches, and concerts where the visual direction must meet the sound direction.

It also has disadvantages: Difficulty of providing a uniform level; poor clarity caused by reverberation and echo; and large output power required where noise level is high. In factories where much noise is produced, the dispersed system mentioned next is suitable.



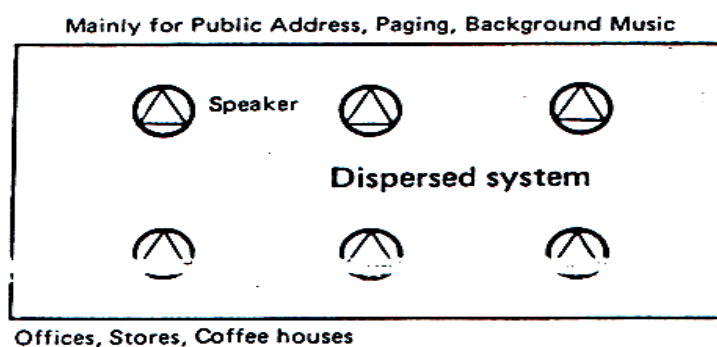
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11.3.2.2 Dispersed system

This system uses speakers in a dispersed arrangement. It is suitable to background music because it provides uniformity of sound level. If a small electric input is applied to one of the speakers to narrow the audible range, sound reflection decreases so that clarity can be increased where reverberation time is long.

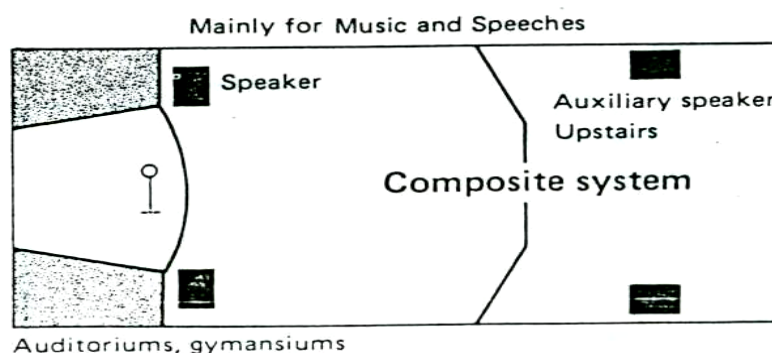
If many speakers of the system interfere with one another, it can lower sound quality. The important point for the dispersed system is to correctly select a number of speakers and the operating range of each speaker.


The dispersed system costs more to install than the centralized system.



11.3.3 Composite system

This is a combination of the centralized system and the dispersed system. It uses centralized speakers to achieve the intended sound pressure and small powered auxiliary speakers in a dispersed arrangement at points where sound pressure is short of the required level. The composite speaker system is frequently seen in auditoriums and gymnasiums.



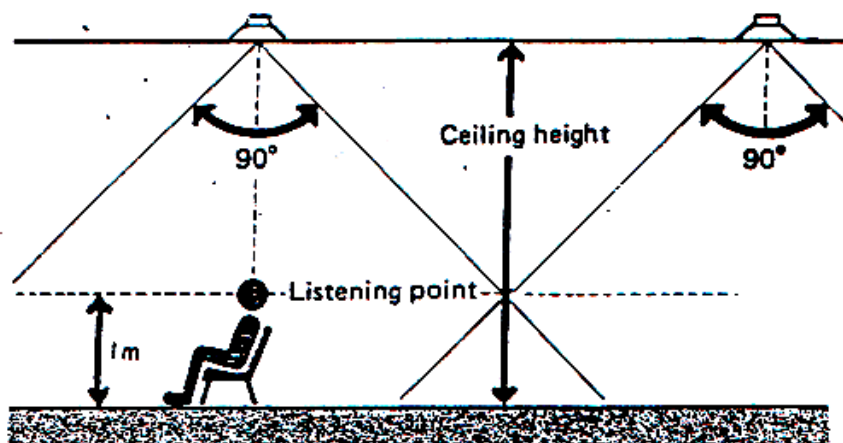
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11.3.3.1 Speaker Arrangement Indoors

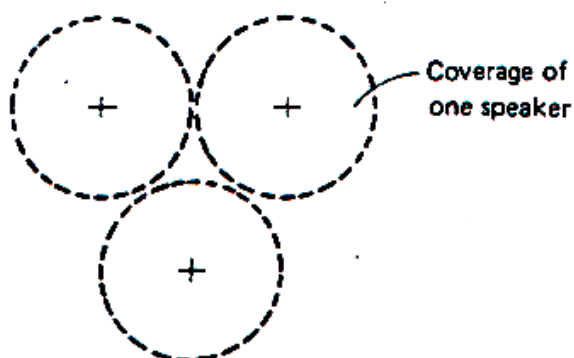
a) Restaurants, Offices, Stores.

Because the ceiling is generally low, install many ceiling mount speakers of about 1 W to 3 W.

Determine a number of speakers suitable to the room size.



Install speakers zigzag to achieve a uniform sound pressure.



The following Table 11.8 applies where noise level is 60 dB, the peak factor 10 dB, and the required sound pressure difference 6 dB.


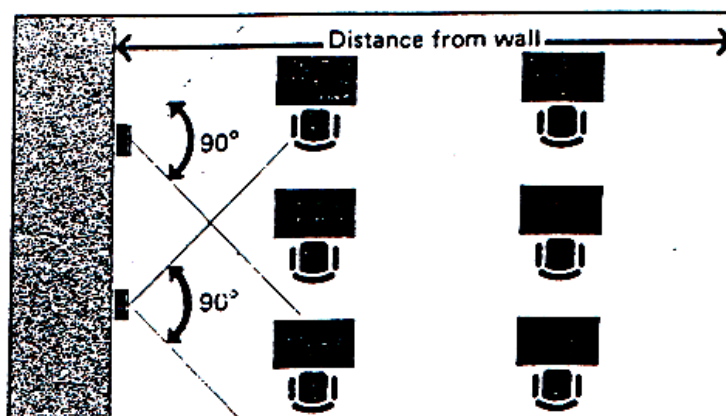
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Table 11.8: Ceiling Height And The Coverage Of Each Speaker

Ceiling height	Speaker spacing	Coverage of one speaker	Input per speaker
2.5 m	3 m	Approx. 9 m ²	1 W
3.0 m	4 m	Approx. 16 m ²	1 W
3.5 m	5 m	Approx. 25 m ²	1 W
4.0 m	6 m	Approx. 36 m ²	3 W
5.0 m	8 m	Approx. 64 m ²	3 W

b) Classrooms and Offices

Select 1 to 6 watt wall mount speakers suitable to the room size.




The following Table 11.9 applies where noise level is 60 dB, the peak factor 10 dB, and the required sound pressure difference 6 dB.

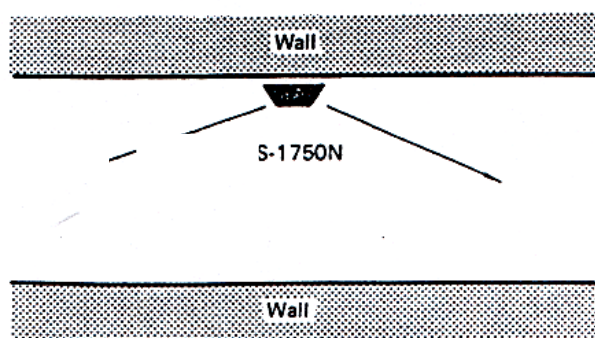
Table 11.9: Distance From Wall And The Coverage Of Each Speaker

Distance from wall	Speaker spacing	Coverage of one speaker	Input per speaker
Up to 4 m	4 m	Approx. 16 m ²	1 W
Up to 7 m	7 m	Approx. 50 m ²	3 W
Up to 9 m	8 to 16 m	Approx. 100 m ²	5 W

Do not install the wall mount speaker facing each other. If wall mount speakers are installed facing with each other the sound clarity will be degraded.

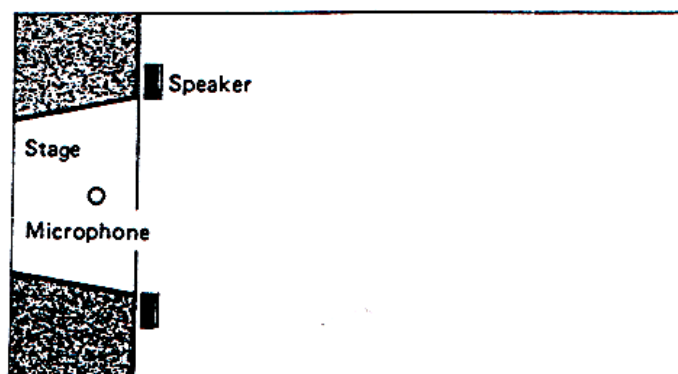
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As bi-directional wall mount speaker emits sound in both directions, it is suitable for wide space or narrow, long areas such as lobbies, waiting rooms or passage ways of hotels, theatres, movie theatres, hospitals, railway stations, airports, etc.




c) Meeting Rooms, Conference Rooms, Gymnasiums

Select 15 W or 30 W 2-way column speakers suitable to the room size



Install the speakers about 4 meters to the front side on the stage, from where the microphone is located. Select a number of speakers and their model from Table (A) where the speakers are intended for music; or from Table (B) where they are mainly for speeches.

There must be a difference of 20 dB or more between the peak sound pressure and noise.

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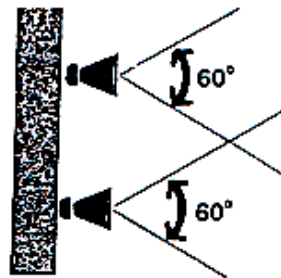
2-way column speaker	Quantity	A	B
		Distance from speaker for obtaining a sound pressure of 90 dB (at maximum output) at audience seats.	Distance from speaker for obtaining a sound pressure of 85 dB (at maximum output) at audience seats.
15W	2	Approx. 10 m	Approx. 18 m
	4	Approx. 14 m	Approx. 25 m
30W	2	Approx. 18 m	Approx. 32 m
	4	Approx. 25 m	Approx. 45 m

d) Noisy Rooms

i. Noise level about 90 dB


If noise level is 90 dB, a sound volume of 96 to 100 dB is necessary.

Use horn speakers which are efficient.



In noisy rooms, install horn speakers on the ceiling or wall.

Horn speaker	Distance for obtaining 100 dB at peak output	Speaker spacing
5 W	Approx. 3 m	Approx. 3 m
10 W	Approx. 4.5 m	Approx. 4 m
15 W	Approx. 7 m	Approx. 6 m
30 W	Approx. 11 m	Approx. 10 m

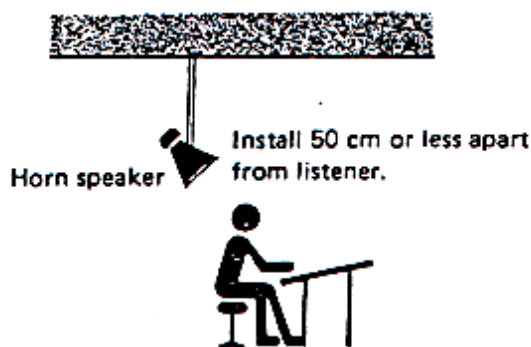
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Horn speaker	Distance for obtaining 96 dB at peak output	Speaker spacing
5 W	Approx. 5 m	Approx. 4 m
10 W	Approx. 7 m	Approx. 6 m
15 W	Approx. 11 m	Approx. 10 m
30 W	Approx. 17 m	Approx. 15 m

ii. Noise level about 100 dB

If noise level exceeds 100 dB, the speaker sound cannot be distinguished from the noise even if the volume is raised above the level.

If noise level is about 100 dB, install a horn speaker of about 5 to 10 watts near each listener.




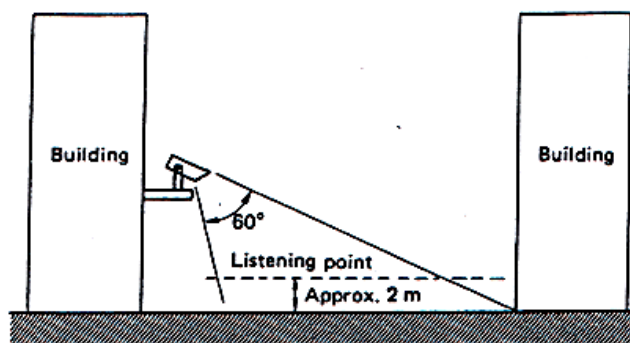
e) Speaker Arrangement Outdoors

i. Factory premises

Install horn speakers of 7 or 15 watts on the premises at the necessary position in a dispersed way.

If speaker sound (sound within a vertical dispersion range of 60°) directly hits the building opposite the speaker, its reflected sound adversely affects clarity. Install the speakers so that the upper limit of the vertical dispersion range will be at the ground level of the opposite building.

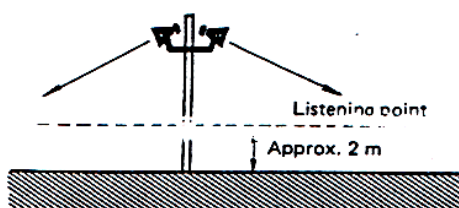
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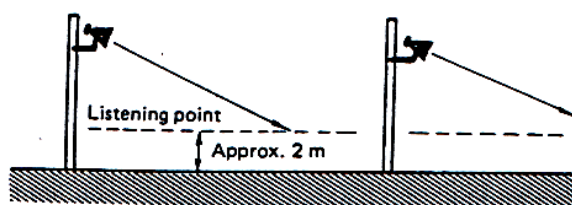
ii. Streets and shopping centres

- Install horn speakers of 7 or 15 watts in a dispersed way.
- Speakers may be installed by either method A or B, but method B is recommended because it provides better sound uniformity and clarity than method A.

A (Where pole-to-pole distance is too large)




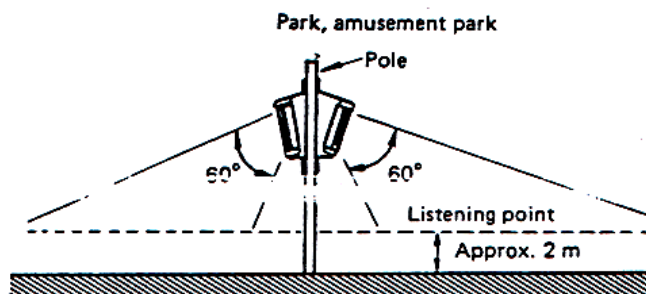
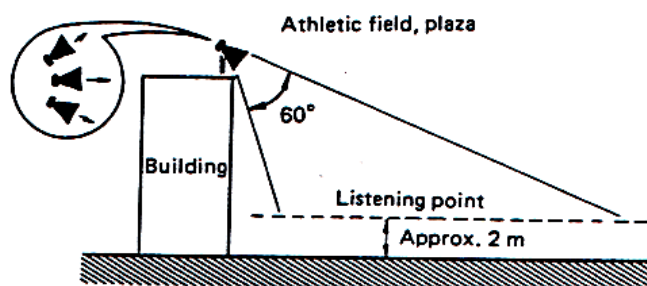
B (Where pole-to-pole distance is small)



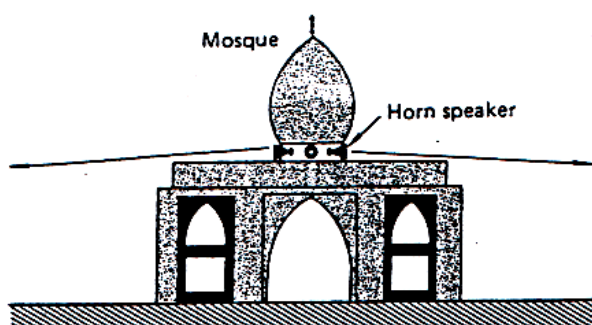
iii. Athletic fields, parks, etc.

- Install horn speakers or weatherproof column speakers of 20 or 30 watts in a centralized arrangement.
- Install the speakers on building roof or on top of a pole, or other elevated location.

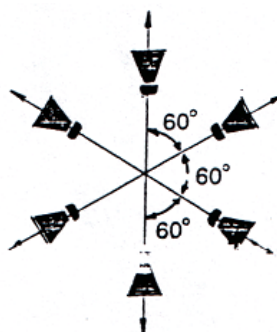
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iv. Mosques, etc.

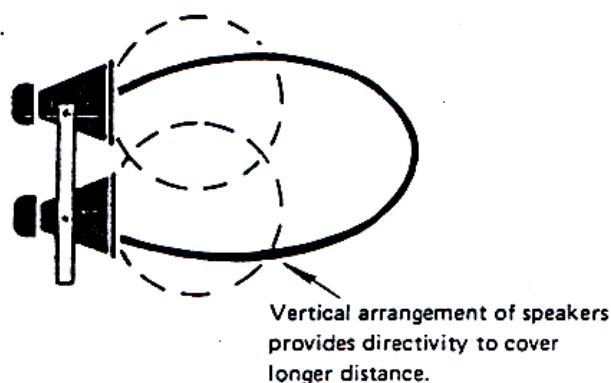


- Install horn speakers of 30 to 50 watts at as high a place as possible. Install them in a circular arrangement to emit sound in all directions.




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- If sound pressure is not enough with a single speaker, combine plural speakers vertically to provide directivity.



- Where speaker sound must reach far and wide, speaker output power must be somewhat greater than normal because the effects of winds, topography, temperature difference, and noise variations cannot be ignored.

Speaker	Quantity	A
		Distance from speaker for obtaining a sound pressure of 90 dB (at maximum output) at audience seats.
30 W	1	Approx. 200 m
	2	Approx. 300 m
	3	Approx. 400 m
	4	Approx. 600 m
50 W	1	Approx. 350 m
	2	Approx. 500 m
	3	Approx. 700 m
	4	Approx. 1,000 m

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11.4 Amplifier selection

After determining speaker arrangement and the required input to each speaker, the total required input (wattage) can be calculated, and an amplifier that has an output power corresponding to it can be selected. Select an amplifier on the basis of, not the maximum output, but the rated output wattage. If additional speakers are planned to be installed in the future, take this into account in selecting an amplifier wattage.

The number of input and output terminals, input and output impedances and levels must also be studied. Performance wise, frequency response, signal-to-noise ratio, and distortion factor also need to be examined. If the speakers are used exclusively for music, the specifications must also be more strict than in other applications.

11.4.1 Amplifier Wattage Selection from Speakers

Too small an amplifier output cannot produce enough sound volume, whereas too great an amplifier output can damage the speakers due to the excessive input applied to the speakers. This problem is particularly true of low-impedance speakers.


a) High-impedance speakers

A system involving multiple speakers normally uses high-impedance speakers connected parallel. As you know, the combined impedance of speakers connected parallel is smaller than the impedance of the individual speakers. It is necessary for an amplifier to meet the following condition in order to drive speakers properly.

$$\text{Amplifier output impedance} \leq \text{Combined impedance of speakers}$$

Therefore, an excessively large number of speakers cannot be connected to an amplifier. To allow simple designing of such a system, the output voltage of the amplifier is regulated at constant level. This is called a 100-V line or 70-V line. A large-output amplifier may be described as one which can supply a large current at a constant voltage.

Because the amplifier output voltage is constant, the input power applied to the speakers can be automatically determined from the input impedance of each speaker. As many speakers as desired can be connected to an amplifier if their total input is within the limits of the rated output of the amplifier.

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Rated amplifier output \geq Total speaker input

Rated amplifier load impedance \leq Combined speakers input impedance

$$\text{Speaker input (100 V line), } P = \frac{100^2}{Z}$$

$$\text{Speaker input (70 V line), } P = \frac{70^2}{Z}$$

Where:

P : Speaker input (W)

Z : Speaker impedance (ohms)

Example 1:


The input impedance is 3.3 k ohms or 10 k ohms. If it is 3.3 k ohms where a 100-V line is used,

$$P = \frac{100^2}{3.3 \times 10^3} = 3 \text{ (W)}$$

If it is 10 k ohms where a 100-V line is used,

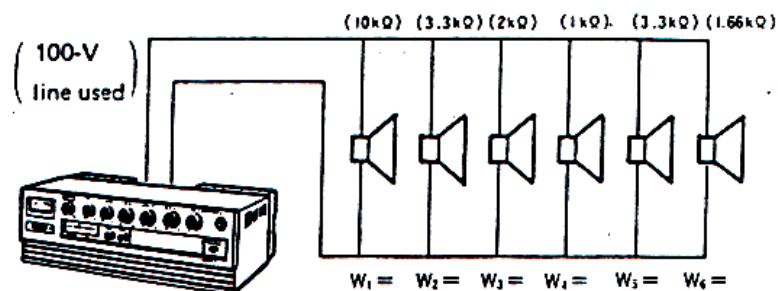
$$P = \frac{100^2}{10 \times 10^3} = 1 \text{ (W)}$$

If the amplifier with an output power of 30 watts is used, up to ten speakers can be connected to it if the input impedance is 3.3 k ohms; or up to 30 speakers can be connected to it if the input impedance is 10 k ohms. Since the output sound pressure of the WS-4000BN is 92 dB, sound pressures of 97 dB and 92 dB can be produced respectively. (Sound pressure increase by 3-watt input is 5 dB). Maximum numbers of speakers to be connected to typical models are shown in the table below.

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Example 2:

What amplifier output wattage is necessary for the speakers connected as shown below?



Calculate W_1 to W_6 for each speaker, and select an amplifier that has an output greater than the calculated total.


$$W_1 + W_2 + W_3 + W_4 + W_5 + W_6$$

$$= \frac{100^2}{10 \times 10^3} + \frac{100^2}{3.3 \times 10^3} + \frac{100^2}{2 \times 10^3} + \frac{100^2}{1 \times 10^3} + \frac{100^2}{3.3 \times 10^3} + \frac{100^2}{1.66 \times 10^3}$$

$$= 28W$$

Speaker impedance	Input to each speaker, W	Connectable number of speakers			
		30 W		60 W	
330 Ω	30 [15]	1 [2]	2 [4]	4 [8]	
400 Ω	25 [12.5]	1 [2]	2 [4]	4 [9]	
500 Ω	20 [10]	1 [3]	3 [6]	6 [12]	
670 Ω	15 [7.5]	2 [4]	4 [8]	8 [16]	
1k Ω	10 [5]	3 [6]	6 [12]	12 [24]	
1.66k Ω	6 [3]	5 [10]	10 [20]	20 [40]	
2k Ω	5 [2.5]	6 [12]	12 [24]	24 [48]	
3.3k Ω	3 [1.25]	5 [10]	20 [40]	40 [80]	
4k Ω	2.5 [1.25]	12 [24]	24 [43]	48 [96]	
5k Ω	2 [1]	15 [30]	30 [60]	60 [120]	
10k Ω	1 [0.5]	30 [60]	60 [120]	120 [240]	

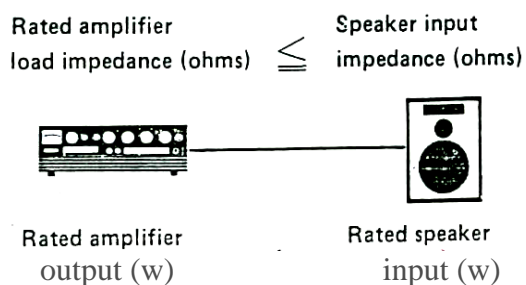
Note: Numbers given in [] indicate those for the 70 V line.

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The above condition is satisfied by an amplifier with a rated output of 30 watts. Remember not to select an amplifier output by simply totalling the rated inputs of the speakers to be used. This method, however, can end with the same result in some cases.

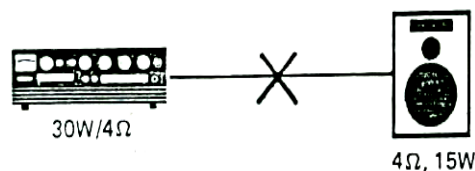
11.4.2 Low-impedance speakers

If low-impedance speakers are used, the amplifier delivers its full output power. Even in this case, the following conditions must be met. Rated amplifier load impedance (ohms)



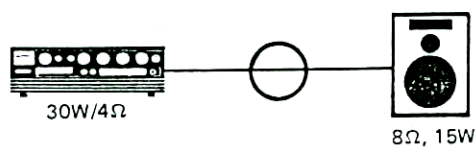
Example 1:


If the volume is raised in a connection as shown below, the 30-watt output of the amplifier is fully applied to the speaker and damages the 15-watt speaker.



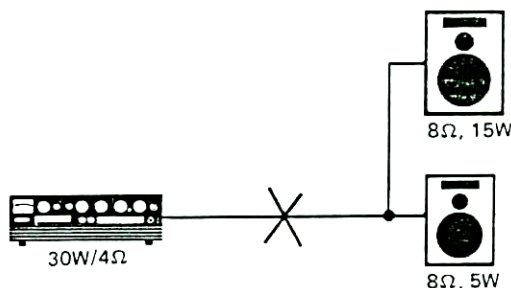
Example 2:

In a connection as shown below, only a 15-watt input is applied to the speaker because the speaker impedance is double the amplifier impedance of 4 ohms.



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Example 3:



If speaker are connected parallel, the combined impedance will be:


$$\frac{1}{\frac{1}{8} + \frac{1}{8}} = 4 \text{ ohms}$$

Therefore, the full output of 30 watts is applied to them from the amplifier. That is, 15-watt output is applied to each speaker. The 15-watt speaker can take it but the 5 watt speaker will break down.

The above can be summarized as shown in the table below. (Rated amplifier load impedance: 4 ohms)

Speaker impedance	Input applied to each speaker	Number of speaker that can be connected parallel
4 ohms	Total rated output	1
8 ohms	Half the rated output	Up to 2
16 ohms	Quarter of the output	Up to 4

When using low-impedance speakers, consider the above in selecting an amplifier wattage

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11.5 Microphone selection

In selecting a microphone, directivity, frequency response, impedance, balanced or unbalanced type, etc .must be studied depending on the purpose of use and the location.

The wrong use can cause poor tonal quality, lack of volume, or howling. It is important, therefore, to fully explain the correct method of using the microphone to the user.

First, select a place of use, and a type of microphone suitable to the purpose of use. It is necessary for this purpose to be fully familiar with the basic characteristics of the microphone.

11.5.1 Types of microphone (Based on method of signal generation)

11.5.1.1 Condenser microphone*

A microphone utilizing a capacitor (condenser) as a pickup element. Electronics are usually contained in the microphone body and a polarizing voltage is necessary; so external or battery power is required, and output levels are usually higher than other types of microphones. Condenser microphones are commonly used for high quality audio applications.


11.5.1.2 Electrets condenser microphone*

A variation of a standard condenser microphone where the element is permanently charged so no external polarizing voltage is necessary. However, due to the electret's very high impedance, an electronic impedance converter is usually built in and does require a small amount of voltage from a battery or external supply.

Electrets condenser microphones have similar characteristics to condenser microphones. Their small size and light weight make them particularly suitable for studio use (tie-clasp livelier microphones etc.) and for speech microphones in which clear tones are required.

11.5.1.3 Dynamic microphone*

A type of microphone which converts acoustical to electrical energy by means of a permanent magnet and a moving coil. Dynamic microphones do not require external power.

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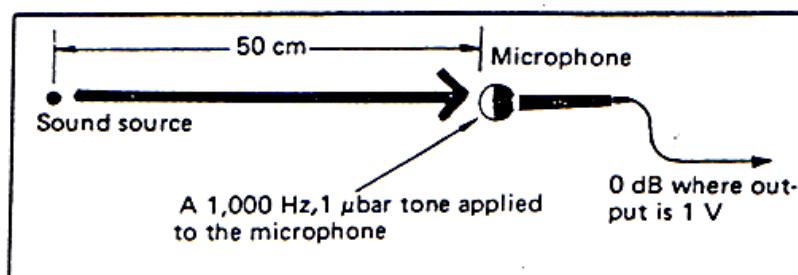
As dynamic microphones are rugged in construction, they provide stable performance and are easily handled. They generate minimum noise when used in windy conditions, and as such they are used in speech and vocal applications.

[* Partially from the CAMEO/Dictionary of Creative Audio Terms]

11.5.2 Microphone Sensitivity

If a 1,000 Hz tone of 1 μ bar (microbar) is applied to a microphone at a distance of 50 cm, and if it produces an output of 1 V, this microphone has a sensitivity of 0 dB. That is, microphone sensitivity represents the capacity of quantitative conversion from sound into electricity. Incidentally, a tone of 1 μ bar is equivalent to a speaker output sound pressure of 74 dB, which is the level of an ordinary human voice heard at a close distance.

A -50 dB microphone has higher sensitivity than a -70 dB microphone by 20 dB. If a 50 dB amplifier is used, its output will be 0 dB.




11.5.3 Microphone Frequency Response

Generally, the range of frequencies audible to the human ear is about 20 to 18,000 Hz.

A microphone is considered having good characteristics if it has a wide frequency band. But a microphone having the required frequency range, though it may be somewhat narrow, can well serve the purpose depending on what it is used for. In paging applications, for example, a microphone that can cover the human voice frequency range of about 150 to 6,000 Hz is satisfactory for the purpose.

A microphone with the unnecessary portion of the bass range cut off can rather permit amplification of clear sound with less "confinement" of sound.

It is important, therefore, to select the correct microphone for the purpose.

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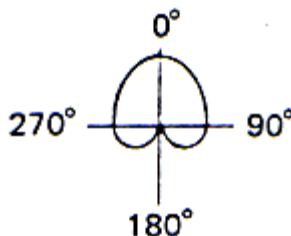
11.5.4 Microphone Directivity

Directivity means the sensitivity difference of a microphone in the direction of the sound source, and can be generally classified into two kinds as follows:

11.5.4.1 Unidirectional (cardioid)*

A microphone with a heart-shaped pickup pattern that is sensitive to sound in the forward direction (0°) and rejects sound from the rear of the mic (180°). At the sides (90° and 270°) the cardioid is about half as sensitive as the front.

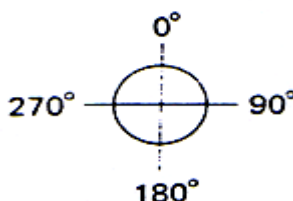
This type of microphone is suited to use in cases in which only a selected sound is required. Since it is resistant to howling when used in public address systems, it is commonly used for a wide variety of purpose.




11.5.4.2 Omni directional*

A microphone that is equally sensitive to sounds in all directions. This type of microphone is suited to use in cases in which the selected sound, as well as reflected sound, and other sounds in the area, are required to give an impression of the surrounding sound environment.

[* Partially from the CAMEO/Dictionary of Creative Audio Terms]



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11.5.5 Output Impedance

The output impedance of a microphone means the impedance of its terminal which is connected to an amplifier. It is necessary to match the input impedance of the amplifier with the output impedance of the microphone. Actually, however, a microphone may be connected to an amplifier having impedance higher than the microphone output impedance.

Microphones come in two output impedances, high and low. An impedance of 10 k ohms or more is called high impedance; and an impedance of 600 ohms or less is called low impedance. There are also dual impedance type microphones, which can be easily converted from one impedance to the other or not verse with a switch or by changing the plug and internal connections.

▪ High impedance

Cable extension distance	10 m or less
To extend cable	Use microphone mixer
Sensitivity (output level)	Relatively high: About -60 dB
Output impedance	20 k ohms to 50 k ohms
Connector	TS phone plug


▪ Low impedance

Cable extension distance		70 to 80 m (balanced type) or 20 m (unbalanced type)
To extend cable		Use microphone mixer
Sensitivity (output level)		Relatively high: About -75 dB
Output impedance		200 ohms to 600 ohms
Connectors	Unbalanced type	TS phone plug
	Balanced type	TRS phone plug
		XL type connector

11.5.6 Balanced Type, Unbalanced Type

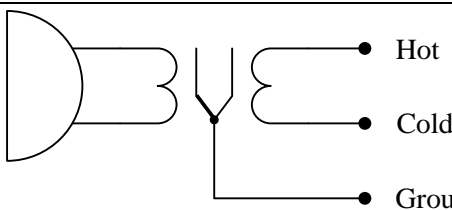
The noise induced in the microphone cable is amplified together with the voice signals by the amplifier.

Therefore, all microphones use a shielded cable to prevent externally induced hum and noise. The type which uses a two-conductor shielded cable is called the balanced

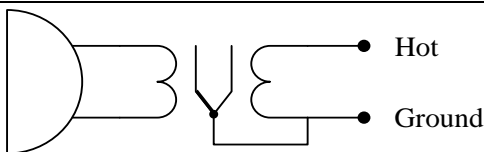
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type; and that which uses a single-conductor shielded cable is called the unbalanced type.


- **Balanced type**

Impedance	Low impedance
Plug	TRS phone plug, XL-type connector
Output circuit	

- **Unbalanced type**

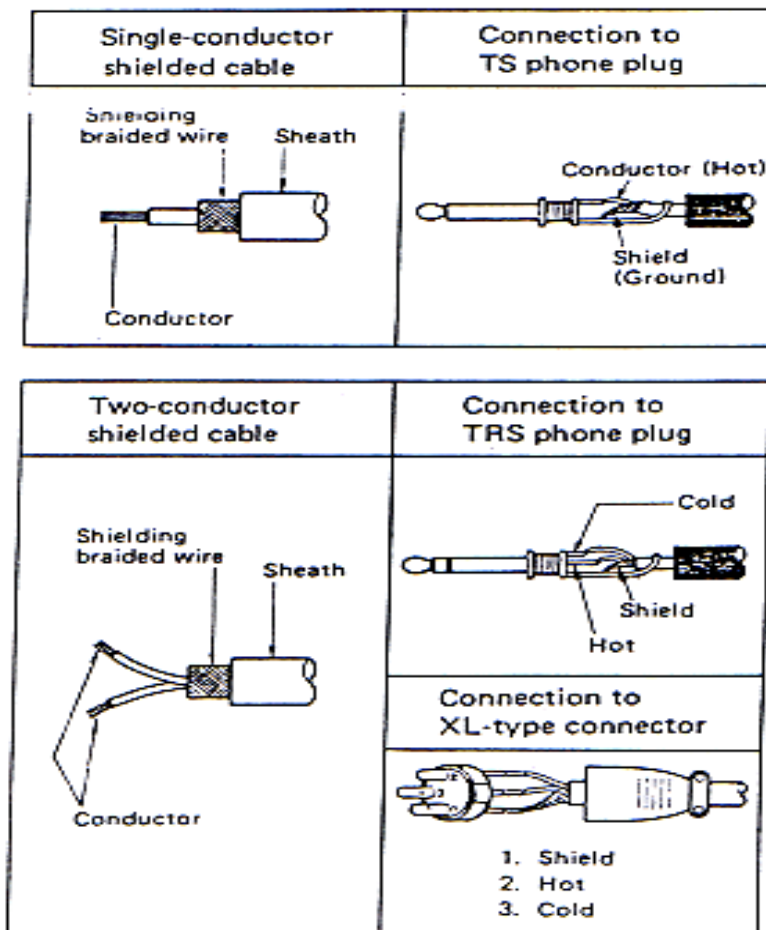
Impedance	High impedance, low impedance
Plug	TS phone plug
Output circuit	


The balanced type is recommended where the microphone is used far away from the amplifier because it is less susceptible to externally induced noise and provides constant tonal quality. In this case, however, the amplifier must have a balanced type input terminal. Some unbalanced type microphones use a two-conductor shielded cable. These microphones can be converted to the balanced type if its TS phone plug is changed to a TRS phone plug or a XL-type connector.

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- Shielded cable and plug connection

• **Shielded cable and plug connection**



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11.5.7 Microphone Selection

Select a suitable microphone by referring to the foregoing explanation. Here are typical examples of microphone selection.

Paging and Public Address



Unidirectional dynamic microphone



Unidirectional dynamic microphone

Vocals



Unidirectional dynamic microphone




Unidirectional dynamic microphone

Meetings and Speeching



Unidirectional electrets condenser microphone

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Outdoor



Unidirectional dynamic microphone with drip-proof filter

Interviews




Omnidirectional electret condenser microphone with tie-clip holder

11.6 Connecting Speakers

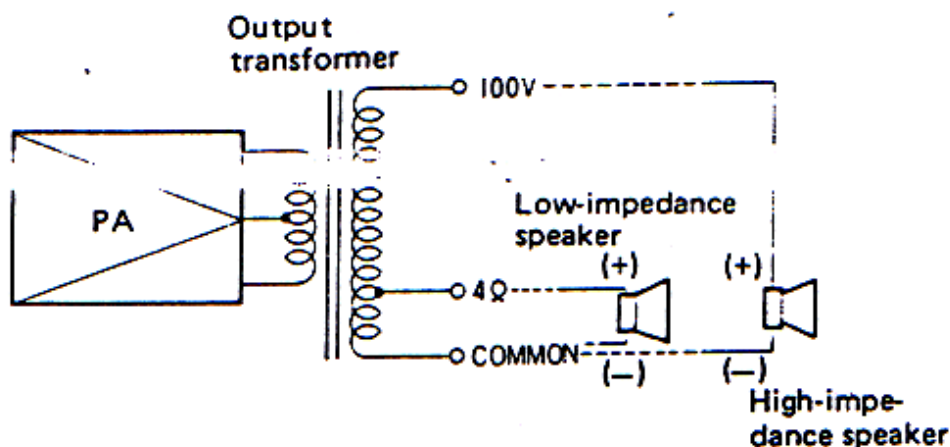
11.6.1 Basic Connection

The output stage of an amplifier contains an output transformer. This transformer is wired as follows.

Connect speakers so that the COMMON terminals are connected to (-), and the 4 ohm terminal of the low-impedance speaker, or the 100 V or 70 V terminal of the high- impedance speaker, is connected to (+) (low and high impedance terminals cannot be used simultaneously, 100 V and 70 V lines cannot be used simultaneously). As the rated load impedance of the 70 V line is half that of the 100 V line, twice the quantity of speakers can be connected when the 70 V line is used (the speaker input, however, will be half that for the 100 V line). For these reasons,

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the 70 V line is used in cases such as BGM broadcasting in which a large number of speakers with relatively small input rating are used.



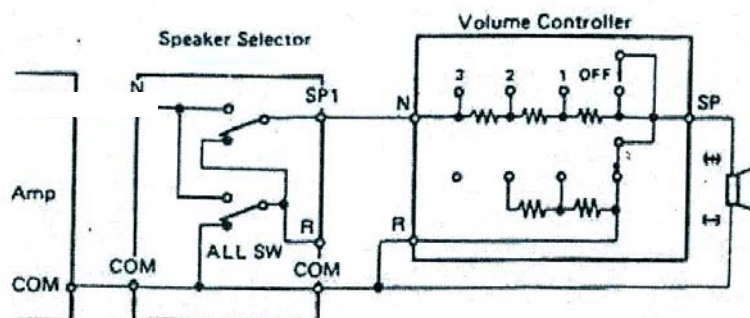
11.6.2 Using Volume Controller

Volume controller may be used only with high-impedance speakers. The wiring for the volume controller is of either the 2- or 3-wire system. Volume control for each speaker is possible with both the 2 and 3 wire systems. However, when it is OFF, emergency announcement is impossible in case the 2 wire system is used; but possible in the 3 wire system.

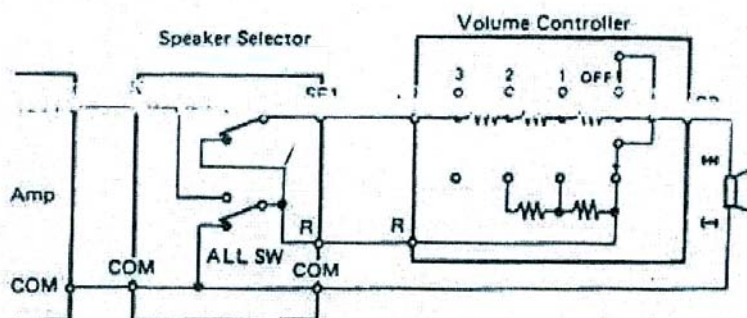
The user should be advised to note that the 2 and 3 wire volume controls are exactly the same. As is obvious from the circuit diagram above, ALL terminal is normally connected to COMMON. However, when the all speaker switch is ON, it is connected to the 100 V output of the output transformer. Since accurate attenuation is not obtained if the volume controller is not suited to the impedance of the connected speaker, a volume controller having the same wattage rating (or a wattage rating within the specified range) as the speaker must be selected. A number of speakers can be connected and controlled together by a volume controller within the specified rating.

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• 2-wire system



• 3-wire system




▪ Volume Controller Selection Table

No.	Suitable Rating, W
1.	1
2.	2
3.	3 to 5
4.	6 to 30

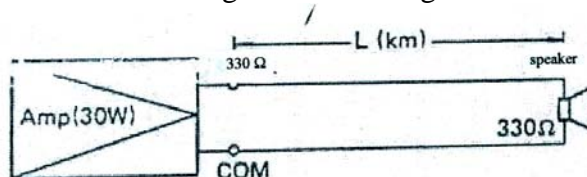
a) Speaker Wiring

As wiring between the amp and speakers must be designed with consideration for transmission losses, line loop resistance must be no more than 10% of the combined impedance of the speakers or the rated load impedance of the amp.

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For Example:

If the rated load impedance of the amp is 330 ohms and wiring is 1.0 mm in diameter, what is the maximum length of the wiring?



The line resistance of annealed copper wire (single strand) is 22.9n/km (at 20°C). The maximum length of wiring is calculated with the following equation:


$$\begin{aligned}
 \text{Loop resistance} &\leq 10\% \text{ of the rated load impedance} \\
 2 \times 22.9L &\leq 330 \times 0.1 \\
 L &\leq 0.72
 \end{aligned}$$

The maximum length of wiring, therefore, is approximately 700 m. Maximum allowable distance between an amplifier and a speaker is shown below.

• Maximum allowable distance between an amplifier and speakers

Rated load impedance of amp \ Wire diameter		1.0mm	1.2mm	1.6mm	2.0mm	2.6mm
Low impedance	4Ω	10m	13m	23m	40m	60m
	670Ω	1,400m	2,200m	3,800m	6,000m	10,000m
High impedance	330Ω	700m	1,100m	1,500m	3,000m	5,000m
	170Ω	350m	550m	1,000m	1,500m	2,600m
	85Ω	180m	280m	500m	770m	1,300m
	42Ω	90m	140m	250m	380m	650m

Note: This table indicates cable lengths for annealed copper wire (single strand) on a condition that loop resistance is approximately 10 percent of the load impedance of the amplifier.

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11.6.3 Radio Antennas

11.6.3.1 AM Radio Antennas

AM radio antennas are always required. In strong broadcast areas, a 2 to 5 m vinyl-covered wire should be attached to the wall or ceiling in a horizontal attitude and as high as possible. Coaxial cable should be used between the antenna and a radio tuner.

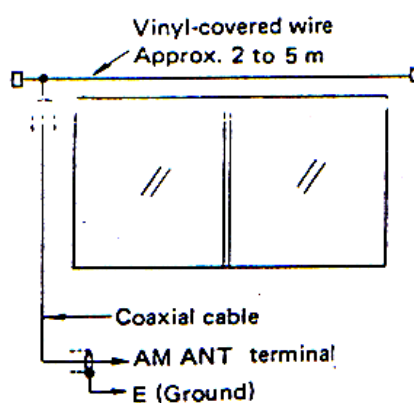




Table 11.10: Guideline for Audio Visual Requirement and Criteria

NO	ROOM TYPE	PROPOSED SIZE (mm)	CRITERIA / GUIDE
1.0	General System		
1.1	P.A. Equipment Room	2000 x 2500	
1.2	Security Control Room	3000 x 4000	Can be combine within the Command Control Centre
1.3	Riser Room	1200 x 900	For MATV / AV / Security / Sound Systems Door kerb: 100mm – 150mm
1.4	Floor Opening	200(w) x 1200(l)	Will be covered by approved 2 hrs fire barrier Door to follow UBBL 75mm kerb around the floor opening; 50mm kerb across the door

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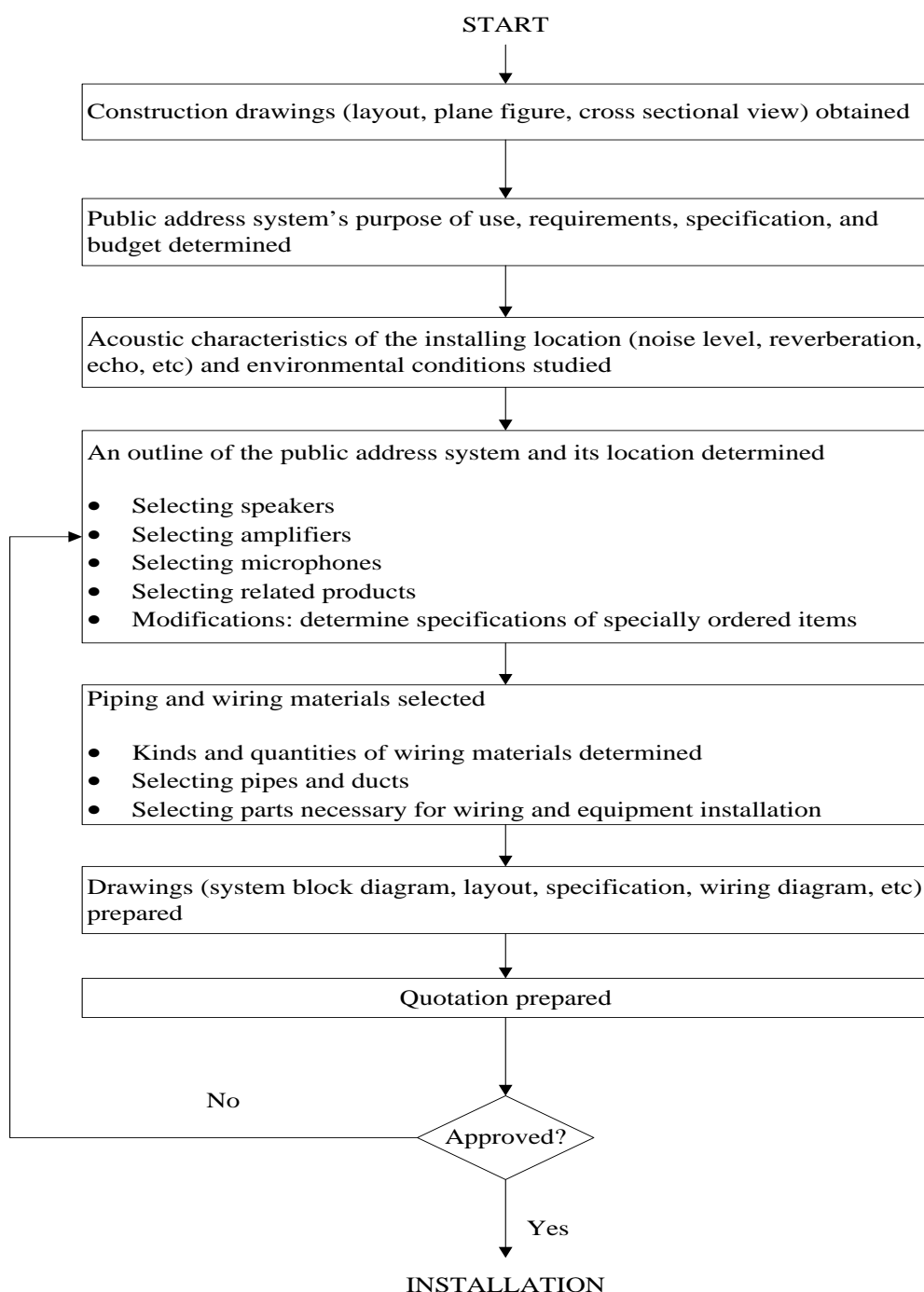
NO	ROOM TYPE	PROPOSED SIZE (mm)	CRITERIA / GUIDE
2.0	Auditorium		Shall be acoustically treated and sound insulated Sound insulation required if metal roofing used
2.1	AV Control Room	4000(l) x 3500(w) 2000 x 900(h)	Fully carpeted, air conditioned Full height partitioned (brick wall or sound insulated partition) Sliding glass window: tinted, 800mm from floor level
2.2	SIS Cubicle / Room	1500 x 2000 1000 x 900(h)	Size is for one cubicle Sound insulation shall follow ISO Std: i.e. full height partitioned (brick wall or sound insulated partition) Fully carpeted, air conditioned Glass window: tinted, 800mm from floor level
2.3	Back Projection Room	6000(d)	For fixed screen system, behind the stage / screen
2.4	Stage Cross beams and roof supports		Required to support the I-beams across the stage area: for all the lighting barrels and curtain railings Approximate load: 4000 kg
2.5	Catwalk Ceiling Catwalk		For maintenance of stage equipments Recessed catwalk within the acoustic ceiling for maintenance
3.0	Meeting / Operation / Seminar / Board Rooms (Single volume rooms)		
3.1	AV Control Room	2500 x 3000 1200 x 900(h)	Fully carpeted, air conditioned Fully height portioned (brick wall or sound insulated partition) Sliding glass window: tinted, 800mm from floor level Sliding board built-ins required


NOTE: All sizes given may differ according to the sizes of the project.

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Appendix A

Flow Chart for System Design



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12.1 Introduction

The purpose of this chapter is to discuss some design concept and guidelines for the installation of sound system in halls. Quite often sound reinforcement system is required in multipurpose halls such as school hall with a stage, flat floor and with some intruding noise. Normally, such halls are long, wide, and rectangular in shape and with high ceiling. If a hall is acoustically treated i.e. the walls are treated with sound absorbent material, ceiling is installed with perforated material and the floor is covered with parquet flooring or carpeted, reflection and reverberation of sound will not cause too much problem. However, halls with poor acoustical environment will produce sound that is not intelligible and quite reverberant. In such cases, special care must be taken in the positioning and selection of loudspeaker system and other audio equipment.

12.2 Design concept

The intended sound system shall pick up, amplify, distribute and reproduce voice and all other signal program satisfactorily. Most of the halls are probably designed for multipurpose, such as speech reinforcement, music, drama performance etc. Therefore system versatility is direct sound, early reflections from walls, ceiling, stage and reverberant sound. The rectangular hall with stage at the parallel walls which may give added fullness. The disadvantage is that the hall is usually long and thus the front and at the back will be great. As a rule of thumb for every doubling of distance from the sound source, this results in a decrease in sound pressure level of 6dB. The ambient noise for hall can be in a range of 40dB to 75dB, depends on the capacity of seated audience. Exhaust fans and wall bracket fans in the hall contribute noise when they are running. Generally, the speech from the loudspeakers must be louder than the ambient noise by at least 10dB in order to be intelligible.

It is generally reckoned that four factors contribute to articulation at any point in the hall. The first is the background noise level which 'masks' the required sound. The second factor is the level of speech above the threshold of hearing. This will depend on the distance from the speaker, the volume of hall and the nature of the surrounding (whether they are highly reflecting or not). The third factor is the reverberant time, if this is very short there will be insufficient reverberant energy to maintain the level of speech. On the other hand, if it becomes too long, sound of successive syllables overlaps, and the resulting 'masks' the speech. The last factor is the shape of the hall if the speech isn't to sound. Unnatural, it is important that the amplified sound shall arrive at the listener just after the sound which has travelled direct from the speaker. Echo can be avoided if the direct and reflected path is kept less than 16 meter. However, if the difference between the reflected and direct sound is 10 dB or more, the reinforcement


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system for halls must be loud enough with sufficient acoustic gain, articulation loss of consonants in speech and cover the listeners with uniformity.

The sound system shall be capable of supplying 90 dB SPL program level plus 10db peaking factor. The system shall have even distribution of the reinforced sound throughout the seating area, typically plus or minus 3dB front to the back and site to site for one-octave band centre at 400 Hz in addition to this, the system shall have uniform frequency response throughout the audience area. Typically plus or minus 3dB as measured with 1/3 octave band of pink noise at position across the main seating area. It shall have adequate dynamic range at an acoustic distortion level sufficiently low to ensure minimum listening fatigue. Signal to noise ratio of the entire system from inputs of main mixer to output of power amplifier shall not be less than 80 dB.

Proper design and selection of equipment, especially loudspeaker system is important. If the acoustic of the hall is good i.e. the reverberation time is correct for speech and there are no specific acoustics defects such as echoes or ‘dead’ areas, a sound reinforcement system will only be needed to make the speech louder, particularly at the back of the hall. One of the methods that may employ is to have two column loudspeakers on either side of the centre – line, i.e. either side of the proscenium arch. Thus nobody will be very far off the axis of one other further from the microphone such that feed-back will be reduced. But, there are two disadvantages. The first is receiving two loudspeaker sounds. The real sound will arrive first, and if it is loud enough it will determine the apparent direction of the speech as coming from the man speaking, which is good. If however, it is not loud enough, the speech will appear to be coming from either one side or the other. This can be irritating. The other disadvantage is that for those who are nearer to either of the loudspeakers than they are to the man speaking, the speech will appear to be coming from the loudspeaker.

For large hall with balcony, second pair of subsidiary loudspeakers can be placed at mid-hall or about a third way from the stage. The subsidiary loudspeakers can be delayed. The time delay introduced shall of course correspond to the time taken for the sound from the stage to reach the rear of the hall, less the time taken for the sound from the mid-hall speaker to reach this area. The amplitude of this subsidiary loudspeaker shall be such that the sound from them reaching the listeners shall not be more than 10 dB up on the sounds reaching them from the front of the hall. Therefore, for halls with bad acoustics, long reverberation time and distances to be covered by the loudspeakers are great, subsidiary smaller loudspeakers with proper time delay shall be introduced to solve the problems. In order to avoid the chance of indirect coupling, reflection directly from the rear wall can be reduced by facing the second pair loudspeakers towards to rear corners. We must make sure that maximum of the rated acoustic energy is directed towards the audience and not toward reflective walls and ceilings. The extent of

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reflections will depend on the nature of the seats. Some seats will act as absorbent. A well filled audience area has absorption very close to 100%. The important frequency bands which influence the intelligibility are the octave band of 2 and 4 KHz. It is important to match the angle of the loudspeaker with the height above floor level. Angling difficulties are increased with the height, 1.8 - 3.0 meter between floor and bottom of the loudspeaker will prove about right in most cases. Two separate amplifiers, each feeding a different pair of loudspeakers, fed from the same mixer can be employed.

The main reason column loudspeaker is used because the sound forward a column loudspeaker is projected from and with a flat beam. Most of the sound is concentrated and possess higher directivity. As one walks away from a column speaker, the drop in volume is barely perceptible until the limit of its range is approached.


Other method of loudspeaker system is to install cluster of loudspeakers in the centre of stage. This usually consists sets of horns and mid-base loudspeaker. The loudspeaker can be suspended from the ceiling using suspension bolts or steel wire ropes. Horn with long throw cover the back seating area and short throw horns cover the front. Stage monitor speakers are for people on stage or performers in concerts. Portable type is preferable and can be placed at both sides. Other areas such as backstage, restroom, dressing room, reception room, foyer etc can be installed with ceiling mounting speakers or box speakers.

In order to maintain the sound quality, low impedance connection is suggested to connect between the amplifier and the loudspeakers without using matching transformer. The loop resistance of the cable should at least be less than one tenth the load impedance of a loudspeaker. This is required to be so in order to reduce the power loss the cable resistance causes and also to make large enough a damping factor which has a close relationship to the sound quality of a loudspeaker. Usually a maximum length of 45m is allowed between a 8 ohm impedance loudspeaker and amplifier when 1.5mm² diameter cable is used.

Care must be taken to have proper matching between power amplifier output and loudspeaker rating. To avoid damage of loudspeaker, the combination of the amplifier and the loudspeaker shall be determined as follows according to a degree of experience of a person who operates a system.

a) Inexperience person:-

A continuous rating of the loudspeaker should be identical with a rating of power amplifier.

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b) Well trained or experience person:-
Match an amplifier rating to a program rating of the loudspeaker.

c) Quality sounds are particular required.
Match an amplifier to a peak input rating of the loudspeaker.

Out of the three cases, case (b) permits the full use of performances of the loudspeaker and it is also economical.

12.3 Design formula

a) Reverberation Time (RT_{60}) Calculation:-

In order to determine articulation losses, reverberation time of the hall (RT_{60}) needs to be measured or calculated. Reverberation time is proportional to the volume of a hall and is inversely proportional to the area. The formula for halls where the expected $RT_{60} > 2.0$ seconds and absorption is relatively uniform and low in value is given as follows:

$$RT_{60} = \frac{0.163V}{Sa}$$


Where,
V is the volume of the hall in m^3
S is the total surface area in m^2
a is the average absorption coefficient.

b) Directivity Index (Q)

The directivity of a loudspeaker varies from 1 (omnidirectional) to values above 50 (highly directional). The directional properties of loudspeakers are generally frequency dependent and hence Q value shall always be qualified by a frequency.

c) Percent of Articulation Loss Consonants (AL_{cons}) Calculation:-

The percent of articulation loss of consonants (AL_{cons}) determined the articulation score in a hall. An AL_{cons} of 15% is considered to be a practical working limit. Formula for % AL_{cons} :-

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$$\% AL_{cons} = \frac{200D_2^2 RT_{60}^2 (N + 1)}{VQM}$$

Where, D_2 is the distance from the loudspeaker to the farthest listener

RT_{60} is the reverberation time in seconds

V is the volume of the hall in cubic meter

Q is the directivity ratio

N is the number of loudspeaker groups identical to group 1 (like sources)

M is the D_c (Critical distance) modifier (usually 1 is chosen except special instances. Modifier due to audience absorption)

The above formula is used for $D_2 < DL$ and $DL = 3.16D_c$.

When $D_2 > DL$, the formula becomes:-

$$\% AL_{60} = 9RT_{60}$$

It is necessary to assume a required signal to noise ratio of 25 dB to make these calculations valid.


The basic formula can be further converted into the following useful formulas:-

Maximum D_2 that allowed an AL_{cons} of 15%,

$$= \frac{15VQM}{200RT_{60}^2 (N + 1)}$$

Maximum RT_{60} that allowed an AL_{cons} of 15%,

$$= \frac{15VQM}{200D_2^2 (N + 1)}$$

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Minimum Q that allowed an AL_{cons} of 15%

$$= \frac{200D_2^2 RT_{60}^2 (N+1)}{15VM}$$

d) Critical Distance (D_c) Calculation:-

In an enclosed space like the hall, the sound field is made up of two components, the direct and reverberant. With increasing distance from the sound source, the component changes from direct to reverberant. D_c is defined as the distance in which the ratio between the direct sound and the reverberation sound comes exactly to 1:1. A knowledge of D_c provides us with distance at which the furthest distance is expressed as $A \times D_c$ i.e. where A is the number of critical distances. The greater the reverberation time the less A can be in order to provide 15% AL_{cons} . Critical distance (D_c) can be obtained from the following equations:-

$$D_c = \frac{0.14QRM}{N+1}$$

Where, Q = Directivity Ratio of loudspeaker

R = Room Constant,

$$\frac{Sa}{1-a}$$


S = Total surface area in the hall

a = Mean absorption coefficient in the hall

e) Electrical Power Required (EPR) AND Sound Pressure Level (SPL) Calculations:-

When the definite acoustic sound pressure level (SPL) at a given distance (D_2) from the loudspeaker is determined you need two important details in order to compute how much electrical power is required:-

- The sensitivity rating of the loudspeaker, measured at 1 meter on axis when the loudspeaker is fed an input signal of one electrical watt.
- The acoustic level change and attenuation between the loudspeaker and the furthest listener position.

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12.5 Microphone

The type of microphone used for speech shall possess unidirectional characteristic. The recommended type is hand-held cardioid microphone mounted on telescopic floor stand with boom arm. It is especially recommended to use balanced type of microphone in order to reduce the external noise. In addition, high quality screened microphone cable high frequency largely varies according to the type of microphone cable. Wireless microphone such as tie-clip type is recommended for light drama on stage or other similar purpose. The microphone cable shall not be too long, the sensitivity decreases over high frequencies due to capacitance between conductors in case of high impedance microphone. The 3-pin XLR type connector is recommended. There shall be at least four microphone floor outlets on the stage and two outlets on both sides of the centre of seating areas and at the back of seating areas.

12.6 Mixer


Input level to the mixer must be properly set within the dynamic range. When the input is too large, a peak part of the program is clipped and the signal is distorted. On the other hand, when the input is too small, the inherent noise of a mixer masks the program signal. Besides level control, mixer panel also has tone control (bass and treble) function that equalizes the sound quality of the input signal. Other knobs and switches are grouping function, monitoring function and many other functions. It is recommended to specify XLR type connector with balanced of input, transformer-isolated and accepts low impedance sources.

12.7 Limiter-Compressor

Placing a limiter between mixer input and the power amplifier input suppress a peak component of the program, preventing the distortion from being caused by the peak clipping of a power amplifier. By using the compressor the overall program level may be higher for the same clipping level than in the case where it is not used. This effect proves advantage in high noise level areas. Therefore, limiters and compressors are used for suppressing a signal higher than the specific level.

12.8 Graphic Equalizer

Graphic Equalizer operates simultaneously at a number of preset frequencies, any of which may be boosted or cut Independently of the others. It is used of ensure that all

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frequencies can reach unity gain at the same time. After the sound system has been installed, the entire system can be equalized to its acoustic environment to ensure the specific tonal response and acoustic gain at each listener's ears. The recommended equalizer shall consists of 31 bands centred on frequencies at intervals of 1/3 octave and covering a frequency range of 20 Hz to 20 KHz.


12.9 Control Room

The control room is best located in the back of seating area. The size of window shall allow easy glance of the entire stage at his or her eye level. Suitable low level desk top shall be provided to place mixer console and other equipment. The input patch pave shall be installed near the console so that the person in charge will have easy access. The monitor speakers in the control room shall be installed above and behind the mixing console. The angle of the speaker shall be aiming at the controller's ears. Wired intercom system consists of one master station and a few slave units shall be installed for communication between the person on the stage and the controller in the control room.

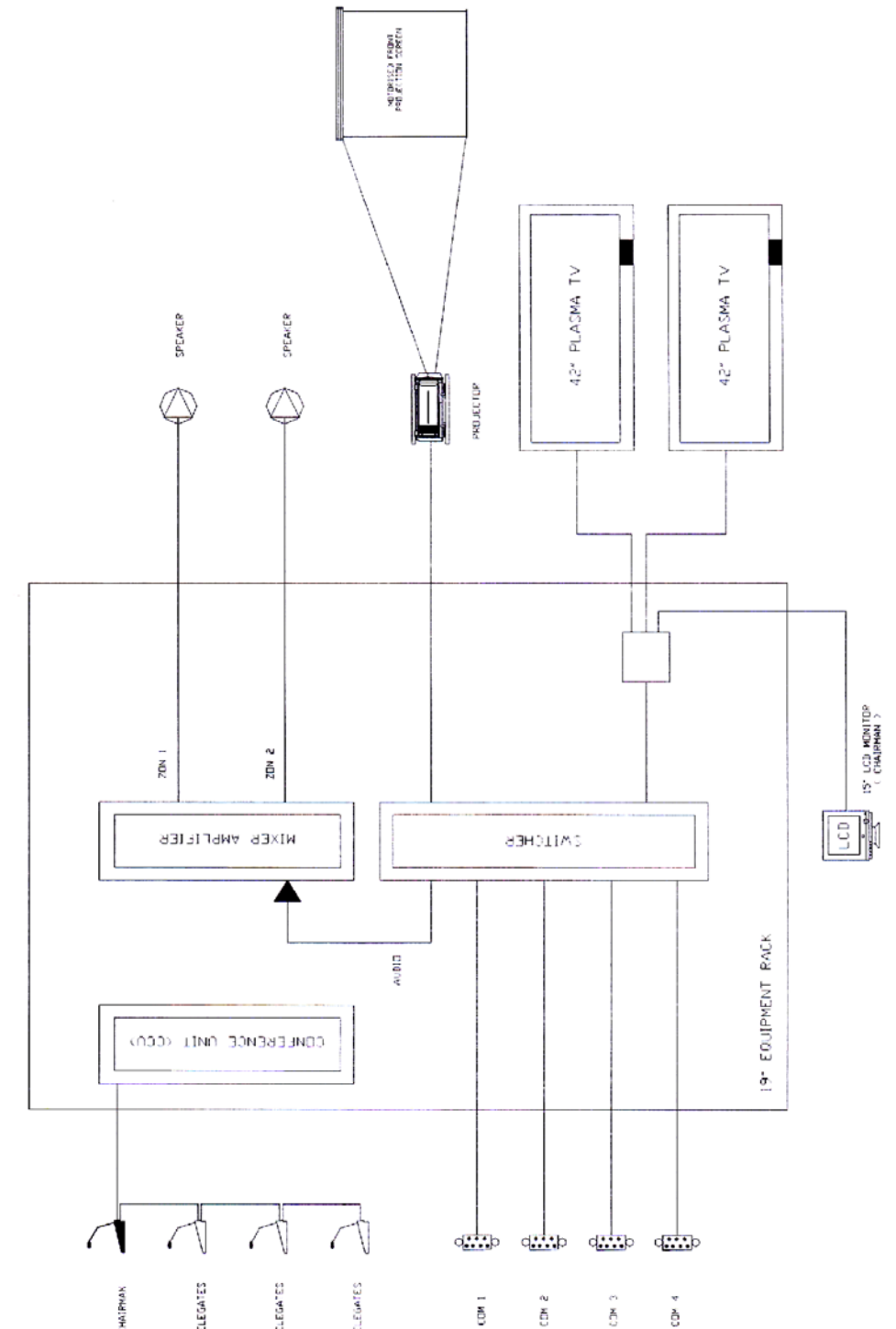
12.10 Cable Selection


For wiring of -80 dBm to -20 dBm signal level, electromagnetic shielded wire shall be applied. For cable with a -20 dBm to + 30dBm signal level, cable materials must be equal to those of the microphone cable. For speaker cable to connect the power amplifier and loudspeakers, electromagnetic shielded type of speaker cable shall be used. Conductor of 1.5mm² is suitable for high impedance connection of loudspeakers for low impedance connection of high output speaker, cables with a 5.5mm² or large nominal sectional area shall be used. When using shielded cable between sound equipment, apply a one point grounding principle, the transmission-side shield must be electrically insulated from the chassis and ground it on the reception side. Also, to avoid oscillation, hum, induced noise, crosstalk and the like, the microphone line should be as separated as possible, from other high signal level lines, high frequency equipment, lighting control lines.

When lighting control system and sound control system are located on the same stage, it is advised to maximum the reduction of electromagnetic noise, by wiring the sound system at one of the wing of the stage and the lighting system at the other wing.

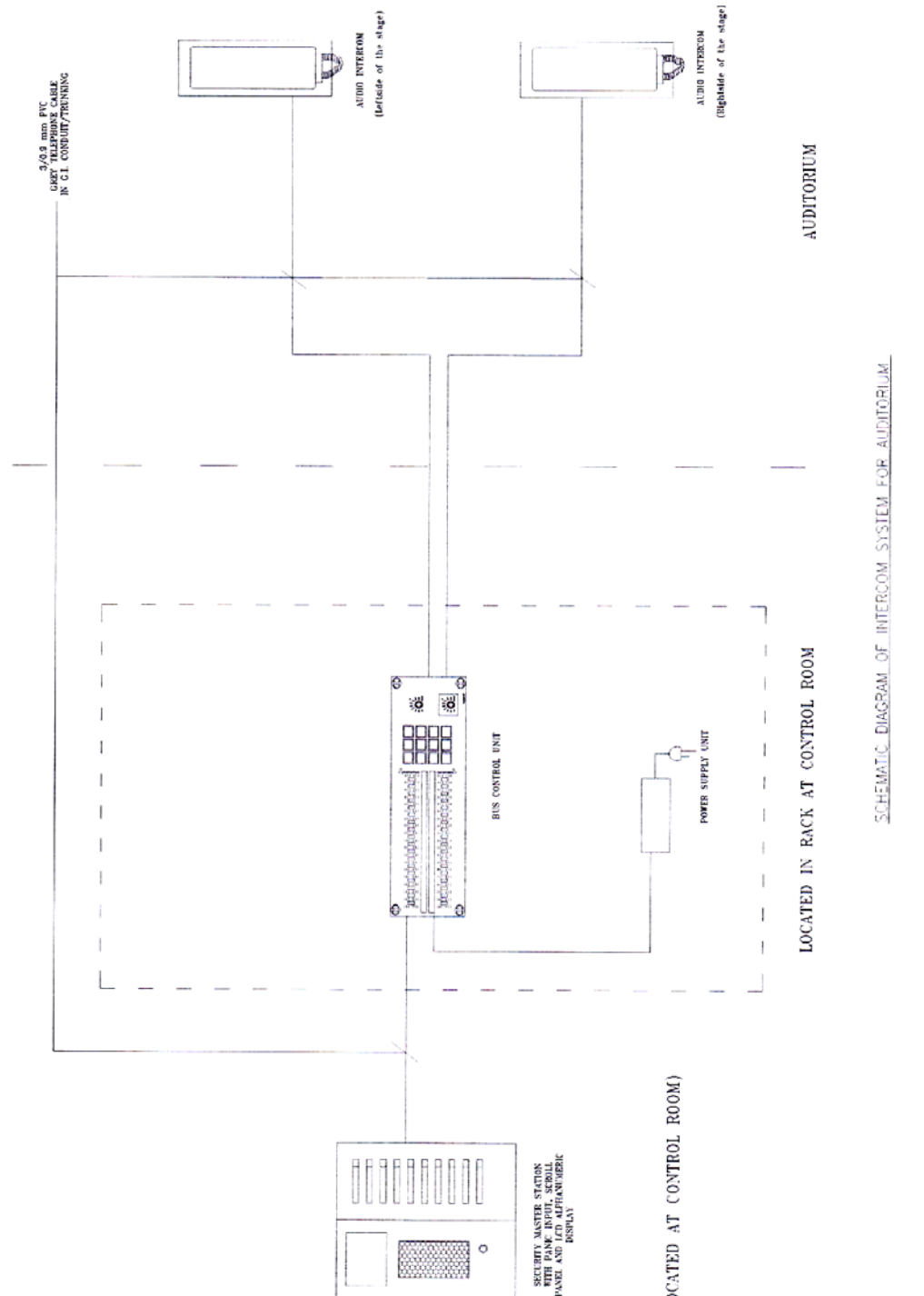
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Appendix 2: Schematic Diagram of Conference System



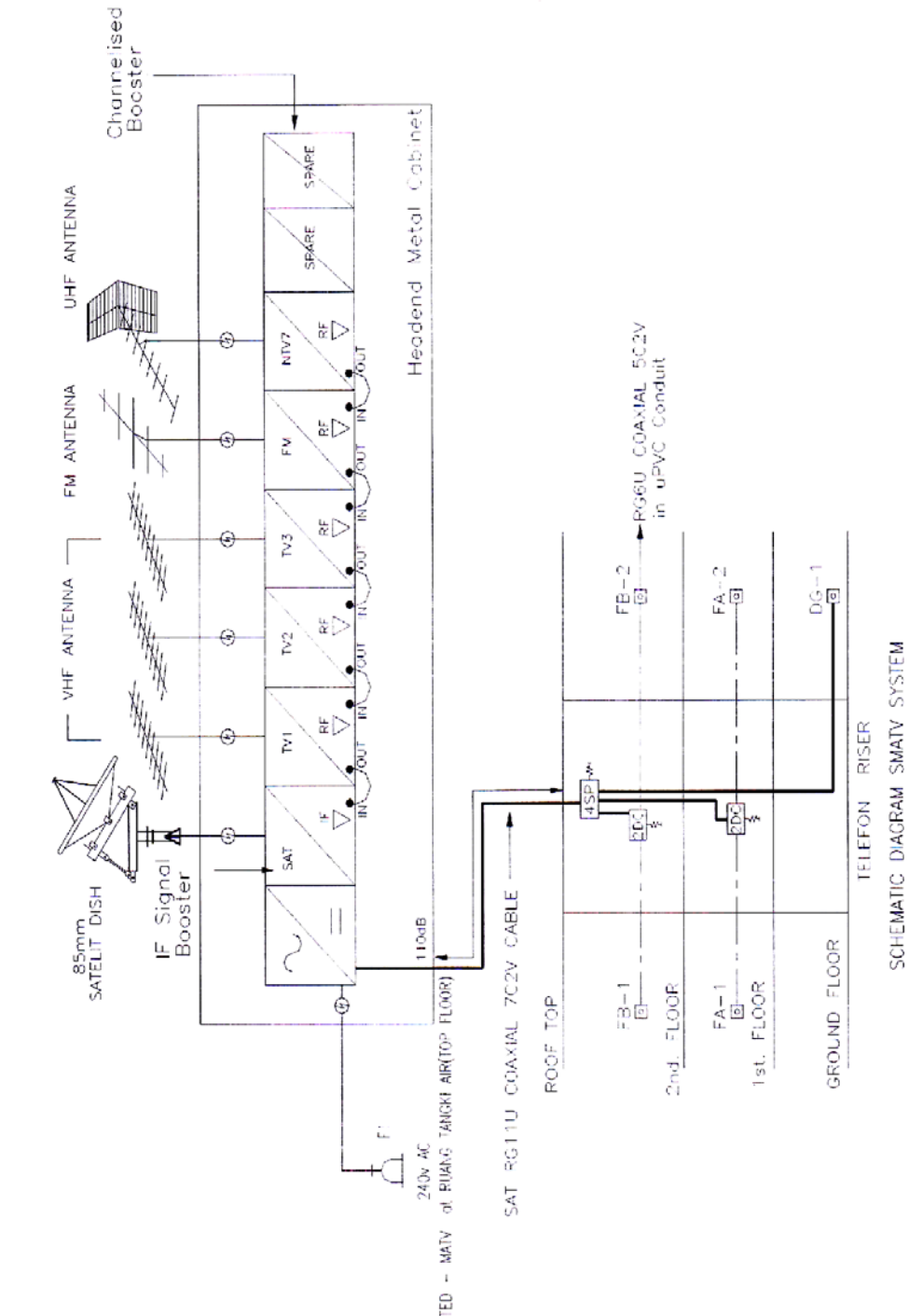
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Appendix 4: Schematic Diagram of Intercom System




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Appendix 6: Schematic Diagram of SMATV System



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Contents of this chapter will be included later.

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14.1 Introduction

Designing an ICT system is one of the workload in CKE. This chapter will discuss in general terms the procedure involved. However, this chapter will not discuss on the ICT technology since IT technology changes rapidly, but will focus more on general terms and procedure.

14.2 Passive Design

The first section in the ICT design is looking into the passive aspect. Here the focus will be on structured cabling design. The general terms used are:

a) External backbone

It refers to external cabling between buildings. The cable used shall be of single mode (for length \geq 500 metre) outdoor/armoured fiber optic type or multi mode for $<$ 500m. The cable shall be installed through underground pipes and manholes, and cable trays and trunkings. Refer to Figure 14.1.

b) Internal / Vertical backbone


It refers to cabling between one switch to another in the same building which can be in different or in the same floors. The cable shall be of indoor multimode fiber type (for length $<$ 500 metre) or single mode for \geq 500m. Refer to Figure 14.1.

c) Horizontal cabling

It refers to cabling from the equipment rack to the faceplate of the network port. These points shall be a minimum of UTP (Unshielded Twisted Pair) Cat 6 or latest (EIA/TIA Cat 6 or latest) c/w modular type RJ45 jack, faceplates, patch cords and RJ45 connectors. Down drop conduits shall be of uPVC Heavy Duty High Impact or Galvanized Iron (G.I) type and to be installed concealed. Refer to Figure 14.2.

d) Network point

It refers to interconnection point within the horizontal cabling. The network point performs a 'straight-through' intermediate interconnection between the horizontal cabling coming from the horizontal termination patch panel and the horizontal

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cabling going to a Multi-User Telecommunications Outlet Assembly (MUTOA) or the Telecommunications outlet in the work area.

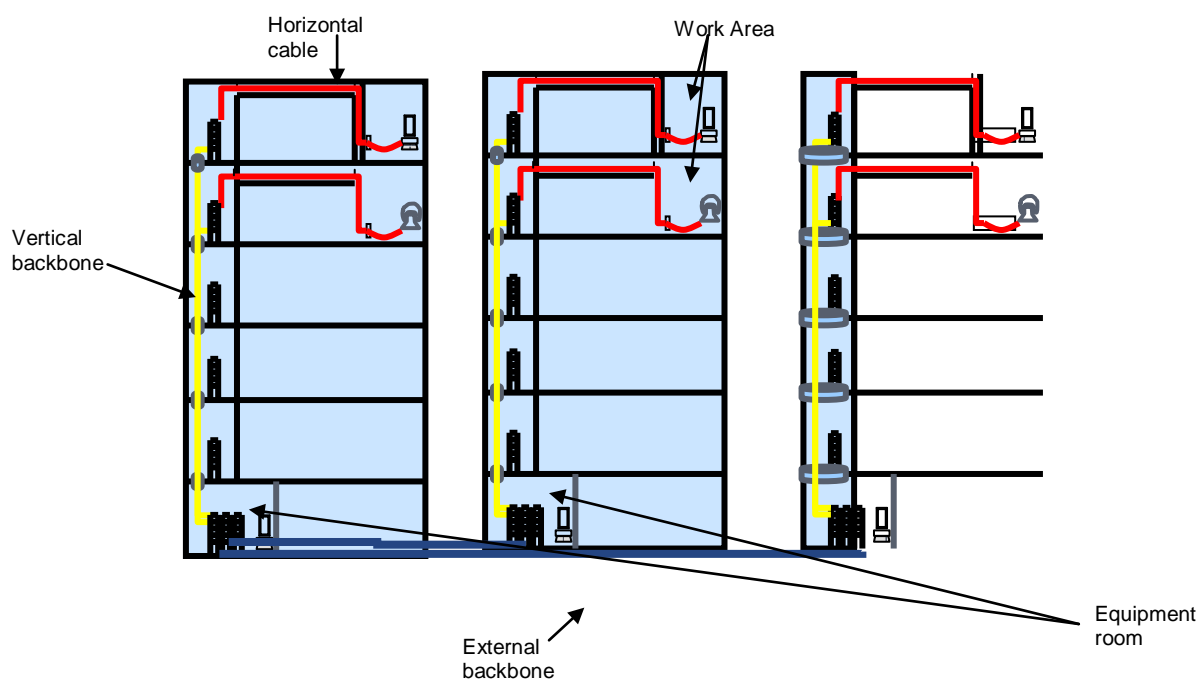


Figure 14.1: Typical ICT System

14.3 Active Equipment


Active equipment refers to the hardware used for the system such as:

- a) Server
- b) Switch

14.4 ICT Terminology

Some basic terminology to remember and to be considered when designing the ICT system:

- a) Vertical Cabling = Internal backbone
- b) External Cabling = External backbone

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- c) Fibre Optic – multimode (length < 500 metre) – for a and b, rack to rack and building to building
- d) Fibre Optic – single mode (length > 500 metre) – for a and b, rack to rack and building to building
- e) Network Point / Port / Outlet
- f) RJ45 Connector
- g) UTP Cat 5E, Cat 6 = Horizontal Cabling
- h) Hub (now obsolete) = Switch
- i) UTP Patch panel
- j) Cable management
- k) Fiber patch panel
- l) Local Area Network (LAN)
- m) Wide Area Network (WAN) / Campus Network
- n) Telecommunication Closet Room (TCR)

14.5 Design Procedure


Upon receiving the design brief from the architect, the DE first must study the client requirement and prepare a simple analysis of the requirement in order to plan the design works of the ICT requirement. At this stage, there is meeting, discussion and coordination with architect regarding the location of riser, TCR, server room etc.

As a norm / electrical design concept, the network point will follow the same route as S/S/O but in different riser and conduit or trunking. The minimum number of network point will be based on the number required by client. Please remember that, for UTP cable, the length from network point to the patch panel must not exceed 90 metre.

When all the network points have been placed onto the layout plan, the next step to consider is the Telecommunication Closed Room (TCR) location.

TC means Telecommunication Closet refers to equipment racks where all cables (fiber and UTP) shall be terminated. TC consists of:

- a) Fibre Termination Unit = Fibre Patch Panel
- b) UTP Patch Panel
- c) Cable Management Unit
- d) Switch (24 or 48 port)
- e) Ventilation Fans
- f) Power Supply = Power Distribution Unit (PDU)
- g) UPS


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Refer to Figure 14.2.

14.5.1 Example calculation of Rack Sizing

Numbers of network points	= 220
Switch type	= 24 port
Total switch needed	$= 220 / 24$ $= 9.2$ $\approx 10 \text{ units}$
10 units 24 port switch	= 10U
10 units 24 port patch panel	= 10U
10 units cable management	= 10U
1 unit Fibre Termination Unit	= 1U
1 unit UPS	= 3U
Total	= 34U
30% - 40% Future Expansion	$= 0.3 \times 34$ $= 10.2$ $\approx 10U$
Thus, Rack Size	$= 34U + 10U$ $= 44U$

Note: In market there is no 44U Rack size, the close size is 42U rack.

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14.5.2 Standard size for rack

Wall mounted


- 9U
- 11U

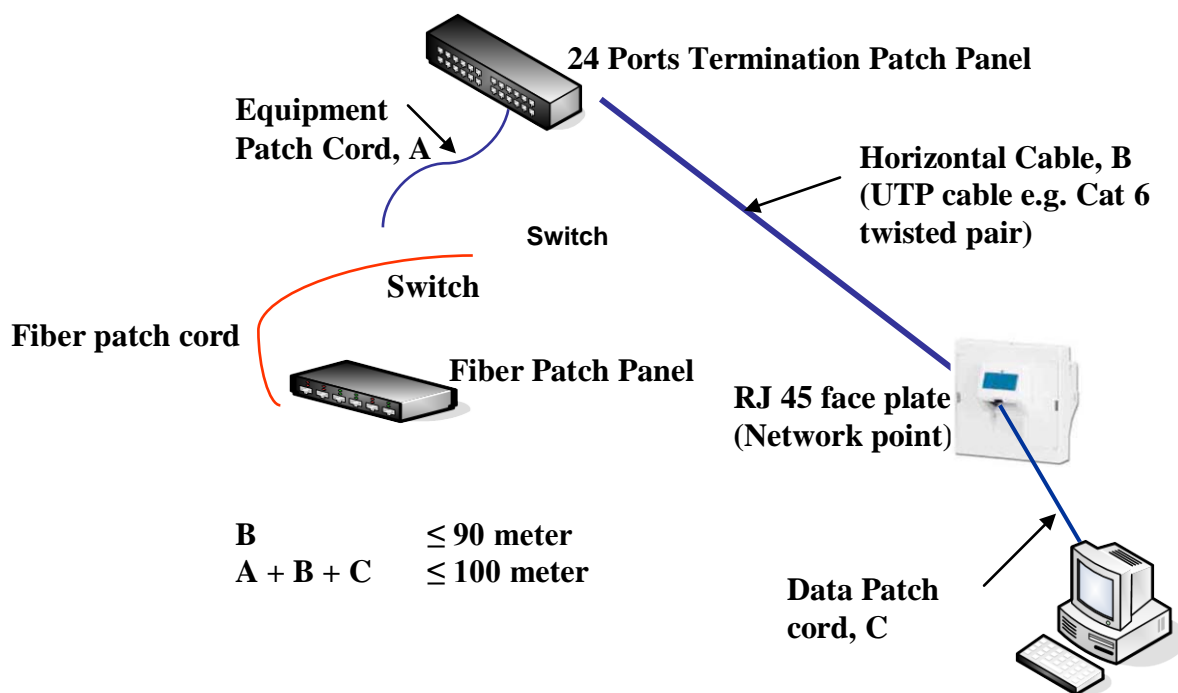
Floor Standing

- 15U
- 21U
- 27U
- 32U
- 37U
- 42U

14.6 More complex ICT system

This is normally where the ICT design works in UPR stops. However the scope is usually further expanded and more complicated when the ICT works is handled by Unit Perunding ICT. This may include the integration of voice communication via the digital network.

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Rack (TC)

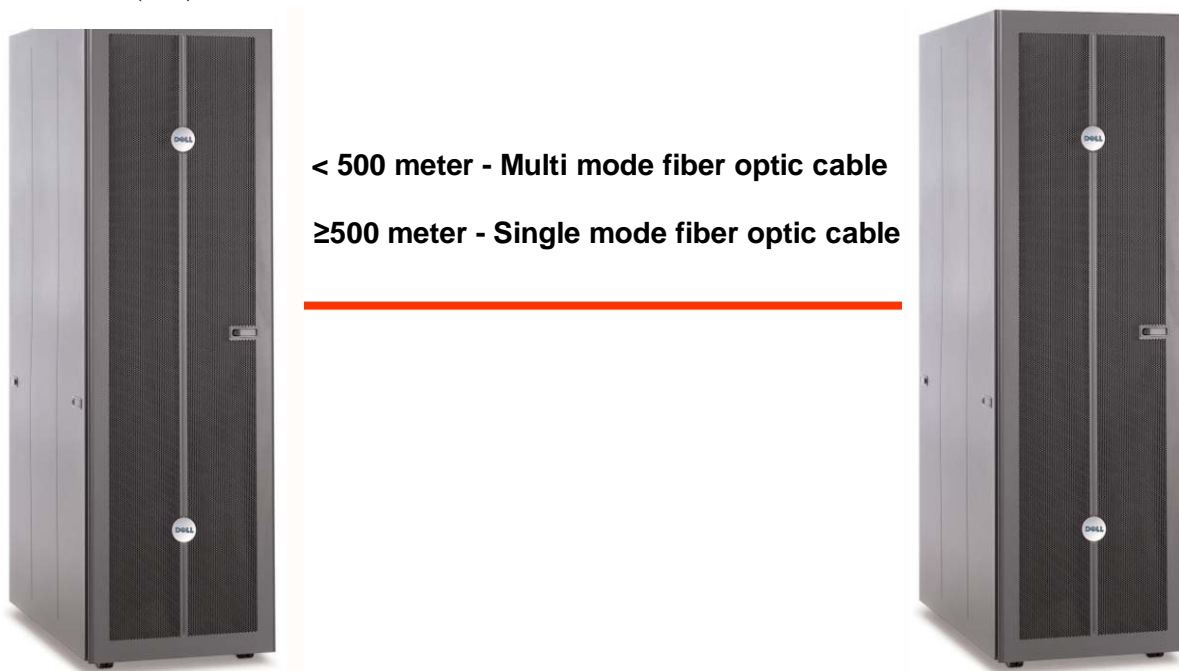


Figure 14.2: Horizontal Cabling



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Table 14.1: Guideline for IT Requirement and Criteria

(Cross refer to Chapter 15 Table 15.4 - some of the spaces/rooms may be shared with telephone services depending on sizes location and other constrains)

NO	ROOM TYPE	PROPOSED SIZE (mm)	CRITERIA / GUIDE
1	SDF Room		May be shared with telephone services
2	MDP Room		May be shared with telephone services
3	Fiber Optic room		May be shared with telephone services
4	PABX Room		May be shared with telephone services depending on whether it is IP based or conventional type
5	IT Riser Room		Shall be aligned in one straight line for multilevel building
6	Telecommunication Closed Room	2000 × 3000 (Minimal size for 1 no. Equipment rack)	May be shared with IT riser room depending on number of switches etc. Floor, wall and ceiling must be dust free type finishes Ducted air cond outlet from 24 hours central air-cond or 2 nos split units AC or enough air flow ventilation 2 nos utility switch socket outlet from essential supply
7	Floor Opening	Subject to size and number of trunking installed	Will be covered by approved 2 hrs fire barrier, by Elect. Contr. Door to follow UBBL 75mm kerb around the floor opening; 50mm kerb across the door
8	Server Room	7000 x 4000	Floor wall and ceiling – fire rated, semi glass wall, dust free finishes 400mm double leafed door (glass with aluminium frame) Air conditioning – <ul style="list-style-type: none"> total heat dissipated by equipment in the room: 50,000BTU* (depending on heat generated by ICT equipment) Operating temperature 20C +- 5% with temperature measured at remote corner Operating hours: 24 x 7 Dedicated, alternate and Auto start Aircond System. Humidity 50% RH

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8 (cont.)	Server Room (continued)	7000 x 4000 (continued)	Fire fighting – no sprinkle system allowed. Use heat sensor / smoke detector with Argonite gas Independent grounding busbar not more than 1.0 ohm
			Power source - For central UPS:
			<ul style="list-style-type: none"> 60A Isolator 3 phase essential supply tapped directly from essential MSB/SSB 60A Isolator 3 phase normal supply tapped from MSB or SSB. Minimum 4 no. 13A SSO in general DB
			Power source -For standalone UPS:
			<ul style="list-style-type: none"> Minimum 8 no. 13A SSO dedicated DB in server room
			Telecommunication lines – 20 way DP box
			Card access security system
			Raised floor
			<ul style="list-style-type: none"> Material – Simen plaster sandwiched between steel top sheet and bottom steel pan Panel tile size – 600mm with pedestals and stringers Overall panel thickness -45mm Floor heights – 250mm (unless specified otherwise) to accommodate under floor IT/power cable trunking Floor finishing – smooth anti static and high pressure laminate Understructure – Rigid grid with stringer Concentrated load – 1000lb Maximum load per tile 2000lb Uniform load – 260lb/ft² Rolling load – 600lbs load on a 6” diameter x 11/2” width wheel for 10,000 passes Impact load – 120lbs drop from a height of 12” Ramp slope – 1/10
			Power source – all utility SSO 13A under the raised floor

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15.1 Introduction

The extent of work to be executed by JKR begins at the boundary of the project site i.e. at the first manhole in the client area. From the TM exchange to this first manhole will be under TM scope of work.

In this chapter we shall be concentrating on 'The design and the installation of the voice telecommunication services' for Government buildings. Internet Protocol (IP) based communication system if any shall be covered under the ICT scope of works.

Topic shall be subdivided as follows:


- a) Building Requirement
- b) Design Of Internal Telephone Layout
- c) Design Of Internal Telephone Cabling
- d) Subscriber Distribution Frame (SDF)
- e) Private Automatic Branch Exchange (PABX)
- f) External Work
- g) Coordination With TM

There are a few telecommunication utilities in the countries. TM is the largest. Most of the following information is based on their requirement and practice.

15.2 Building Requirement

There are 3 categories classified by TM:

- a) Category 1
 - More than 5 storey and any building with total floor space exceeding 650m²
 - TM specified underground cable exceeding 50 pairs
- b) Category 2
 - Less than 5 storey with total floor space less than 650m²
 - TM specified underground cable less than 50 pairs
- c) Category 3
 - Terrace or link houses for residential purpose only,
 - Bungalow for residential purpose only.

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TM require that plans for telephone facilities for all Category 1 buildings must be drawn up by telecommunication engineers or electrical consultant engineers and submitted to TM for approval. Most of the government complexes fall into this category. All or some of the rooms as stated in Table 15.4 may be required.

15.3 Design of Internal Telephone Layout

Usually telephone requirements and location are obtained direct from the client department and then ductings are suitably sized to suit. But TM also gives a basic guideline to design the size of the under floor duct and the multicore cables as follows:

‘It is estimated that for every 9 sq m to 10.9 sq m of office space, a telephone line is required and that a 625 sq mm of duct can accommodate 7 line 2-wire 0.63mm gauge type telephone cable taking into consideration a space factor of 50%’


Hence Table 15.1 below was devised as a guide.

Table 15.1: Guide for Design of Internal Telephone

Size of ducts commonly used	Max. No. of single 2-wire cables than can be accommodated	Size junction box (Inner Dimension) for Floor Ducting L × B × D
25 mm diameter	6	100 mm × 100 mm × 38 mm to 50 mm
25 mm × 25 mm	7	- ditto -
50 mm × 25 mm	14	- ditto -
75 mm × 25 mm	21	150 mm × 150 mm × 38 mm to 50 mm
100 mm × 25 mm	28	150 mm × 150 mm × 38 mm to 50 mm
(75 mm × 25 mm) × 2 Nos	42	200 mm × 200 mm × 38 mm to 50 mm

Methods of providing final distribution to actual telephone points

- PVC or mild steel under floor trunking complemented with junction and outlet boxes, this system is most commonly used and is most versatile since it can be applied in a grid system or branching layout or perimeter layout.
- 3 compartments under floor system
- Hollow skirting along the wall
- Hollow dados along the wall
- Chases in the floor

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Generally, the actual system used are a combination of all the above. Trunking /conduit wiring in the false ceiling are generally not permitted.

15.4 Design of Internal Telephone Cabling

Standard sizes of internal tinned copper conductors, PVC insulated, twin/triple formations and PVC sheathed cables (all coloured grey) are as follows:

1 pr/ 0.63 mm	&	10 pr/ 0.5 mm
5 pr/ 0.63 mm		30 pr/ 0.5 mm
10 pr/ 0.63 mm		50 pr/ 0.5 mm
29 pr/ 0.63 mm		100 pr/ 0.5 mm
30 pr/ 0.63 mm		
100 pr/ 0.63 mm		

For colour codes refer to Table 15.2 and 15.3 below.

Table 15.2: Colour Code for Internal PVC Telephone Cable with Unit Type Configuration.

Pair No.	Colour or Conductor Insulation	
	A leg (1 st wire)	B leg (2 nd wire)
1 2 3 4 5 6 7 8 9 10	White “ “ “ “ Red “ “ “ “	Blue Orange Green Brown Grey Blue Orange Green Brown Grey
10 pair unit		First 5 pair unit Second 5 pair unit
1 pair only	White	Orange
3 wire	White	Orange


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Table 15.3: Colour of Binder Tape

Unit No. (10 pair unit)	Colour of Binder
1	Blue
2	Orange
3	Green
4	Brown
5	Grey
6	Blue – White
7	Orange – White
8	Green – White
9	Brown – White
10	Grey – White

Cabling to DP boxes from SDF is made up of a combination of the above cables. Protective conductors or earth wires shall be run continuously from the top to bottom of the building and connected to SDF. These wires shall be installed and terminated to the nearest DP boxes in the riser.

It should be noted that all direct lines and other TM facilities at each floor shall be taken from the respective direct line DPs.


15.5 Subscriber Distribution Frame (SDF)

The SDF is the final termination point of the TM network and the beginning of the subscriber network. The SDF consist of:

- Vertical frames or vertical c/w brackets/hooks
- Termination blocks
- Earth bar
- Lightning arrestors

TM room (SDF) which will be handed over to TM upon completion of the project normally consists of a minimum three verticals namely:


- VERTICAL NO. 1 - TM incoming vertical
- VERTICAL NO. 2 - TM outgoing vertical
- VERTICAL NO. 3 - Equipment (PABX) vertical

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On the distribution side, consumer room (Intermediate Distribution Frame, IDF) can be combined with PABX room and normally consists of a minimum of three vertical namely:

- a) VERTICAL NO. 1 - From equipment vertical SDF
- b) VERTICAL NO. 2 - Outgoing to extension DPs
- c) VERTICAL NO. 3 - Incoming from PABX

For a smaller system where SDF is combined in the same room with IDF equipment vertical can be omitted as shown in Figure 15.1.

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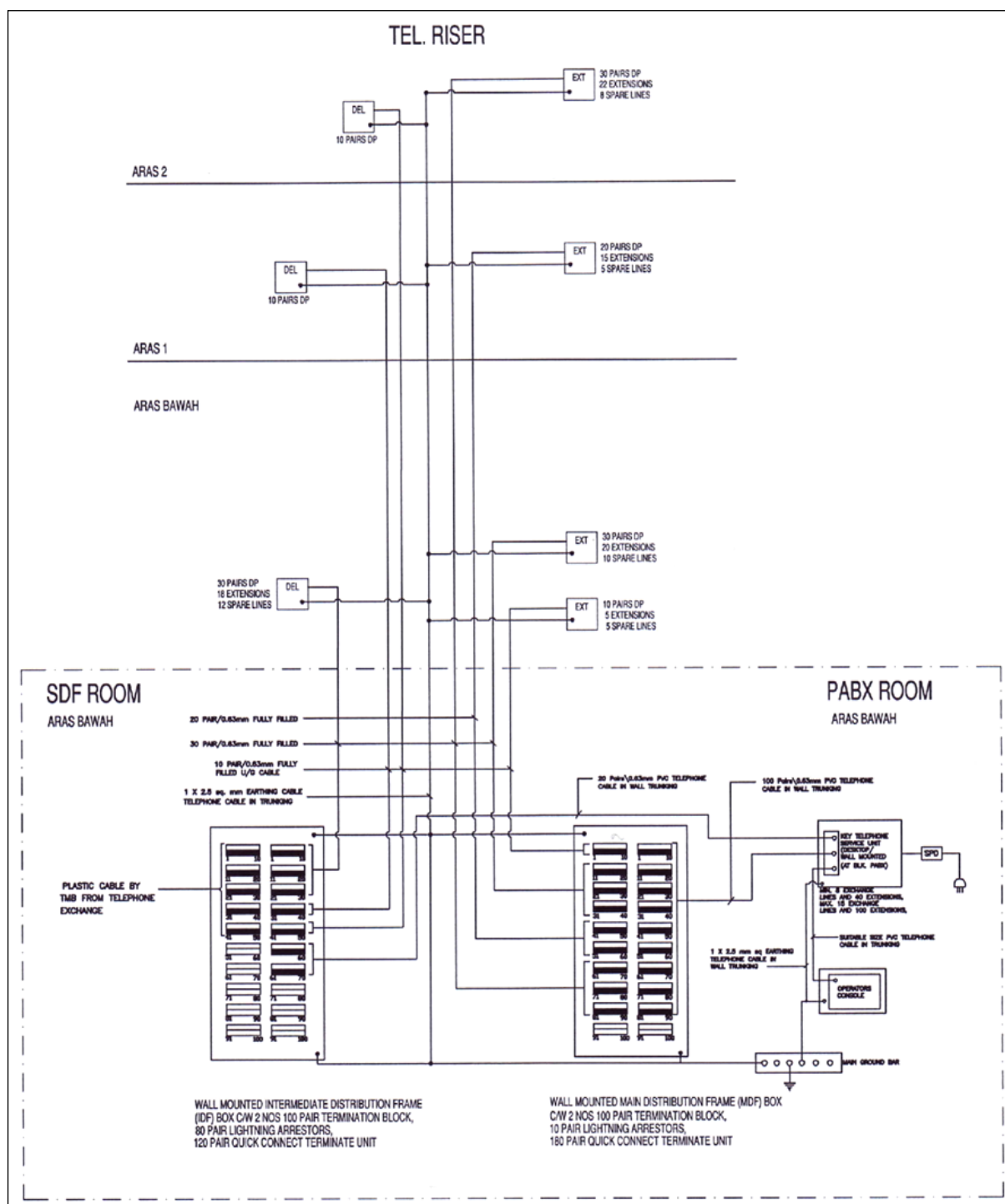



Figure 15.1: System where SDF is Combined in the same Room with IDF Equipment

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15.6 TM Incoming Vertical

TM incoming cables from their exchange shall be terminated at this vertical. Normally a 100 pair vertical is sufficient to cater for the entire telecommunication network of the project. The size of the termination blocks required for the incoming vertical is according to the size of the TM incoming cable which in turn depends on the number of trunk lines to PABX, trunk lines for direct telephones and public phones, data communication (telefax, telex, digital lines, leased lines, etc).

Connection between various verticals shall be done via jumpers or jumper cables meant to activate the required lines.

15.7 TM Outgoing Vertical

The TM outgoing vertical shall cater for all direct line DPs. This includes all the trunk lines to the PABX. The size of termination block shall be the total pairs of all the direct lines DPs and the PABX trunk lines. The vertical frame shall be sufficiently sized to house these termination blocks.

15.8 Equipment Vertical


Equipment vertical is required when there is a requirement for PABX. Trunk lines to the PABX can be distributed either from the equipment vertical to distribution vertical or the floor direct lines DP for multi tenants high rise building.

The quantity of the termination blocks shall be the summation of total pairs of trunk line cables designed for maximum capacity of the PABX.

15.9 Distribution Vertical

There are two types of distribution vertical, namely the incoming and outgoing distribution from PABX for extension lines.

Connection from PABX shall be terminated to the incoming distribution vertical. The quantity of the termination blocks shall be the summation of extension line cables designed for. The frame shall be large enough to mount these termination blocks.

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The tie cables for each floor extension DPs shall be pulled from outgoing distribution vertical. The quantity of the termination blocks shall be the summation of total pairs of extension DPs design for. The frame shall be large enough to mount these termination blocks.

15.10 Earth

TM requires that SDF earth resistance to be less than 5 ohms. However, if the earthing cable for the PABX is connected to the SDF earth bar the earth resistance should then be less than 1 ohm.

15.11 Lightning Arrestors


Lightning arrestors shall be installed at the TM incoming vertical for the TM incoming cable and at the Distribution vertical for any other external tie cables (underground or overhead). The size of these lightning arrestors shall be equivalent to the size of the cables. It shall also be of the quick connect gas filled type. Typical descriptions of the SDF may be as follows:

- Wall mounted SDF c/w 4 no. 200 (4 x 200) pair vertical frames, 550 pairs quick connect termination block and 3 x 10 pair lightning arrestors. or
- Wall mounted SDF c/w 6 no. 100 (6 x 100) pair vertical frames, 550 pairs quick connect termination block and 3 x 10 pair lightning arrestors. or
- Wall mounted SDF c/w 2 no. 100 (2 x 100) pair vertical frames, 550 pairs quick connect termination block and 3 x 10 pair lightning arrestors.

15.12 Private Automatic Branch Exchange (PABX)

15.12.1 What Is PABX Equipment?

PABX is a kind of telephony switching equipment. Others of the same category are key phone system, PMBX, Hybrid systems, etc.

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15.12.2 When to Use a PABX?

As a basic but non restrictive guide, a PABX is required when there is a need for more than 40 extensions (this may be the total number of telephone points requested by the client plus 20 % future development)

A key phone system may be more economical for extension less than 40 and with very minimal future expansion.

There is also IP base type PABX. The usage and design of such system shall be discussed with ICT design section.

15.12.3 Sizing of PABX.

- Sketch all the floor DP boxes schematic diagrams.
- Totalling the sizes of all DP boxes shall give the maximum capacity of your PABX.
- The minimum capacity of PABX shall be the present telephone point requirement.
- Maximum allowable ratio by TM is 1 DEL: 10 extensions. For flexibility the ratio may range from 1 DEL to 5, 6, 7 or 8 extension. This depends greatly on the traffic flow normally expected by the client.

Note: DEL – Direct Exchange Line or Trunk Lines


15.12.4 Working Example:

Referring to schematic diagram in Figure 15.1, we have a 3 storey block with 2 numbers of 30 pair, 1 number of 20 pair and 1 number of 10 pair extensions DPs.

$$\begin{aligned}
 \text{MINIMUM capacity: } 22 + 15 + 20 + 5 &= 62 + 20\% \\
 &= 62 + 12.4 \\
 &= 74.4 \text{ ext}
 \end{aligned}$$

$$\begin{aligned}
 (\text{Rounding up}) \text{ approx.} &= 75 \text{ ext}
 \end{aligned}$$

$$\begin{aligned}
 \text{No. of trunklines (DEL)} &= 75 / 6 \\
 &= 12.5 \text{ DEL or approx. } 13 \text{ DEL}
 \end{aligned}$$

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MAXIMUM capacity: $30 + 20 + 30 + 10 = 90$ ext

No. of trunklines $= 90 / 6$
 $= 15$ DEL

Assuming a heavy traffic flow, the size of the PABX may be as follows, but it is up to the designer to decide on the economical capacity after consultation with the client :-

Minimum no. of extension lines	- 75
Maximum no. of extension lines	- 90
Minimum no. of trunk lines	- 13
Maximum no. of trunk lines	- 15

15.12.5 PABX Specification


The following shall be specified as minimum requirements of a PABX:

- Type approved by TM
- Digital
- Stored program control, SPC
- Compatible with ISDN technology (using ISDN interface)
- Port type
- Maintenance free battery (for small system only)
- IDF quick connect termination type
- Earthing shall be less than 1 ohm
- Testing and commissioning
- Training
- Drawing and manuals

15.12.6 PABX Facilities

All PABX have the following type of facilities:

- minimum or standard facilities
- optional facilities (card have to be specifically purchased and stated in the BQ, e.g. Direct In Dialling - DID, ISDN, etc)
- programmable facilities (group hunting line, call pick up, follow me, etc)

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TM however requires that for the following facilities prior application must be submitted for their planning as it involves additional TM telephone lines:

- a) Tie lines between PABXs
- b) DID more than 100 extensions (to reduce traffic congestion)
- c) Data line

15.13 Room Requirement


Only PABX with ultimate capacity of more than 300 extensions require separate rooms by itself, its batteries and its operators. Otherwise separate rooms are not needed, but when space is not a restriction it is preferable to have these rooms separately for smaller systems. The PABX room shall be/have:

- a) Free from susceptible vibration, always free from direct sunlight and dust. Moisture must be controlled at 30 – 65% for less than 300 extensions, a normal air conditioned office is sufficient but bigger systems require 24 hrs air conditioning at 15 – 30 degrees Celsius.
- b) Floor able to withstand 300 – 1000 kg / sq meter depending on type and capacity.
- c) Flooring of material that is anti static, easy to clean and not susceptible to accumulation of dust, preferably vinyl type.
- d) Required 2 no. standard 13A 3 pin socket outlet power point. However, PABX of capacity exceeding 1000 extensions require higher current rating and three phase supply.
- e) Trunking or cable trays must be provided and shall be sufficiently large to accommodate PABX cables from PABX equipment to SDF room or the riser distribution box and the operators' room.
- f) Separate IDF required for the PABX terminations.
- g) CO2 or other suitable type fire fighting preferred. No water sprinkler allowed.
- h) Good to equip with wall mounted lockable cabinets to house manuals for the PABX maintenance and programming.

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- i) PABX shall be placed at least 1 meter from the wall and have a 1 meter allowance in front for maintenance purposes.
- j) For large systems when a separate battery room has to be provided it shall be located adjacent to PABX rooms and ventilated to prevent harmful effects of battery acid and fumes.
- k) Smaller batteries of the sealed maintenance free type may be installed in a separate cubicle in the same PABX room.
- l) The separate battery room shall be equipped as follows:
 - Glazed tiles up to 1.5m around all sides of the wall Exhaust fan
 - Minimum room size 3m x 1.8m
 - Wash basin
 - Exhaust fan
- m) When separately provided, the operators room shall be situated not more than 50 meters away from PABX room. It should be sized to comfortably seat the required number of operators. It shall be of half glass partitions furnished with suitable operator tables and chairs and with 1 extension line of category C type.

Table 15.4 shows the several types of telecommunication room and criteria.


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**Table 15.4: Guideline for Telecommunication Requirement and Criteria
Telecom Operator's Room**

NO	ROOM TYPE	PROPOSED SIZE (mm)	CRITERIA / GUIDE
1.0	Telecom Operator's Room		PSTN: TM, Time Tel. Maxis, Bina Riang, etc.
1.1	SDF Room (Refer Fig. 15.2)	2000 × 2000 (Up to 50 DEL) 3000 × 3000 (>50 DEL) for more refer to Table 15.5	Entry ducts from outside the building shall be designed to run parallel with the length of the longer side of the SDF room. Any turning or bending shall be avoided. SDF room must be flood free either on ground or 1st floor with a 150 mm kerb across doorway (basement not allowed). Must be dust free - avoiding louvered doors and windows. Normally equipped with Exhaust Fan, A/C if located in the basement / lower ground floor Must be fitted with suitable lighting At least 2 no. of 13A power points. Sprinkler system not allowed. Must be provided with one lockable cabinet, table and chair for TM staff use.
1.2	MDP Room	< 50 DEL	MDP room with telephone pit
1.3	Fiber Optic room	Minimum 4000(L) × 4000(W) x 3000(H) Actual size dependent on TM local infrastructure	Provided with pit or cable trench Must be flood free either on ground or 1st floor with a 150 mm kerb across doorway (basement not allowed). Must be dust free - avoiding louvered doors and windows. Equipped with Exhaust Fan, 24 hrs A/C Must be fitted with suitable lighting At least 3 no. of 13A power points. 30A 3 phase DB (TNB main supply) for rectifier Framed Schematic diagram installed on wall 2 separate earthing both less than 1 ohm Sprinkler system not allowed. Must be provided with one lockable cabinet, table and chair for TM staff use.


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NO	ROOM TYPE	PROPOSED SIZE (mm)	CRITERIA / GUIDE
2.0	Consumer's Room		Build up area up to 9100 sq.m
2.1	IDF Room (Refer Fig.15.3)	1500 × 1000	Shall be nearby the SDF Room
2.2	PABX Room (Refer Fig. 15.4)	1500 × 1500	May be combined with IDF Room or located elsewhere on other floor A/C; 3 nos S/S/O
2.3	Telephonist/Operator Room	1500 × 2000	Separate room for 1 person only Should not be > 50m away from PABX Room With half glass door or half glass partition Can also be part of admin, office area
2.4	Riser Room	TM's sizes: <10 storeys [0.9m x 0.45m] ≥ 10 storeys [1.2m x 0.45m] JKR practice according to Fig. 15.5 and 15.6	The cable risers stretch from the SDF room to the full height of the building and have access to distribution conduits on each floor of the building. For buildings with large floor areas (longer than 90m) in each storey, more than one cable riser at strategic points may be planned on every floor. This riser hole shall be sealed up with fire resistant barriers. It is important that no other services be allowed in this enclosure. Enclosures shall have fire resistant locked doors of min 2.1m height with the words 'TELEPHONE RISER' displayed on it One set of keys of the door shall be kept by owner for safe custody and the other by TM.
2.4.1	TC and Riser Room (Refer to Fig. 15.5)	2000 × 3000	Best to be A/C or at least naturally ventilated
2.4.2	Telephone Riser / DP Room (Refer to Fig. 15.6)	1000 × 900	Should not be the same room as IT, but must be side by side or nearby
2.5	Floor Opening (Refer to Fig. 15.7)	Subject to size and number of trunking installed	Will be covered by approved 2 hrs fire barrier, by Elect. Contr. Door to follow UBBL 75 mm kerb around the floor opening; 50mm kerb across the door

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NO	ROOM TYPE	PROPOSED SIZE (mm)	CRITERIA / GUIDE
3.0	Infrastructure Requirement		
3.1	Screeding to cover the Integrated	50	To cover the boxes (a total provision of 55 mm)
	Underfloor Ducting System or	5 – 10	To level the slab (60 mm thick or screeding required). Floor slab shall be recessed to allow for raised floor system
	Raised Floor System	150 – 450	
3.2	Manholes (external) (Refer to Fig. 15.8)	JC9/C	For road, tarmac, hard standings
3.3	Joint Boxes / Telephone Pits (internal) (Refer to Fig. 15.8)		2 sizes: 460 (I) × 460 (w) × 460 (d) or 460 (I) × 460 (w) × 760 (d) Required at all cable access into the building Conduit required from floor junction boxes to wall telephone outlet Several different sizes available Design to follow TM Guidelines of Planning for Building
3.4	Trenching Requirement (for SDF Room) (Refer to Fig. 15.2)		Layout of the trenches may differ according to projects; Elect. Designer will furnish the info.
3.5	Earthing		≤ 1 ohm

NOTE: All sizes given may differ according to the sizes of the project.

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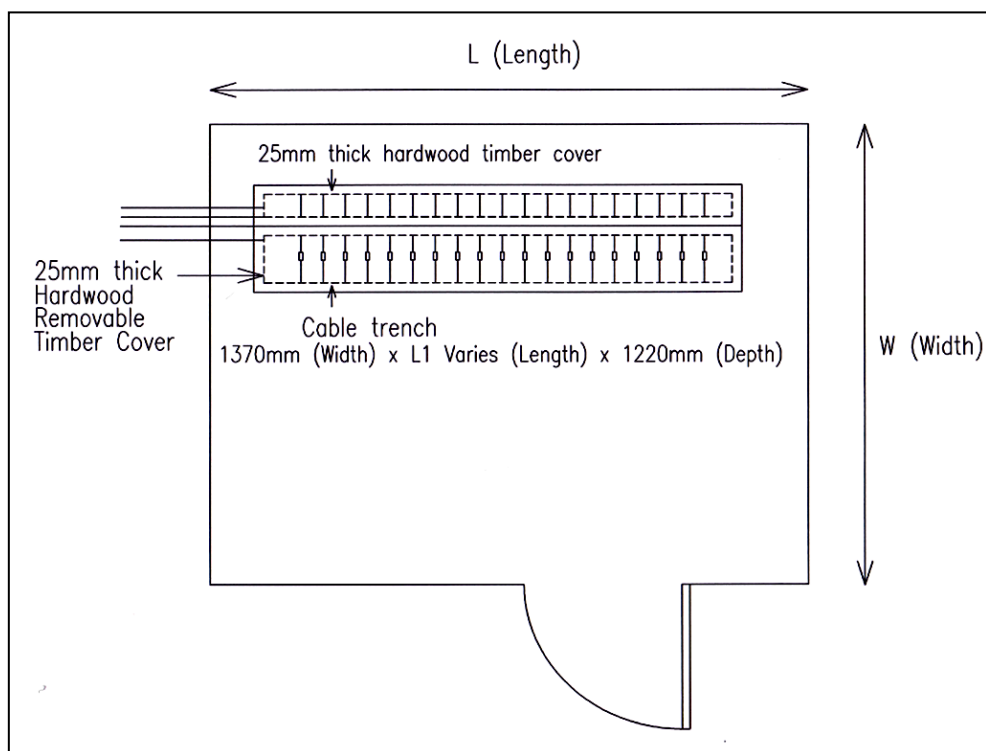


Figure 15.2: SDF Room

Table 15.5: Standard room size requirement for SDF rooms.

Size of Cables (Pairs)	For Incoming Cable		SDF Room (L × W × H) (m)	Max. No. of Floor
	No. of Entry Duct	Width of Cable Tray (mm)		
50 – 200	2	300	$2.4 \times 1.8 \times 3$	6
200 – 400	2 – 4	300 – 350	$3 \times 2.4 \times 3$	8
400 – 600	4	350 – 400	$3.6 \times 3 \times 3$	10
600 – 1000	6	400	$4.8 \times 3 \times 3$	12
> 1000	> 6	> 400	$< 6 \times 3 \times 3$	> 12

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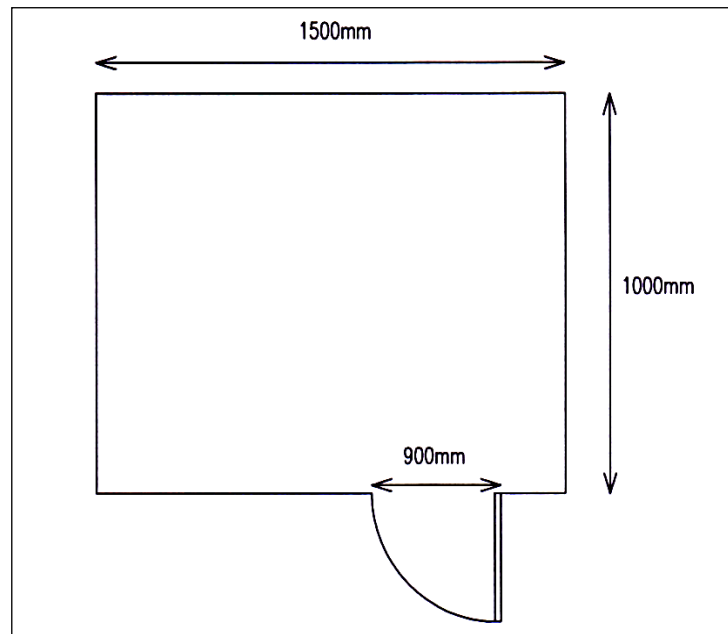


Figure 15.3: IDF Room

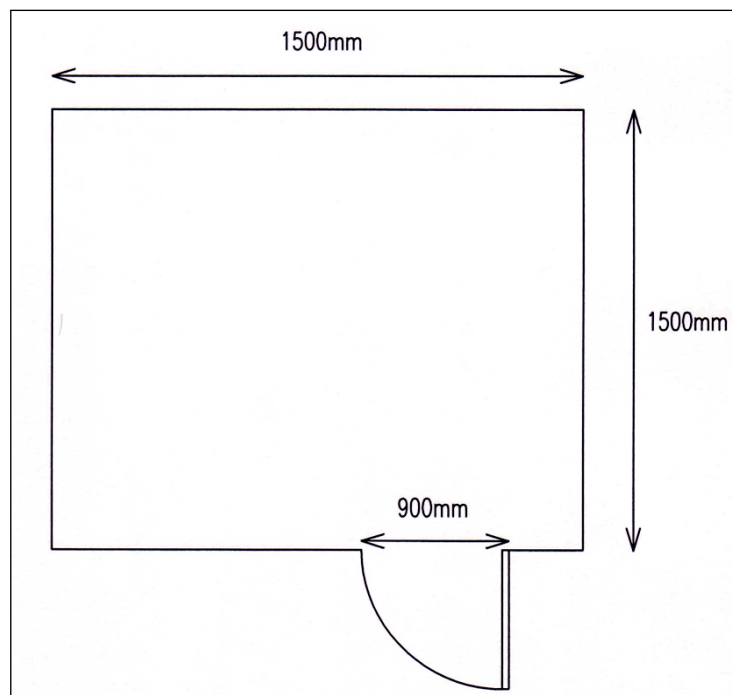



Figure 15.4: PABX Room

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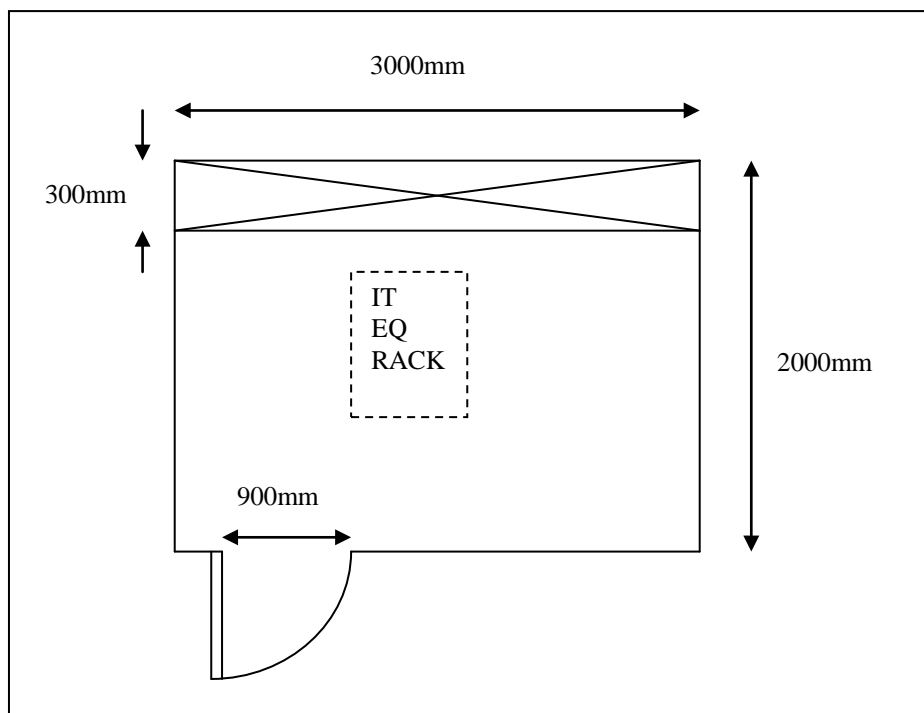


Figure 15.5: TC and Riser Room

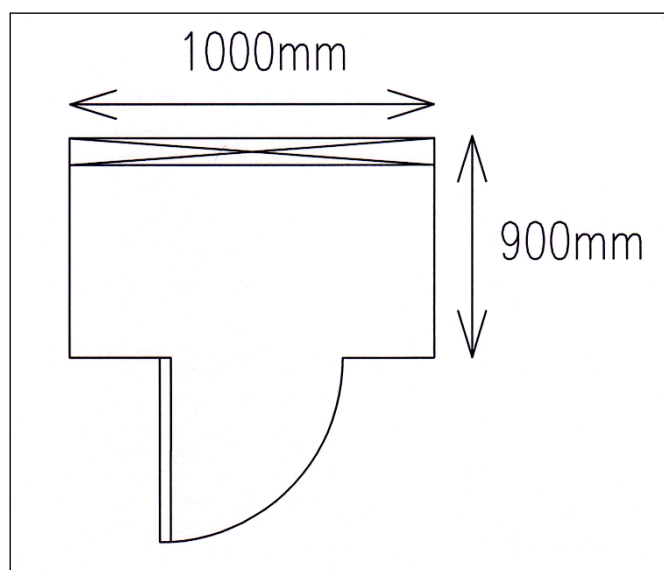



Figure 15.6: Telephone Riser / DP Room

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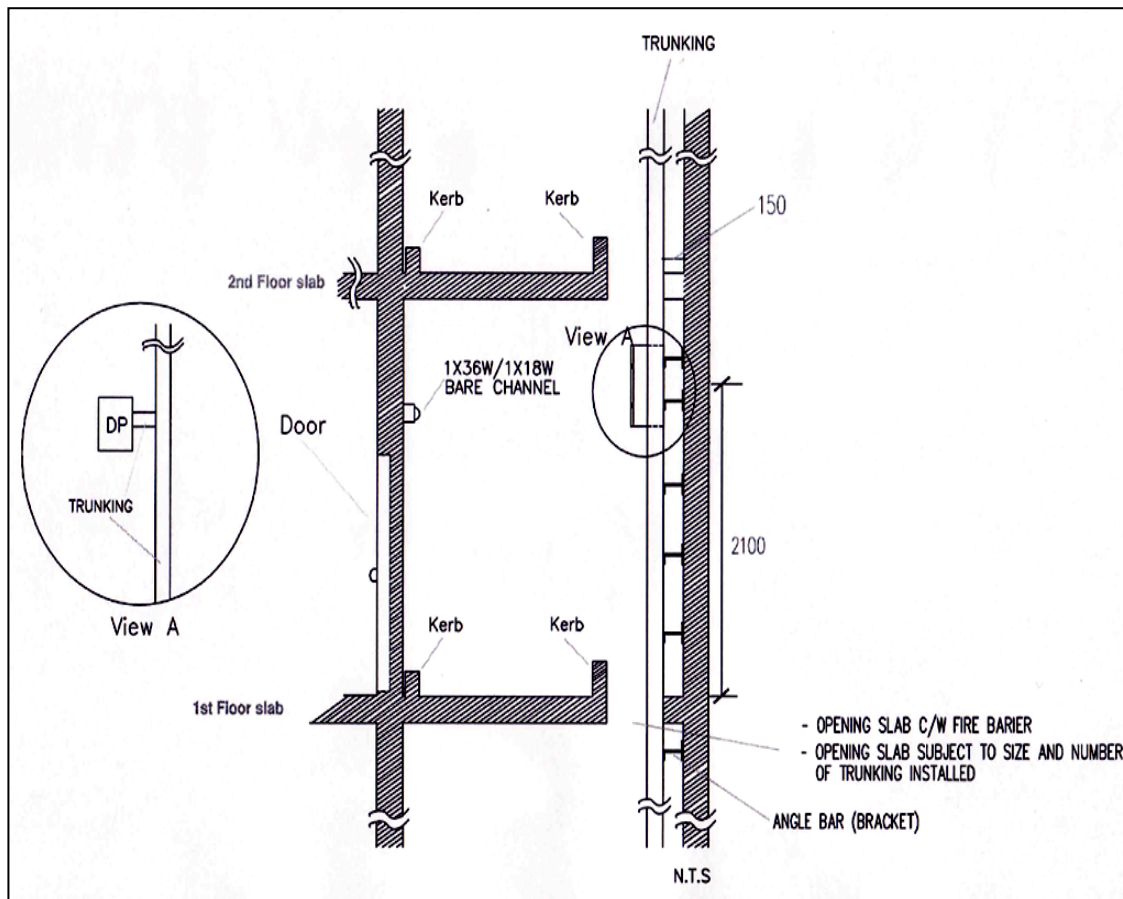



Figure 15.7: Floor Opening

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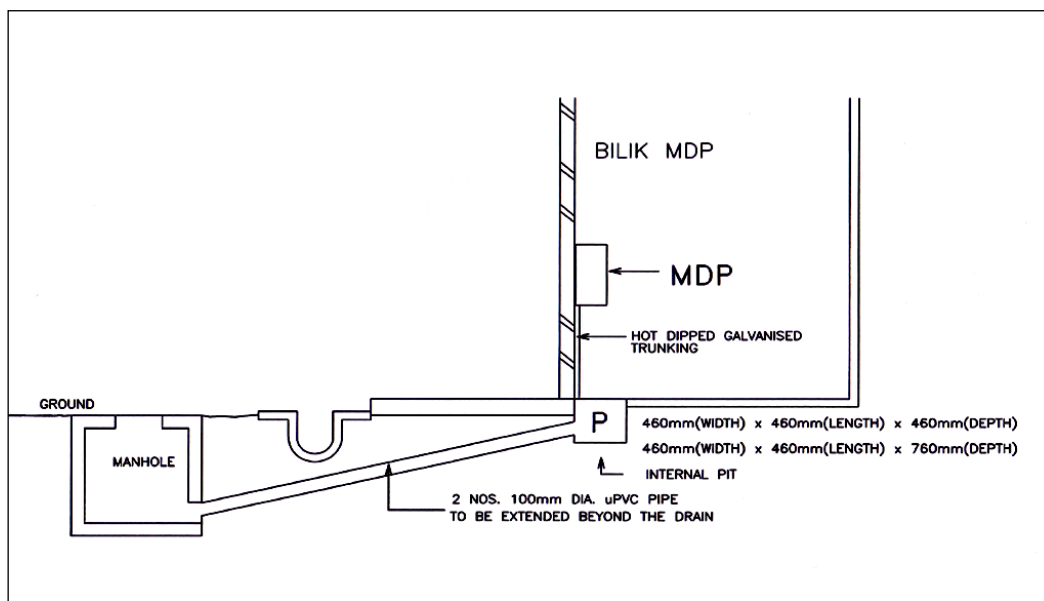


Figure 15.8: Manholes and Joint Boxes


15.14 Acceptance Test and Training

TM does not test or commission the PABX. It is the duty of the consultant/contractor to check that all facilities as required in the specification are provided and complied to. It is also the duty of the consultant/contractor to ensure that appropriate training is conducted by the PABX supplier / contractor for JKR staff and of course the end users. At the end of the training the supplier / contractor shall provide hard copy of programmed extension numbers with circuit and location, programmed telephone facilities demonstrated during the training session.

15.15 External Works

This topic shall be subdivided into two namely:

- Civil Engineering work
- Underground cabling

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15.15.1 Civil Engineering Work

This portion of work involves the construction of manholes, joint boxes, duct laying etc. Generally, the most common manholes/joint boxes constructed for most JKR projects are as follows:

- a) Telephone pits
- b) JB30
- c) JC9
- d) JRC7
- e) JC9/C
- f) R2A


And all or some of them may be requires depending on the extent scope of the project and also on the recommendation and approval of the local TM office. The detailed plans of all the above may be obtained from the local network offices of TM. TM has standardized the use of 100mm diameter PVC ducts for all the ducting required. Usually, these ducts have to be encased in concrete at road crossings and crossing with other services and when more than 8 ducts are required. TM has also required the use of GI pipes where drains or streams have to be crossed. GI pipes are also required where there is insufficient earth coverage underground. As a rule of thumb 110cm of cover is required above the PVC ducts. The exact maximum distances between joint boxes were not defined by TM but generally it is about 120 meters for plastic fully filled cables. Clearance from other services:

Water mains

- a) At least (nominal) 150mm running parallel.
- b) At least 50mm at crossing

Electricity supplies

- a) High voltage single core cables exceeding 650V at least 460mm with no exceptions.
- b) High voltage multicore cables exceeding 650V at least 300mm.
- c) Low and medium voltage cables not exceeding 650V at least 50mm
- d) Where the two sets of electrical plants cross each other

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15.15.2 Underground Cabling

For JKR projects we are usually required to use underground cables in PVC ducts. It is recommended by TM that we use Plastic fully filled telephone cables. For this distribution cable, it is important to specify the parameter of capacitance to be 55 nano Farad/km.


15.16 Coordination with TM

15.16.1 Plan Approval Process

It is an advantage to have a preliminary discussion between consultant/DE and TM before submission of proposed infrastructure plan for telecommunication services. It helps TM to identify the development at an early stage enabling the planning of cable network for the development. The consultant can obtain relevant information on the existing plant so that accurate proposal can be made and method on how to link to this plan can be made. If necessary a site visit is to be arranged so that a better picture can be obtained. Other issues on the provision of SDF room, frame, blocks and the type of material to be used are normally discussed during this preliminary meeting. Once all information has been obtained, the consultant/DE will submit two sets of draft proposal to TM for checking. A copy of the plan is then returned to the consultant for further amendments (if required) before submitting four sets of the final proposal for approval.

15.16.2 Implementation

It is the responsibility of the developer (in this case JKR) to engage registered contractors with Pusat Khidmat Kontraktor under subhead I-9 and VIII-2a/b to carry out Telecom infrastructure works. Details of the contractor and the work schedule have to submit to TM before the work begins. During the implementation stage, TM supervisors will perform spot checks to ensure that the work is executed as planned. Any change to the plan has to be referred back to TM for further discussion and approval. On the completion of the work, the consultant/SO representative will have to inform TM for the joint acceptance test.

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15.16.3 Acceptance Testing

Acceptance testing shall be carried out jointly between TM staff, consultant/SO representative and the contractor on the following works:-

1. External Civil Works

- a) Rodding of ducts installed by contractor right to the duct seal in the building.
- b) Checking the manhole dimensions, fittings and finishing.
- c) Checking the duct seal for water leakage into the building.


2. Internal trunking

- a) Perforated cable tray finishes such as smooth bending, clearance between trays and ceilings/other services.
- b) Riser trunking, riser DP boxes, riser rooms plus labelling of the DP boxes.
- c) Junction boxes and floor trunking, depth of junction boxes, finishing and draw wires between junction boxes.

3. Cabling

- a) Insulation resistance (IR) test for every cable pair provided between SDF and the individual riser DP.
- b) Continuity test for every cable pair from SDF to riser DP.
- c) Earth resistance measurement of SDF frame shall be less than 1 ohm.

The foregoing notes are only meant as a brief guide to those who are new to a telephone system design. More detailed information and knowledge of the telephone service are definitely required for the complete detail design. However it is hoped that the brief guide and notes may serve as a stepping stone in the initial design.

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16.1 Introduction

Road lighting installation shall provide sufficient visual information for road users to proceed safely and give them a sense of security. This will be possible if the lighting installation ensures:

- Reliability of Perception and
- Visual Comfort

These two aspects are interrelated, whereby ease of perception will only be obtained if both the reliability of perception and the degree of visual comfort are satisfactory.

16.2 Luminance Concept

As the visual sensation received by the retina of the human eye is dependent upon the luminance distribution in its field of view, quality parameters for lighting should, thus, be in terms of luminance. For some forms of lighting application this may be either difficult or even impossible because of the wide range of reflective properties of the various surface concerned.

However, the visual environment for a driver on a road at night is mainly formed by the view of the road ahead. The reflective of good surface can be described and measured with sufficient accuracy for the purpose of luminance calculations.

16.2.1 Parameter Influencing Reliability of Perception


- i. Average Road Surface Luminance, L_{av}

A suitable average road surface luminance not only improves the driver's eye sensitivity, but also increases the contrast of possible obstructions on the road.

- ii. Overall Uniformity, U_o

$$U_o = \frac{L_{\min}}{L_{av}}$$

In order to ensure sufficient perceptibility at all spots on the road, the permitted difference between minimum and average luminance must be defined.

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iii. Threshold Increment, TI

Threshold increment is the amount of extra contrast required to see an object when there is glare, relative to the original contrast. It is the measure of the loss of perceptibility caused by disability glare.

Threshold contrast means that an object which can be seen when there is no glare (Threshold Contrast) and cannot be seen when there is glare, unless the actual contrast is increased.

16.2.2 Parameters influencing Visual Comfort

Visual comfort on the road is not luxury but is the most-important requirement for traffic safety. Lack of visual comfort also has a harmful/bad influence on the efficiency of the driver's eye.

i. Average Road Surface Luminance, L_{av}

Higher adaptation level of the driver's eye will provide better visual comfort. Visual Comfort depends upon the average road surface luminance provided that it is below the glare level).

ii. Longitudinal Uniformity, UI


$$UI = \frac{L_{min}}{L_{max}} \text{ (lengthwise)}$$

The sequence of dark and bright areas of the road that appears in front of a driver while he is driving is called 'patchy' or 'zebra' effect, which is very disturbing to a driver and can be reduced by limiting difference between the darkest and brightest spots.

iii. Glare Control Mark, G

The discomfort glare experienced by a driver is dependent on the characteristics of the luminaries used. Glare control mark is the measurement for limiting discomfort glare.

Discomfort glare is also dependent on the size of the light source and the height of luminaire. It decreases with the size and height of the light source.

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iv. Visual Guidance

Visual guidance is another important aspect both from a reliability of perception and the visual comfort point of views.

The visual guidance shall provide the driver a clear indication; both at the immediate situation and the road ahead.

16.2.3 Recommendations

The standards which must be met by road lighting installations are outlined in various national recommendations. Several countries base their standards on the international recommendations formulated by the International Commission on Illumination (CIE).

In Malaysia, the Malaysian Standards MS825: Part 1: 2006 governs the design of road lightings. Other supporting standards to be referred to are:

- i) RD/CEN/TR 13201-2004
 - *Road Lighting Part 1: Selection & Lighting Class*
- ii) BS EN 13201-2:2003
 - *Road Lighting Part 2: Performance Requirement*
- iii) BS EN 13201-3:2003
 - *Road Lighting Part 3: Calculation & Performance*

16.3 Principle of Road Lighting – Design


There are four basic concepts in lighting design.

16.3.1 Luminous Flux (Φ)

This is the measure of the amount of light radiated from a light source.

Units: LUMENS (lm)

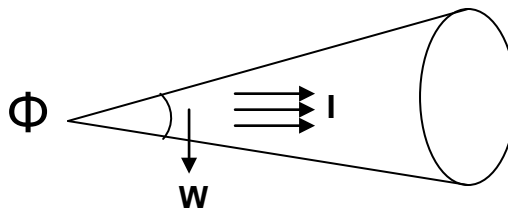
e.g. a 250W High Pressure Sodium Vapour lamp emits approximately 25000 lm of light.

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16.3.2 Luminous Intensity (I)

It is amount of light leaving the source propagated in an element or solid angle containing the given direction and the element of the solid angle.

Units: Candela (cd)



W = solid angle in steradian (SR)

$$I = \frac{\Phi}{W}$$

$$= \frac{\text{lm}}{\text{SR}}$$

$$= \text{cd}$$


16.3.3 Illuminance – E

It is the measurement of luminous flux incident on an element of the surface.

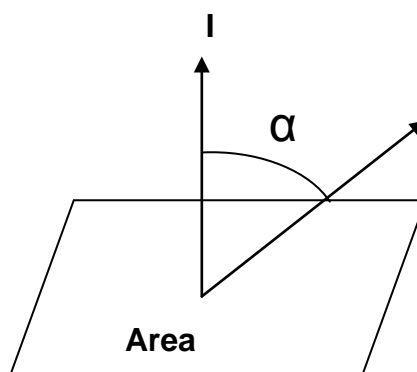
$$\begin{aligned} \text{Illuminance} &= \frac{\text{Luminous flux}}{\text{Area}} \\ E &= \Phi / A \\ &= \text{Lumen / sq. metre} \\ &= \text{LUX or lumen sq. ft} \\ &= \text{foot candle} \end{aligned}$$

16.3.4 Luminance – L

The luminance, in a given direction at a point on the surface of a source or a receptor or at a point on the path of a beam is the quotient of the luminous flux part leaving, arriving at, or passing through an element of surface at this point and propagated in direction defined by an elementary cone containing the given direction, by the product

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of the solid angle of the cone and the area of the orthogonal projections of the elements of the surface on a plane perpendicular to the given direction.



$$\begin{aligned}
 \text{Unit luminance} &= \frac{I}{\text{projected area}} \\
 &= \frac{\text{cd}}{\text{m}^2} \\
 &= \frac{I}{A \cos \alpha}
 \end{aligned}$$

16.4 Recommendations for road lighting

There are requirements that road lighting installation must be met in order to provide adequate visual conditions for a smooth moving and safe traffic pattern. They are dependent upon the intensity, speed and composition of the traffic and upon the complexity of the road system. Road lighting recommendations must therefore state the different requirements for the different categories of road. Table 16.1, 16.2, 16.3 and 16.4 give information on the selection of lighting class as defined by the MS 825: Part 1: 2006 'Road Lighting – Part 1: Lighting Of Road And Public Amenity Areas whereas Table 16.5, 16.6 and 16.7 summarizes the values of the photometric parameters, for different classes of lighting class as recommended in BS EN 13201-3:2003 'Road Lighting Part 2: Performance Requirement'.



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Table 16.1: Lighting Classes for Highways and Traffic Routes

Hierarchy Description	Type of Road/General Description	Detailed Description	Lighting Class
Highway ^a	Limited access	<p>Routes for fast moving long distance traffic. Fully grade-separated and restrictions on used.</p> <p>Main carriageway Emergency lanes</p>	<p>ME1 ME4a</p>
Strategic route	Trunk and some principal “A” roads between primary destinations	<p>Routes for fast moving long distance traffic with little frontage access or pedestrian traffic. Speed limits are usually in excess of 60km/h and there are few junctions. Pedestrian crossings are either segregated or controlled and parked vehicles are usually prohibited.</p> <p>Single carriageway and dual carriageways</p>	ME2
Main distributor ^b	Major urban network and inter-primary links Short-to medium-distance traffic	<p>Routes between strategic routes and linking urban centres to the strategic network with limited frontage access. In urban areas speed limits are usually 60 km/h or less, parking is restricted at peak times and there are positive measures for pedestrian safety reasons.</p> <p>Single carriageways and dual carriageways</p>	ME2
Secondary distributor	Classified road (B and C class) and unclassified urban bus route, carrying local traffic with frontage access and frequent junctions	<p>Rural areas (Zone E1/2^c) These roads link the larger villages to the strategic and main distributor network.</p> <p>Urban areas (Zone E3^c) These are residential or industrial inter-connecting roads with 50 km/h speed limits, random pedestrian movements and uncontrolled parking.</p>	<p>ME3a ME2</p>
Link road	Road linking between the main and secondary distribution network with frontage access and frequent junctions	<p>Rural areas (Zone E1/2^c) Roads link the smaller villages to the distributor network. They are of varying width and not always capable of carrying two-way traffic.</p> <p>Urban areas (Zone E3^c) Residential or industrial inter-connecting roads with 50 km/h speed limits, random pedestrian movements and uncontrolled parking.</p>	<p>ME5 ME4b or S2</p>
<p>NOTES:</p> <p>1. Public Works Department’s <i>Arahan Teknik (Jalan)</i> 8/86, Chapter 2, may be useful for the interpretation of road hierarchy in this table.</p>			

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2. See table 16.2 for conflict areas.
3. Traffic flow can vary significantly during the night, and use of different lighting levels at some periods may be considered. For this purpose, a detailed analysis of traffic flow is carried out, considering hourly flow through the night.
4. If the average daily traffic flow (ADT) is available the selection of lighting classes may be referred to the authorities concerned. It can be assumed that there is a reasonably consistent relationship between ADT and peak daily traffic, and that the lighting classes suggested are thus suitable for peak daily traffic flow.
5. Where lighting levels are reduced at certain periods, any lower levels selected can use the L values from appropriate lower ME classes, but retain U_0 and U_L values of the ME class selected for the peak period.

Free flow link roads connecting highways may be lit to the same standards as the main carriageway of the highways they are connecting. Highway slip roads may be lit to one class lower than the main carriageway. In the case where the main carriageway class is ME1, the slip road class is ME2. Slip road lighting may be extended to cover the full length of the slip to provide additional lighting at the conflict point.

^b In urban areas consideration may be given to the use of ME3a or ME3b in place of ME2, in view of the lower traffic speeds and shorter viewing distances.

^c Environmental zone, as given in the ILE publication *Guidance notes for reduction of light pollution*.

16.4.1 Conflict Areas

Conflict areas are areas where significant streams of motorized traffic intersect with each other or with other road users (pedestrian and cyclists) such as junctions, intersections, roundabouts and pedestrian crossings.

Table 16.2: Lighting Classes for Conflict Areas

Traffic route lighting class	Conflict area lighting class
ME1	CE0
ME2	CE1
ME3	CE2
ME4	CE3
ME5	CE4


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Table 16.3: Lighting Classes for Subsidiary Roads (Pedestrians and Cyclists)

Crime Rate	R _a Value	Lighting Class					
		Low Traffic Flow ^a		Normal Traffic Flow ^b		High Traffic Flow ^c	
		E1/E2 ^d	E3/E4 ^d	E1/E2 ^d	E3/E4 ^d	E1/E2 ^d	E3/E4 ^d
Low	R _a < 60	S5	S4	S4	S3	S3	S2
	R _a ≥ 60	S6	S5	S5	S4	S4	S3
Moderate	R _a < 60	S4	S3	S3	S2	-	S1
	R _a ≥ 60	S5	S4	S4	S3	-	S2
High	R _a < 60	S2	S2	S2	S1	-	S1
	R _a ≥ 60	S3	S3	S3	S2	-	S2
<p>NOTES:</p> <ol style="list-style-type: none"> Crime rates are relative to the local area, not national. Assistance can be obtained from the local crime prevention officer. The lighting levels shown in this table may be increased by one lighting class in the vicinity of traffic calming measures. <p>^a Low traffic flow refers to areas where the traffic usage is of a level equivalent to a residential road and solely associated with the adjacent properties.</p> <p>^b Normal traffic flow refers to areas where the traffic usage is of a level equivalent to a housing estate access road and can be associated with local amenities such as club shopping facilities, public houses, etc.</p> <p>^c High traffic flow refers to areas where the traffic usage is high and can be associated with local amenities such as clubs, shopping facilities, public houses, etc.</p> <p>^d Environmental zone, as given in the ILE publication <i>Guidance notes for reduction of light pollution</i></p>							


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Table 16.3: Lighting Classes for City and Town Centres

Type of Traffic	Lighting class			
	Normal traffic flow		High traffic flow	
	E3 ^a	E4 ^a	E3 ^a	E4 ^a
Pedestrian only	CE3	CE2	CE2	CE1
Mixed vehicle and pedestrian with separate pedestrian walkways	CE2	CE1	CE1	CE1
Mixed vehicle and pedestrian on some surface	CE2	CE1	CE1	CE1

^a Environmental zone, as given in the ILE publication *Guidance notes for reduction of light pollution*

Table 16.5: ME series of lighting classes

Class	Luminance of the road surface of the carriageway for the dry road surface condition			Disability glare	Lighting of surroundings
	L in cd/m ² [minimum maintained]	U ₀ [minimum]	U ₁ [minimum]	TI in % ^a [minimum]	SR ^{2b} [minimum]
ME1	2,0	0,4	0,7	10	0,5
ME2	1,5	0,4	0,7	10	0,5
ME3a	1,0	0,4	0,7	15	0,5
ME3b	1,0	0,4	0,6	15	0,5
ME3c	1,0	0,4	0,5	15	0,5
ME4a	0,75	0,4	0,6	15	0,5
ME4b	0,75	0,4	0,5	15	0,5
ME5	0,5	0,35	0,4	15	0,5
ME6	0,3	0,35	0,4	15	No requirement

^a An increase of 5 percentage points in TI can be permitted where low luminance light sources are used. (see note 1)

^b This criterion can be applied only where there are no traffic areas with their own requirements adjacent to the carriageway.


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Table 16.6: MEW Series of Lighting Classes

Class	Luminance of the road surface of the carriageway for the dry and wet road surface condition				Disability glare	Lighting of surroundings
	Dry condition		Wet			
	L in cd/m ² [minimum maintained]	U ₀ [minimum]	U _I ^a [minimum]	U ₁ [minimum]	TI in % ^b [minimum]	SR ^c [minimum]
MEW1	2,0	0,4	0,6	0,15	10	0,5
MEW2	1,5	0,4	0,6	0,15	10	0,5
MEW3	1,0	0,4	0,6	0,15	15	0,5
MEW4	0,75	0,4	no requirement	0,15	15	0,5
MEW5	0,5	0,35	no requirement	0,15	15	0,5
^a The application of this criterion is voluntary, but it can be applied on motorways						
^b An increase of 5 percentage points in TI can be permitted where low luminance light sources are used. (see note 1)						
^c This criterion can only be applied where there are no traffic areas with their own requirements adjacent to the carriageway						

NOTE 1 The threshold increment (TI) indicates that although road lighting improves visual conditions it also causes disability glare to a degree depending on the type of luminaries, lamps and geometric situation. Low-pressure sodium lamps and fluorescent tubes are normally considered to be low luminance lamps. For these lamps, and luminaries providing less or equivalent luminance, footnote a of table 16.5 and footnote b of table 16.6 permits higher value.

NOTE 2 Lighting confined to the carriageway is inadequate for revealing the immediate surrounds of the road and revealing road users at the kerb. The requirements for the surround ratio (SR) apply only where there are no traffic areas with their own requirements adjacent to the carriageway, including footways, cycleways or emergency lanes.

NOTE 3 In some countries, the road surface is damp or wet for a significant part of the hours of darkness. For a selected wet condition, an additional requirement to the overall uniformity (U₀) can be made to apply to avoid a serious downgrading of the performance for some of the damp periods. The relevant table in that case is Table 16.6


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Table 16.7: CE Series of Lighting Classes

Class	Horizontal illuminance	
	\bar{E} in lx [minimum]	U_o [minimum]
CE0	50	0,4
CE1	30	0,4
CE2	20	0,4
CE3	15	0,4
CE4	10	0,4
CE5	7,5	0,4


NOTE The CE classes are mainly intended for use when the conventions for road surface luminance calculations do not apply or are impracticable. This can occur when the viewing distances are less than 60 m and when several observer positions are relevant. The CE classes are simultaneously intended for other road users on the conflict are.

16.4.2 Aids to road lighting design

When designing road lighting installation three-aspects shall be considered namely lighting quality economic and energy efficiency.

The values of the photometric parameters determining the road lighting quality, as obtained with a particular installation depend on:

- the type of light source use
- the luminous intensity distribution of the luminaries used,
- the reflective properties of the particular road surfaces,
- the geometry and type of arrangement.

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16.5 JKR Standard Design

16.5.1 Type of Lamps

The two types of lamp used for road lighting are:

- i) High – pressure sodium vapour (SON)
- ii) Low - pressure sodium vapour (SOX)

The SON lamp is used because of its lumen efficiency, good colour rendering and longer life. The SOX lamp is normally used to denote junctions but not in some areas which are prone to fogs. SON lamps are used due to its good visibility in such situations.

The wattage of lamps used is:-

- i) SON – 250W or 400W
- ii) SOX – 90W or 135W

16.5.2 Type of Column

The type of column used is hot-dip galvanized steel/concrete/fiberglass reinforced of 10 metres or 12 metres height. They are normally of the planted type or flange mounted depending on site situation. The length of arm for the column shall depend on the road profile (median, number and width of lanes etc).

16.5.3 Service Door Cover


The service door cover shall be double slot hinged and the material shall be of composite fiberglass to prevent vandalism.

16.5.4 Concrete Footing

Concrete footing for flange mounted pole shall be designed according to soil type/condition and must be approved and endorsed by Civil and Structure Engineer.

16.5.5 Label

Labelling of the pole and feeder pillar shall be of reflective sticker. The label shall be referred to local maintenance authorities (JKR/PBT/State Government).

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16.5.6 Terminal Block

There are two types of terminal block commonly used in road lighting installation:

- i) Cut-Out Neutral Link
- ii) Modular Junction Box

For safety purposes modular junction box is preferable.

16.5.7 Type of Arrangement

- a) single sided
- b) opposite arrangement
- c) staggered
- d) central median
- e) a combination of (a) and (d)

For installation on bridges/elevated structures, location of cable shall be coordinated with Road Structural Designer.

16.5.8 Voltage Drop

The total voltage drop along one complete circuit for each phase shall not exceed 20 V from the supply meter to the last pole.


16.5.9 Type Of Cable

PVC/SWA/PVC underground cable for road lighting shall be either 2-core or 4-core and maximum of 25 mm².

16.5.10 Ducting For Underground Cables

All underground cables crossing the roads shall be laid in 100/150mm diameter GI pipe class C/reinforced fiber composite duct/uPVC pipe class D (encased in concrete). All underground cables at road shoulders, paved shoulders, bridges and elevated structures shall use GI pipe class B. For underground cables installed within the New Jersey Barrier (NJB), HDPE double wall corrugated pipe shall be used if necessary.

For road crossing where open cut is not allowed to lay the pipe (normally existing or newly upgraded road) horizontal direct drilling (HDD) or pipe jacking (GI pipe) shall be taken into consideration.

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16.5.11 Supply Feeder-Pillar


The supply for the road lighting lanterns is normally taken from a feeder-pillar which can either be of a single-phase or a 3-phase system.

16.5.12 Road Safety Audit, RSA

During planning stage, RSA preliminary report should be referred to for any specific requirement of road lighting and traffic light system that needs to be incorporated in the electrical design. A set of detail electrical design drawing is to be forwarded to RSA for their comments. There are 5 stages of RSA:

- Stage 1: Feasibility & Planning Stage
- Stage 2: Preliminary (Draft) Design Stage
- Stage 3: Detailed Design Stage
- Stage 4: During Construction and Pre-Opening Stage of A New Project
- Stage 5: Audit of an Existing Road

For typical luminaire positions please refer to Annex K of MS825: Part 1: 2006 (Refer Attachment A)

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REFERENCES

Standards publications:

- [1] MS825: Part 1: 2006, '*Lighting of Roads and Public Amenity Areas*'
- [2] RD/CEN/TR/13201-1:2004, '*Road Lighting Part 1: Selection of Lighting Classes*'
- [3] BS EN 13201-2:2003, '*Road Lighting Part 2: Performance Requirement*'
- [4] BS EN 13201-3:2003, '*Road Lighting Part 3: Calculation of Performance*'

Other publications:

- [1] JABATAN KERJA RAYA MALAYSIA, *Guidelines for the Safety Audit of Roads and Road Projects in Malaysia*
- [2] JABATAN KERJA RAYA MALAYSIA, *Arahan Teknik Jalan 8/86 A guide on geometric design of roads*

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ATTACHMENT A
MS 825: Part 1: 2006

Annex K
(Informative)

Luminaire and column positions for typical single level junctions and roundabouts using 10 m or 12 m columns

K1. T-junctions

K1.1. T-junctions on straight roads

Typical luminaire positions for T-junctions are shown in Figure K1. Four luminaries are directly associated with the junction.

- Luminaire A reveals the end of the minor road to traffic approaching along it and pedestrians crossing its mouth.
- Luminaire B reveals both the junction with the minor road to traffic in the major road (approaching from the right in Figure K1) and a vehicle waiting in the mouth of the minor road.
- Luminaire C reveals turning movements to traffic in the major road (approaching from the left in Figure K1).
- Luminaire D reveals the traffic conditions in the mouth of the minor road to traffic entering from the major road.

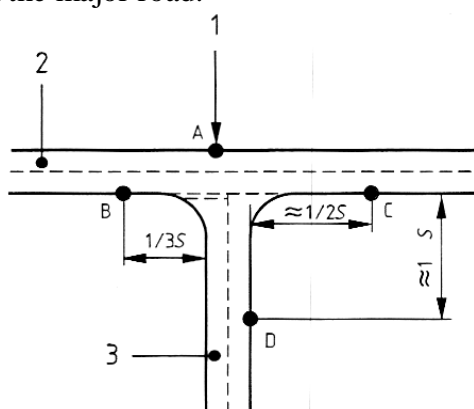



Figure K1. T-junctions on straight roads

Key

- Luminaire positions
- Major road
- Minor road

NOTE. The design spacing S relates to the major road

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K2. T-junctions on bends

The design solution for a T-junction with a curved major road can differ from that for junctions illustrated in Figure K1. Typical luminaire positions for a T-junction on a bend are shown in Figure K2.

a) T-junction with minor road on inside of bend

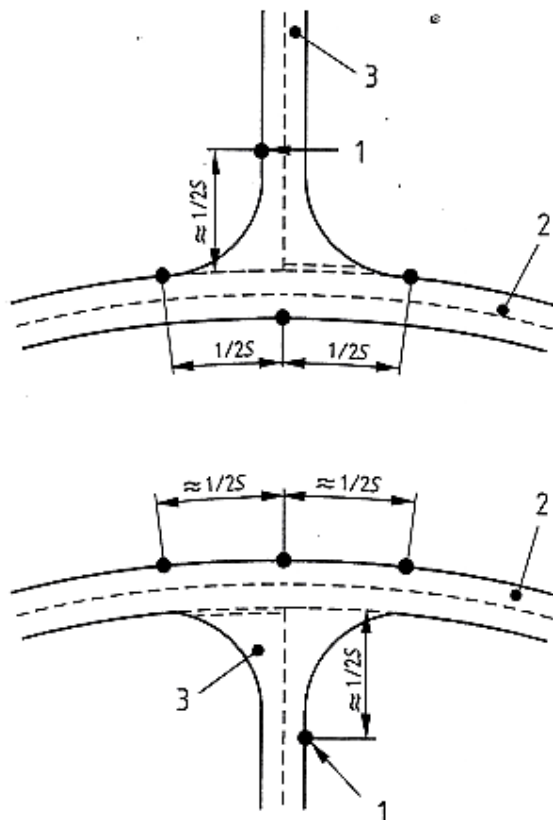



Figure K2. T-junctions on bends

Key:

- 1) Luminaire positions
- 2) Major road
- 3) Minor road

NOTE. The design spacing S relates to the major road

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K3. Staggered junctions

Two T-junctions (X) and (Y) on opposite sides of the main road, as shown in Figure K3, may be considered independently in the first instance as separate conflict area. If they are closer together, and considered as one area, compromise positions may be chosen for luminaries A or B.

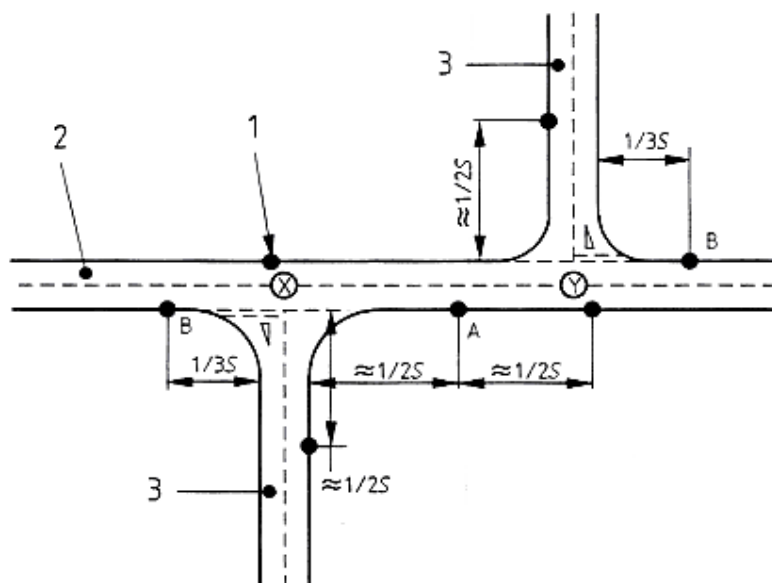



Figure K3. Staggered junctions

Key:

- 1) Luminaire positions
- 2) Major road
- 3) Minor road

NOTE. The design spacing S relates to the major road

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K4. Crossroads

Typical luminaire positions for a crossroads are shown in Figure K4. Luminaries A serve to reveal crossing and turning traffic.

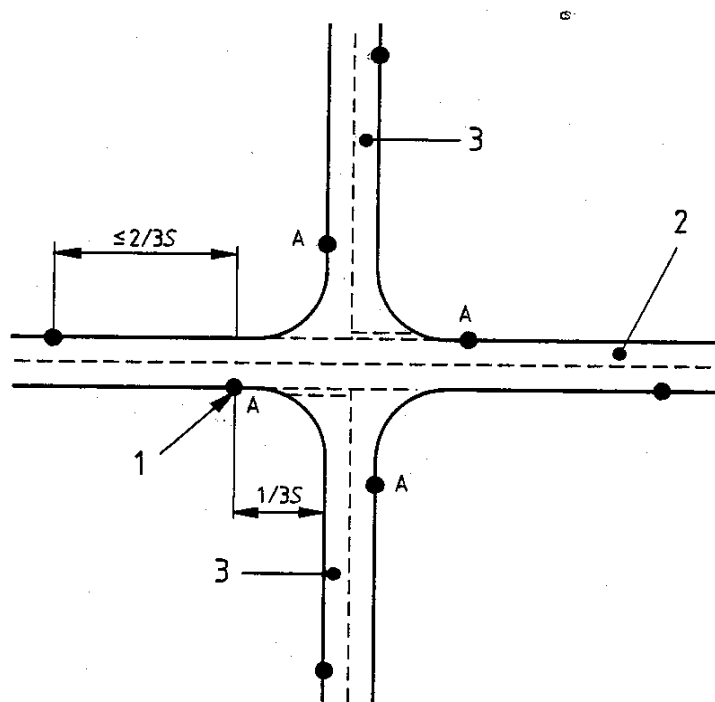



Figure K4. Crossroads

Key:

- 1) Luminaire positions
- 2) Major road
- 3) Minor road

NOTE. The design spacing S relates to the major road

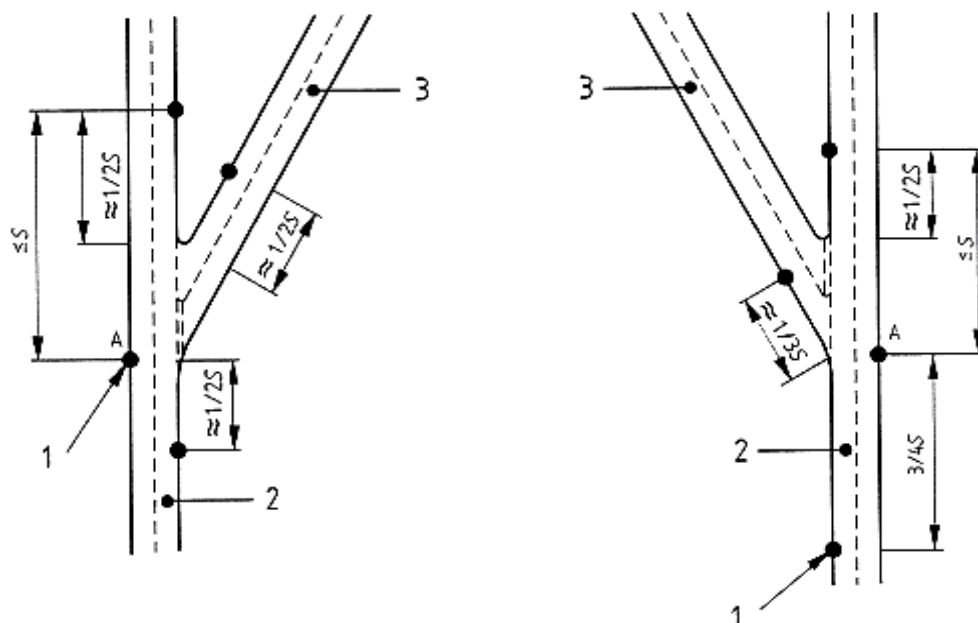
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K5. Y-junctions and fork-junctions

K5.1 Y-junctions

Typical luminaire positions for a staggered arrangement at Y-junctions are shown in Figure K5. These luminaries serve to reveal the junction in much the same way as for T-junctions. Luminaire A reveals road layout and traffic movement along the minor road.

NOTE. At a Y-junction on a wide road a lighting column on a refuge or traffic island in the mouth of a wide entry road might be necessary in order to avoid excessive luminaries spacing.




a) Y-junction with minor road on the right b) Y-junction with minor road on the left

Figure K5. Y -junctions

Key:

- 1) Luminaire positions
- 2) Major road
- 3) Minor road

NOTE. The design spacing S relates to the major road

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K5.2 Fork-junctions

A fork -junction may be lit as a bend with luminaries in the major road along the outer kerb and at appropriately reduced major road design spacing. Typical luminaire positions for a staggered arrangement are shown in Figure K6.

NOTE. In order to span the minor road without exceeding this design spacing, there might be situations where one luminaire has to be mounted on a longer bracket arm or on a lighting column situated on a refuge or traffic island in the mouth of the minor road.

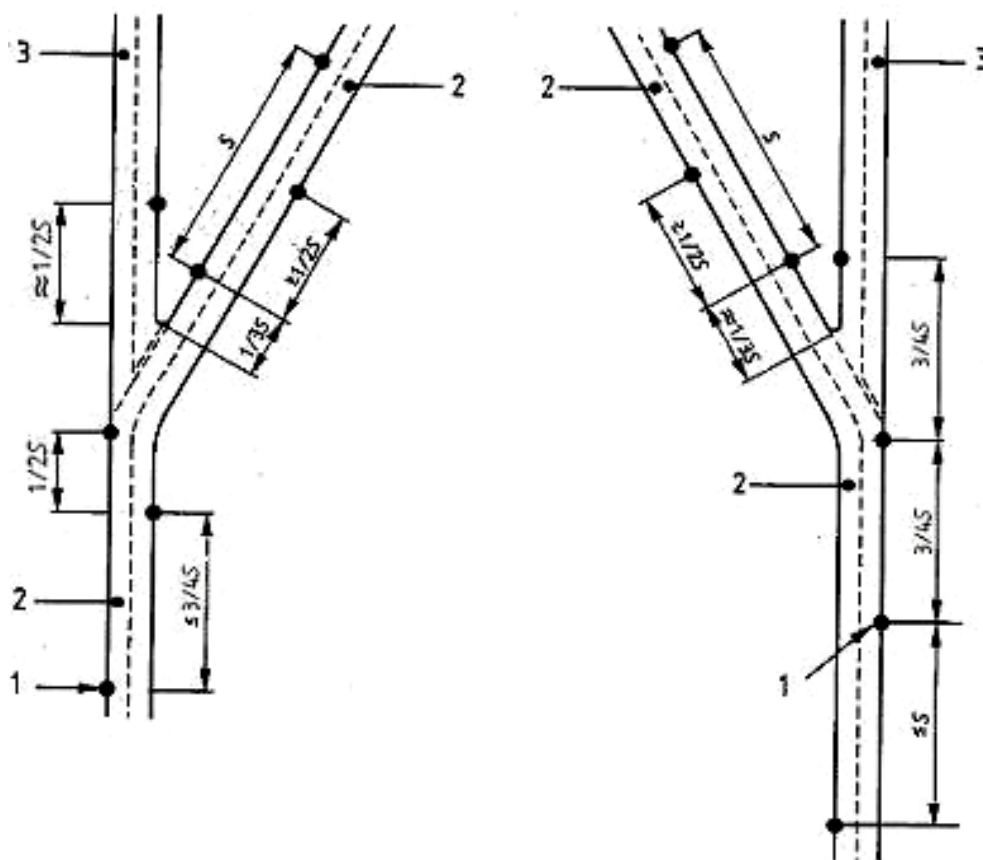



Figure K6. Fork -junctions

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K6. Junctions with triangular islands

In some junctions, traffic from the minor road might be separated from that on the major road by a triangular island. Figure K7 indicates the possible arrangements of luminaires where the minor road approaches the major road at an obtuse angle of 135° , and Figure K8 where the minor road joins the major road at an acute angle of 45° .

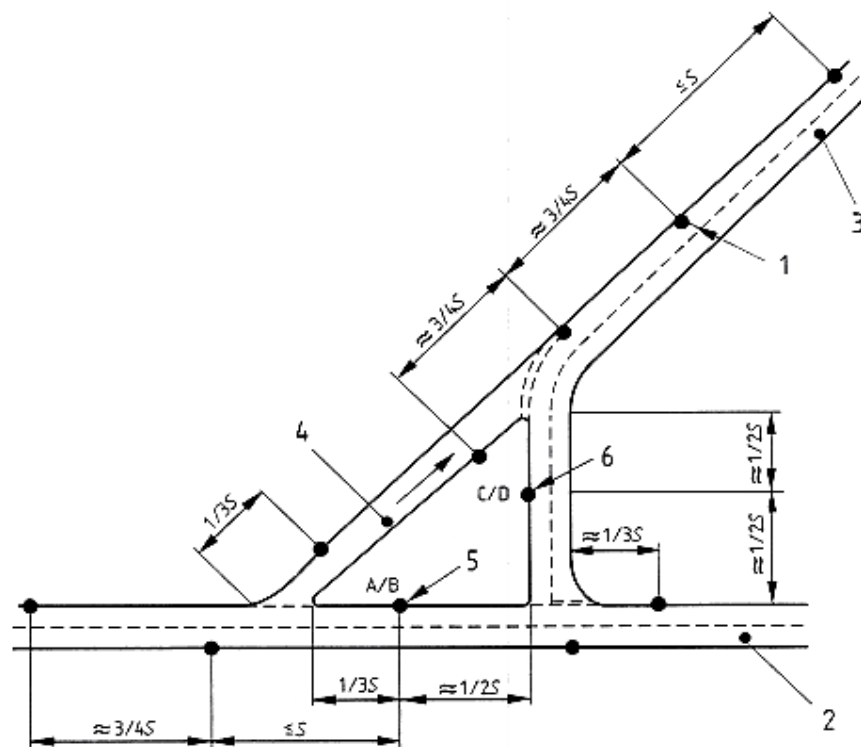



Figure K7. Junctions with triangular island (minor road at obtuse angle)

Key:

- 1) Luminaire positions
- 2) Major road
- 3) Minor road

NOTE. The design spacing S relates to the major road

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K7. Junctions with ghost or traffic islands

Typical luminaire positions for a junction with ghost or traffic islands and right-turn lanes are shown in Figure K9.

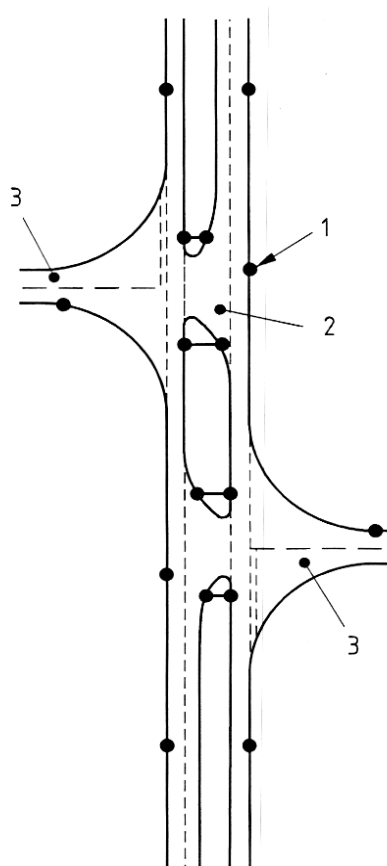



Figure K9. Junctions with ghost or traffic islands and right -turn lanes on the major road

Key

- 1) Luminaire positions
- 2) Major road
- 3) Minor road

NOTE. The design spacing S relates to the major road.

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K8. Roundabouts

K8.1 Central traffic island roundabouts

Figure K10 and Figure K11 give examples of typical luminaire positions for central traffic island roundabouts with different numbers of access roads.

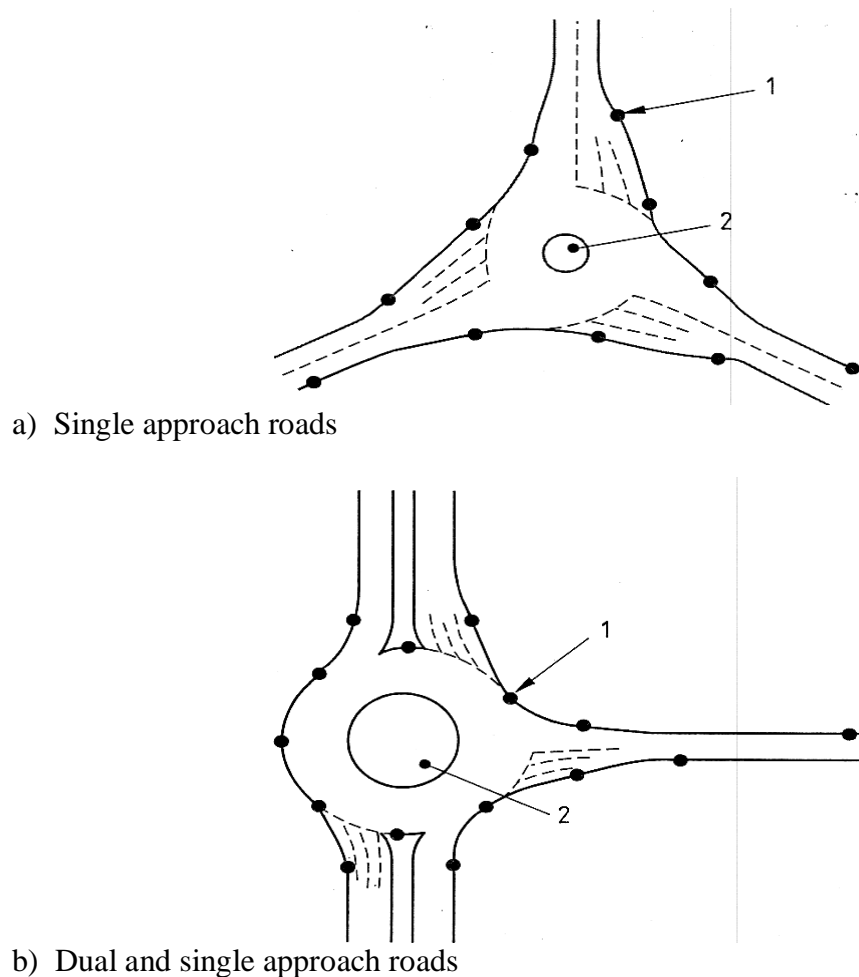



Figure K10. Roundabouts at three -way junctions

Key

- 1) Luminaire positions
- 2) Central island

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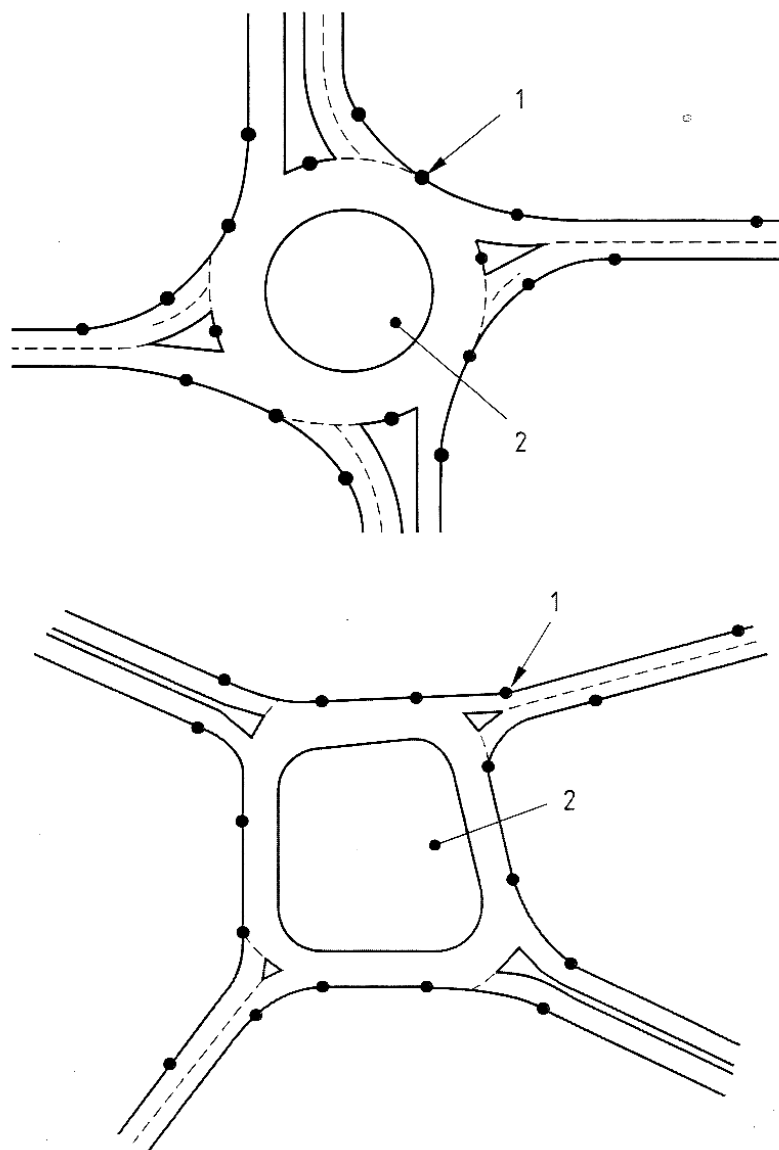



Figure K11. Roundabouts at four -way junctions

Key

- 1) Luminaire positions
- 2) Central island

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K8.2 Mini-roundabouts

Figure K12 and Figure K13 give examples of typical luminaire position for mini-roundabouts of different configurations.

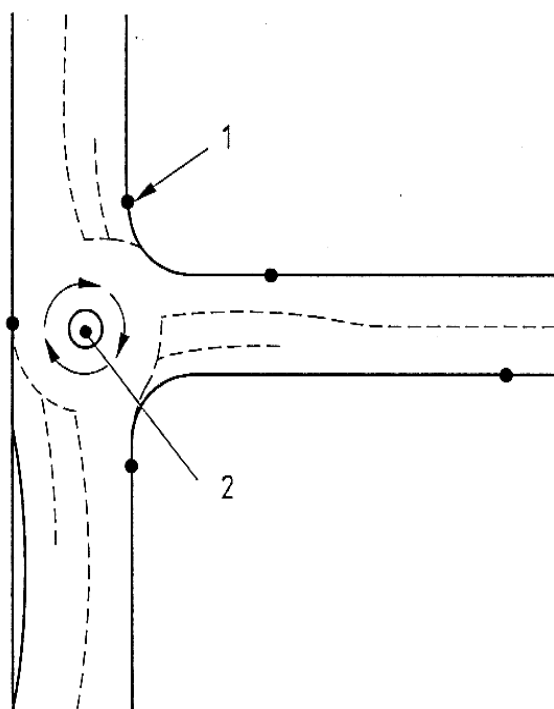



Figure K12. Mini -roundabouts at T -junctions

Key

- 1) Luminaire positions
- 2) Central island

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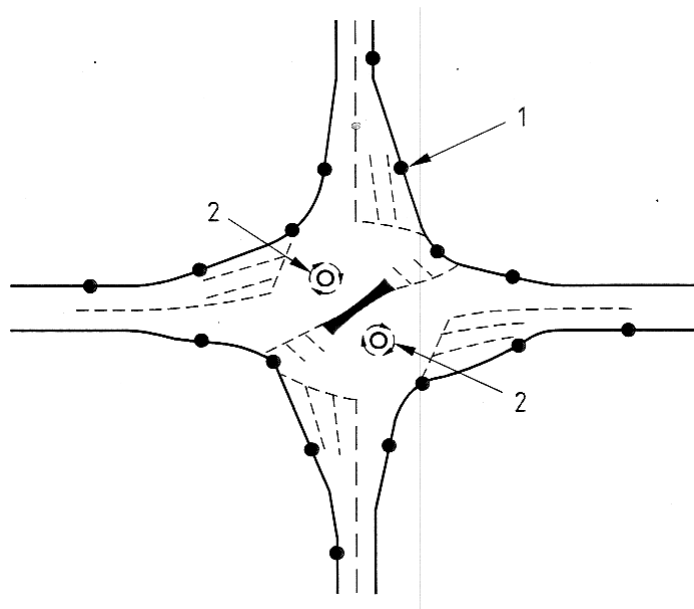



Figure K13. Double mini -roundabouts (with large right -turning flows)

Key

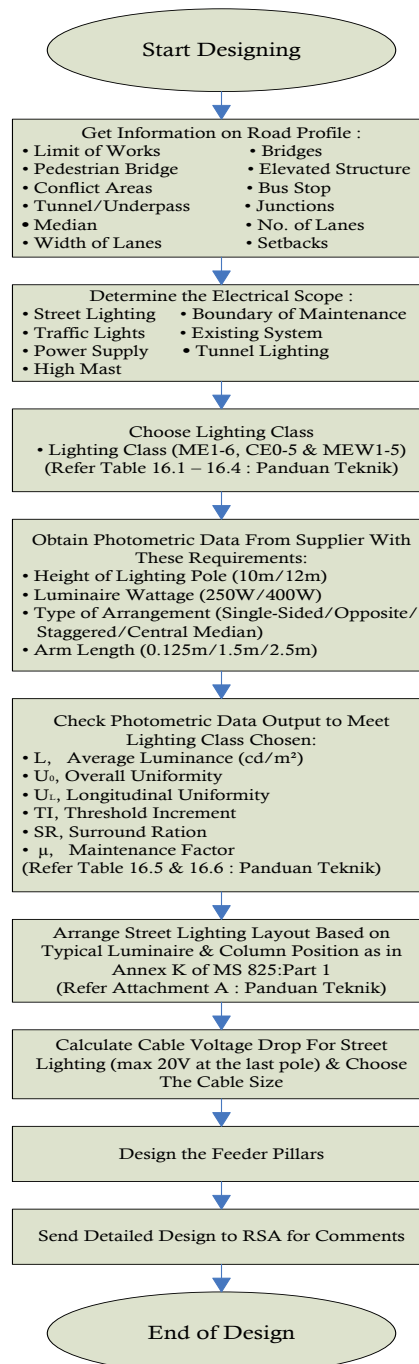
- 1) Luminaire positions
- 2) Central island


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ATTACHMENT B

ATTACHMENT B

FLOWCHART OF JKR DESIGN PROCESS



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17.1 Introduction

Lightning is one of nature's most powerful and destructive phenomena. Lightning discharges contain awesome amounts of electrical energy and have been measured from several thousand amps to over 200,000 amps. Even though a lightning discharge is of a very short duration, typically 200 microseconds, it is a very real cause of damage and destruction.


The effects of a direct strike are obvious and immediately apparent such as buildings damaged, trees blown apart, personal injuries and even death. However, the secondary effects of lightning can caused overall performance of electronic systems severely affected by lightning induced transients and switching actions, which give rise to transient over voltages or surges.

A reliable lightning protection scheme must encompass both structural lightning protection and transient over voltage (electronic systems) protection.

17.2 Lightning Statistic

The major role of lightning protection is to secure a structure from lightning damage by intercepting flashes and guiding their currents to the ground. Since lightning tends to strike at the highest object in the vicinity, rods are typically placed at the apex of a structure and along its ridges; low-impedance copper conductor connects them to the ground.

The isoceraunic map (lightning threats map) shown in Figure 17.1 below will depict the number of lightning days per year where Malaysia stands as the world's number 2 lightning hotspot and with an average of 240 lightning days per annum which is about 40 strikes per square kilometre per year.

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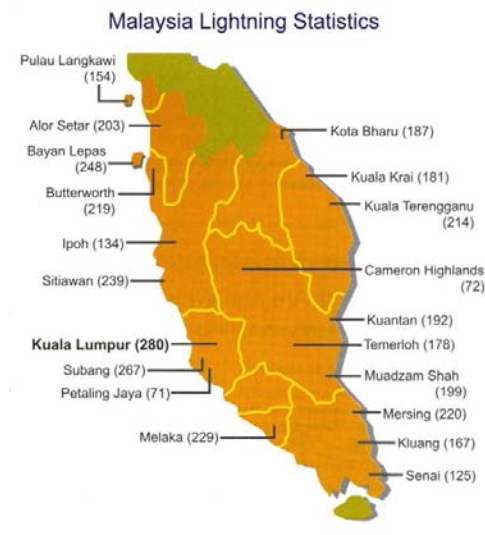


Figure 17.1: Malaysia Lightning Statistics

***Source: Meteorological Department, Malaysia**

**** () denotes the number of lightning days per year**


17.3 Effects of Lightning Strike

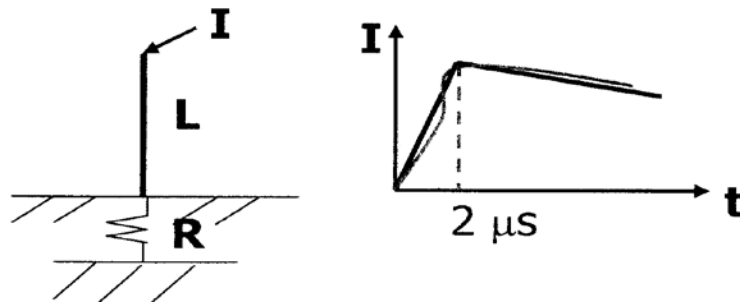
17.3.1 Electrical Effects

Main cause of lightning damage is **HIGH CURRENT** which in turn causes **HIGH VOLTAGES** to arise on stricken or affected objects.

As the current is discharged through the resistance of the earth electrode of the lightning protection system, it produces a resistive voltage drop which may momentarily raise the potential of the protection system to a high value relative to true earth. It may also produce around the earth electrode a high potential gradient dangerous to people and animals.

The resulting voltage drop in the protection system is therefore the arithmetic sum of the resistive and inductive voltage components. It can be derived by referring to a simplified example as shown below:

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Where the values given are:

$I = 20\text{kA}$ (over 75% of lightning strokes have currents greater than this)

$R = 10\text{ ohms}$, resistance of earth connection

$L = 20\text{mH}$, inductance of tower

$$\text{Tower top: Voltage } V_{tt} = IR + L \frac{dI}{dt} = 20 \times 10 + 20 \times 10^{-6} \frac{20}{2 \times 10^{-6}}$$

$$= 200 \text{ kV} + 200 \text{ kV} = 400 \text{ kV}$$

$$\text{Tower footing: Voltage } V_f = IR = 20 \times 10 = 200 \text{ kV} \quad !!!$$

ie. VERY HIGH VOLTAGES ARE CAUSED


17.3.2 Side-flashing

When a lightning protection system is struck, its electrical potential with respect to earth is raised and, unless suitable precautions are taken, the discharge may seek alternative paths to earth by side-flashing to other metal in the structure. There is therefore a risk of flashover from the protection system to any other metal on or in the structure. If such flashover occurs, part of the lightning current is discharged through internal installations, such as pipes and wiring, and therefore constitutes a risk to the occupants and the fabric of the structure.

There are two ways of preventing side-flashing namely:

- Isolation
- Bonding

Isolation requires large clearances between the lightning protection system and other metal in the structure. The main drawbacks to isolation lie in the difficulty in obtaining

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and maintaining the necessary safe clearances and in ensuring that isolated metal has no connection with the ground. In general, bonding is the more commonly used method.

17.3.3 Thermal effects

For the purposes of lightning protection, the thermal effect of a lightning discharge is confined to the temperature rise of the conductor through which the current passes. Although the current is high, its duration is short and the thermal effect on the protection system is usually negligible.

In general, the cross-sectional area of a lightning conductor is chosen primarily to satisfy the requirement for mechanical strength, which means that it is large enough to keep the rise in temperature.

17.3.4 Mechanical effects

Where a high current is discharged along parallel conductors in close proximity of along a single conductor with sharp bends, considerable mechanical forces are produced. Secure mechanical fittings are therefore essential.

17.4 Component Parts


The principal components of lightning protection systems are as follows:

17.4.1 Air terminations

The primary function of air termination is to capture the lightning strike to a preferred point, so that the discharge current can be safely directed via the down conductor(s) to the grounding system.

The minimum dimension of lightning conductor to form the air termination is 20 x 2.5 mm (50 mm²). Copper and aluminium are the recommended materials for installations required to have a long life. If there is any difficulty in the use of copper or aluminium, galvanized steel strip of the same cross-section as that recommended for copper may be used.

On a reinforced concrete structure, the air termination should be connected to the reinforcing bars in the number of positions needed for down conductors.

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For buildings where the roof forms part of the air termination network, the minimum thickness of metal used for roofing not less than those given in Table 17.1 below.

Table 17.1: Minimum Thickness of Sheet Metal Used For Roofing and Forming Part of The Air Termination Network.

Material	Minimum thickness, mm
Galvanized steel	0.5
Stainless steel	0.4
Copper	0.3
Aluminium and zinc	0.7
Lead	2.0
NOTE The figures in this table are based on contemporary building practice and will be satisfactory where the roof forms part of lightning protection system. However, damage by way of puncturing may occur with a direct arc-connected strike.	


17.4.2 Down conductors

The function of the down conductor is to provide a low impedance path from the air termination to the ground system so that the lightning current can be safely conducted to earth, without the development of excessively large voltages. In order to reduce the possibility of dangerous sparking (side-flashing), the down conductor route(s) should be as direct as possible with no sharp bends or stress points where the inductance, and hence impedance, is increased under impulse conditions.

The position and spacing of down conductors on large structures is often governed by architectural convenience. However, there should be one down conductor for each 20m or part thereof of the perimeter at roof level or ground level, whichever is the greater. Structures over 20m high should have one per 10m or part thereof.

17.4.3 Joints and Bonds

Any joint other than one of welded type represents a discontinuity in the current conducting system and is susceptible to variation and failure. Accordingly, the lightning protection system should have as few joints as possible. Therefore, joints should be mechanically and electrically effective, e.g. clamped, screwed, and bolted, riveted or welded. With overlapping joints, the overlap should be not less than 20mm for all types of conductors.

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Bonds are used to join a variety of metallic parts of different shapes and compositions and cannot therefore be of standard form. Because of their varied use and the risk of corrosion, careful attention needs to be given to the metals involved, i.e. that of the bond and of the items being bonded.

17.4.4 Test joints.

Each down conductor should be provided with a test joint in such a position that, whilst not inviting unauthorized interference, it is convenient for tests. Plates indicating the position, number and type of earth electrodes should be fitted above each test point.

17.4.5 Earth termination


When dealing with the dispersion of the lightning current (high frequency behaviour) into the ground, whilst minimizing any potentially dangerous over voltages, the shape and dimensions of the earth-termination system are the important criteria. In general, a low earthing resistance (if possible lower than 10 ohm when measured at low frequency) is recommended.

Based on British Standard BS 6651:1999, the whole of the earth termination network should have a combined resistance to earth not exceeding 10ohms without taking account of any bonding to other services. If the value obtained for the whole of the lightning protection system exceeds 10 ohms, a reduction can be achieved by extending or adding to the electrodes or by interconnecting the individual earth electrodes of the down conductors by a conductor installed at least 0.6m below the ground, sometimes referred to as a ring earth electrode.

From the viewpoint of lightning protection, a single integrated structure earth-termination system is preferable and is suitable for all purposes (i.e. lightning protection, power systems and telecommunication systems).

17.4.6 Earth electrodes

Earth electrodes should consist of metal rods, tubes or strips or a combination of these. Interconnected reinforcing steel in concrete foundations or other suitable underground metal structures should preferably be used as an earth electrode. When metallic reinforcement in concrete is used as an earth electrode, special care shall be exercised at the interconnections to prevent mechanical splitting of the concrete.

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17.5 Management Of The Lightning Protection System

A good engineering practice in any system to be selected has to carefully include the Risk Assessment analysis based on lightning localized parameter, level of protection required, type of structures to be protected, area of coverage, bonding selection to the other system, organized supervision during installation, monitoring for system performance and maintenance aspect of the system during the operation.

17.5.1 Direct Strike Protection System


‘Zone of protection’ is the volume within which a lightning conductor gives protection against a direct lightning strike by directing the strike to it. For the design of the air-termination system, the following methods should be used, independently or in any combination, providing that the zones of protection afforded by different parts of the air-termination overlap and ensure that structure is entirely protected.

- i) protective angle method;
- ii) rolling sphere method;
- iii) Mesh method.

i) Protective angle method

Air termination conductors, rods, masts and wires should be positioned so that all parts of the structure to be protected are inside the envelope surface generated by projecting points on the air-termination conductors to the reference plane, at a protective angle to the vertical in all directions.

Figure 17.2 below shows the volume protected by a vertical rod is assumed to have the shape of a right circular cone with the vertex placed on the air-termination axis.

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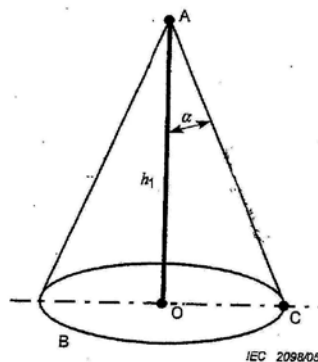


Figure 17.2: Volume Protected by a Vertical Rod

Key

- A tip of an air-termination rod
- B reference plane
- OC radius of protected area
- h_1 height of an air-termination rod above the reference plane of the area to be protected.
- α protective angle

For structures not exceeding 20 m in height, the angle between the side of the cone and the vertical at the apex of the cone is known as the protective angle. For the practical purpose of providing an acceptable degree of protection for an ordinary structure up to 20 m high and up to a height of 20 m for a higher structure, the protective angle of any single component part of an air termination network, namely either one vertical or one horizontal conductor, is considered to be 45°. Between two or more vertical conductors, spaced at a distance not exceeding twice their height, the equivalent protective angle may, as an exception, be taken as 60° to the vertical.

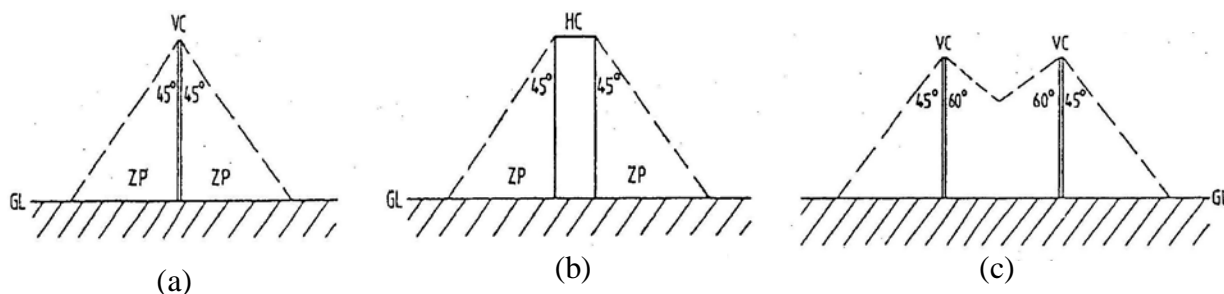



Figure 17.3: Protective Angles and Zone of Protection for Various Forms of Air Termination

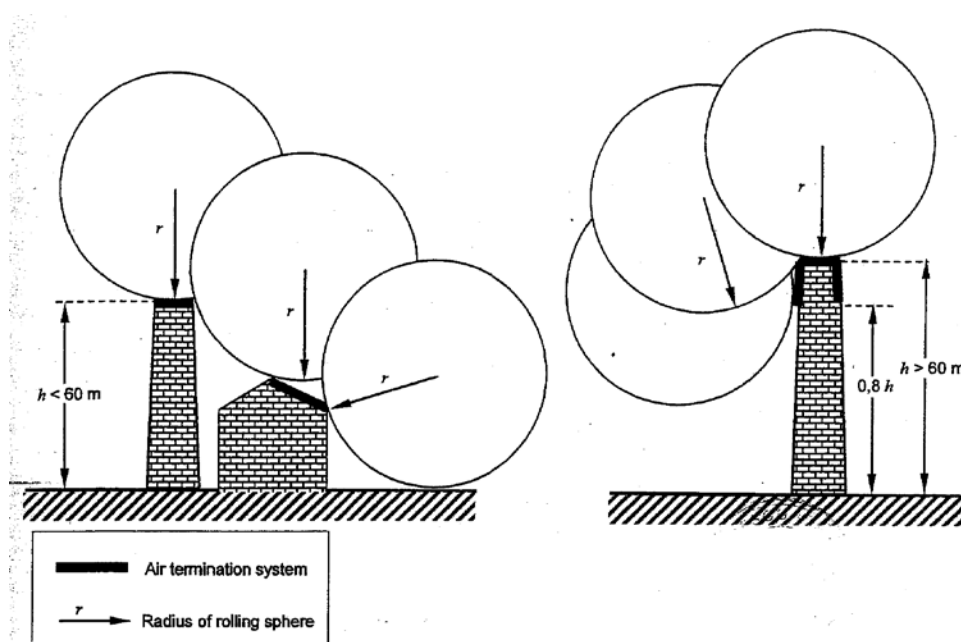
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ii) Rolling Sphere method

Rolling sphere method may be used to identify non-protected parts of tall, complex structures. For structures exceeding 20 m in height, the protective angle of any conductors up to the height of 20 m would be similar to that for lower structures. However, if there is a possibility of such buildings being struck on the side, it is recommended that the protected volume is determined using rolling sphere method.

On all structures higher than the rolling sphere radius r , flashes to the side of structure may occur. Each lateral point of the structure touched by the rolling sphere is a possible point of strike. However, the probability for flashes to the sides is generally negligible for structures lower than 60 m.

In general, the smaller the size of the sphere, the greater the protection but the more costly the installation. Sizes from 20 m to 60 m have been recommended but BS 6651 recommended that calculations should normally be based on a sphere of radius 60 m. However, a sphere of radius 20 m should be used for buildings with explosive or highly flammable contents or which contain sensitive electronic equipment.



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iii) Mesh method

Method used for protecting large area of flat roof whereby the network of the air-termination is recommended to be in the form of a grid to reduce the effect of flashover caused by large induction loops.

Air termination networks may consist of vertical or horizontal conductors or combination of both. No part of the roof should be more than 5m from the nearest horizontal conductor except an additional 1 m may be allowed for each metre by which the part to be protected is below the nearest conductor. For large flat roofs, this is achieved typically by use of an air termination network mesh of approximately 10m x 20m. Various forms of air termination are given in Figure 17.4 and 17.5.

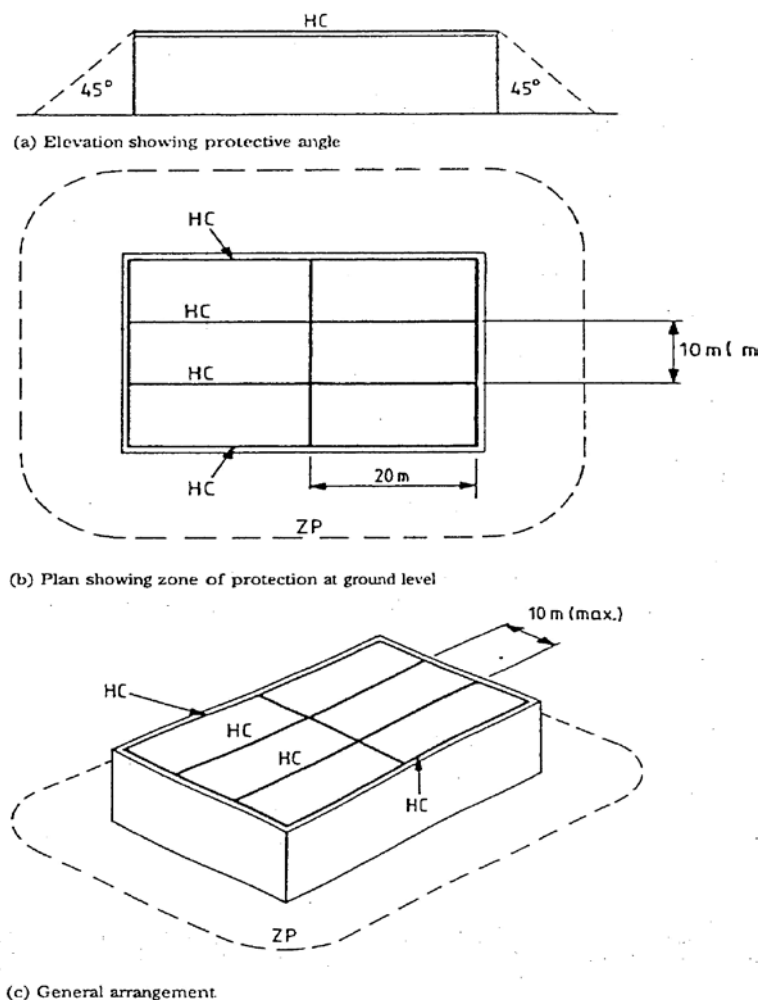



Figure 17.4: Air Termination for A Flat Roof

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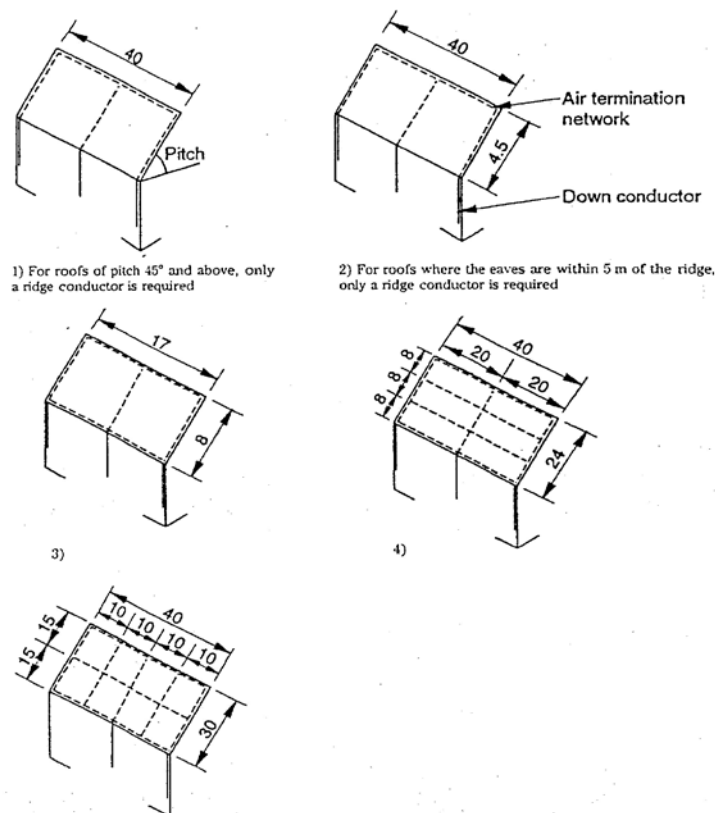


Figure 17.5: Air Terminations and Concealed Conductors for Buildings Less Than 20m High With High Sloping Roofs


These are examples of air terminations for various sizes of roof, but the criteria to be met when designing the roof network are:

- no part of the roof should be greater than 5 m from the nearest conductor.
- a 20 m x 10 m mesh should be maintained.

17.5.2 Transient Over voltage (Electronic Systems) Protection

When lightning strikes a building, transients are generated on adjacent power, data, telephone and/or RF lines. As these transients pass through electronic equipment on their way to earth, they can cause both immediate damage or longer term component degradation.


Today our electronic systems are intrinsically connected to the outside world; not only by mains power cables, but also through data and telephone lines, RF feeders, etc.

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Transient over voltages from lightning activity up to 1 km away can destroy electronic equipment inside a building, even when the building itself has not been struck.

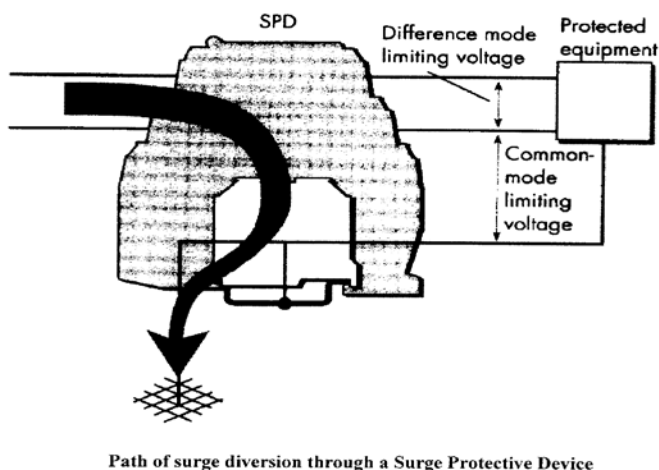
Transient over voltages are large, very brief and potentially destructive increases in voltage. It can be caused by:

- i) Resistive coupling: the most common cause of transient over voltages and it will affect both underground and overhead lines. Resistively coupled transients occur when a lightning strike raises the electrical potential of one or more of a group of electrically interconnected buildings (or structures). Common examples of electrical interconnections are :
 - power feeds from substation to building or building to building.
 - power supplies from the building to external lighting, CCTV or security equipment.
 - telephone lines from the exchange to the building or between building telephone lines.
 - between building LANs or data communication lines.
 - Signal or power lines from a building to external or field based sensors.
- ii) Inductive coupling: is a magnetic field transformer effect between lightning and cables. A lightning discharge is an enormous current flow and whenever a current flows, an electromagnetic field is created around it. If power or data cabling passes through this magnetic field, then a voltage will be picked-up by, or induced onto it.
- iii) Current injection from a direct strike: direct lightning strikes to installation wiring or exposed electrical systems such as sensor heads or aerials may inject sufficient current into the wires to cause explosive vaporization. This can cause considerable physical damage to the installation wiring over a considerable length.
- iv) Owing to the very high voltages associated with direct injection, damage to other circuits is possible as a result of high voltage breakdown and flashover on the terminal blocks, plugs and sockets, etc. so injecting large currents or voltages into the other circuits and causing multiple failures in them.

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17.6 Surge Protection Devices (SPD) and Location Categories

Surge Protection Devices limit the transient voltage to a level which is safe for the equipment they protect by conducting the large surge current safely to ground through the earth conductor system. Current flows past, rather than through, the protected equipment and the SPD thereby diverts the surge.




The SPD limits both common and difference mode voltages to the equipment. The voltage which the equipment receives during a surge is called the 'limiting' or 'let-through' voltage.

17.6.1 Let-Through Voltage

The larger the transient voltage reaching the electronic equipment, the greater the risk of interference, physical damage hence system downtime. Therefore, the transient over voltage let through the protector should be as low as possible as and certainly lower than the level at which interference or component degradation may occur.

Thus, a good surge protection device must have a low let-through voltage between every pair of conductors. More importantly, since lightning is a multiple event, the surge protection device must be able to withstand repeated transient over voltages.

Let-through voltage should be quoted for a relevant standard test.

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17.6.2 Mode of Protection

A transient over voltages can exist between any pair of conductors:

- Phase to neutral, phase to earth and neutral to earth on mains power supplies.
- Line to line and line(s) to earth on data communication, signal and telephone lines.

Thus, the transient over voltage protection devices should have a low let-through voltage for all combinations of conductors as shown in Figure below.

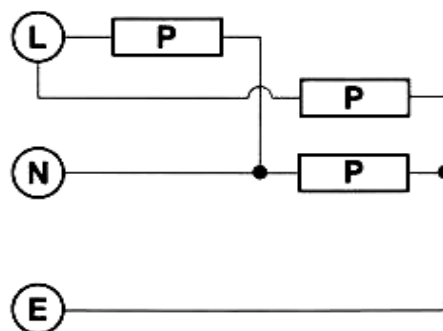


FIGURE 1 - Modes of protection (P)
for single phase mains power supply

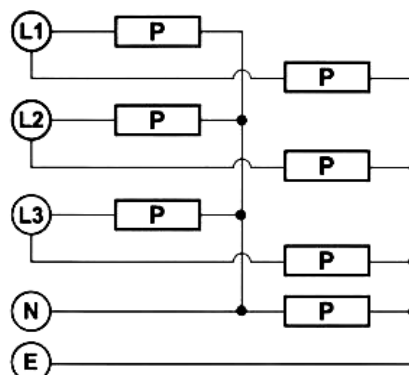



FIGURE 2 - Modes of protection (P)
for three phase mains power supply

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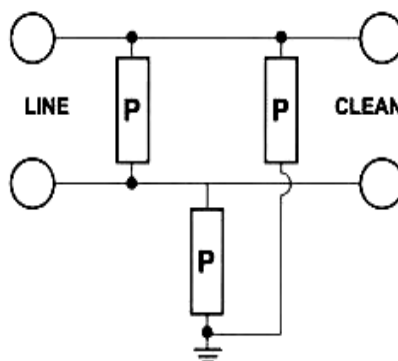


FIGURE 3 - Modes of protection (P) for data communication, signal or telephone lines.
Note: Data line protectors usually include some line impedance, which is omitted from the above for clarity.

Three categories of protection are addressed in mains power, and their locations are as follows:

- Location Category C


Surge protection devices installed in the following locations fall into category C.

- i) on the supply side of incoming power distribution boards/switchgear (i.e. boards that bring power into a building, from the supply authority, HV/LV transformer or another building)
- ii) on the load side of outgoing power distribution boards/switchgear (i.e. boards that take power to other buildings, external lights, pumps etc.);
- iii) on the outside of a building.

- Location Category B

Protection devices installed in the following locations fall into category B:

- i) on a power distribution system, between the load side of the incoming mains power distribution board/switchgear and supply side of a socket outlet/fused connection unit;
- ii) within apparatus that is not fed via a socket outlet/fused connection unit;
- iii) load side of socket outlets/fused connection units located less than a 20m cable run from category C.

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▪ Location Category A

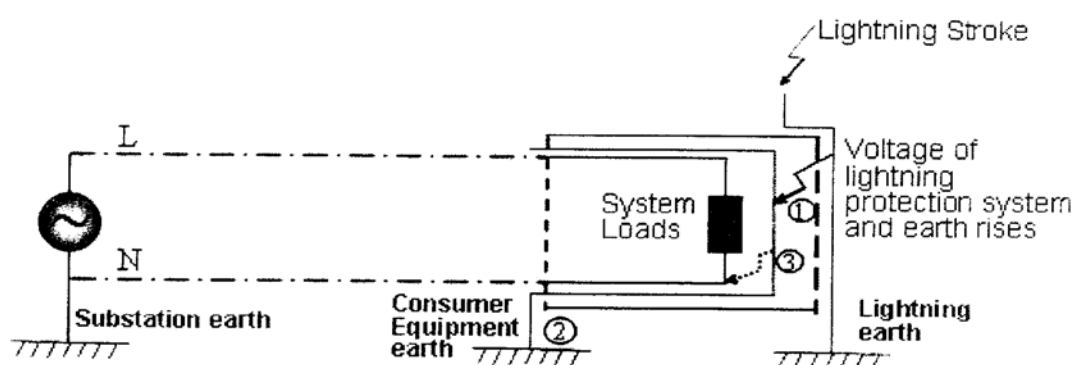
Protection devices installed on the load side of socket outlets/fused connection units and more than a 20m cable run from category C, fall into category A. Category A does not appear in small buildings where socket outlets are all less than 20m from category C.

Within a given location category, the severity levels of the transients encountered will increase as risk of transients occurring increases. This can be represented by the system exposure level, which in turn can be derived from the Risk Assessment.


17.7 Earthing System

17.7.1 Connection of Lightning & Earthing System

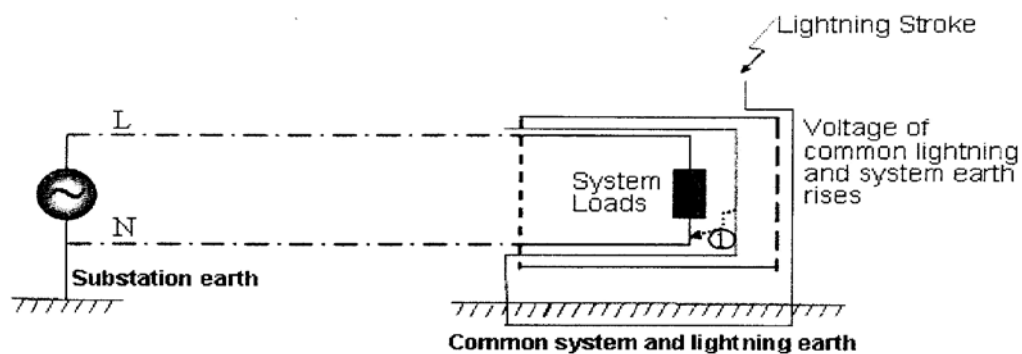
A. Separate Lightning & System Earths



- ① Strong likelihood of flashover to unbounded equipment connected to system earth as there exists potential differences.
- ② Voltage at system earth will still rise, due to close proximity of lightning and system earth, but perhaps to a smaller value as compared to case when the earths are common.
- ③ Therefore, the probability of flashover to line and neutral 3 of power supply line is not eliminated.

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B. Common Lightning & System Earths



- 1 Likelihood of flashover to line and neutral of power supply line when voltage on earth system (i.e. lightning protection & system earth) rises – as the neutral is remotely earthed at the Utility substation.

Advantages:

- Little likelihood of side flashes to earthed objects/appliances in the premises.
- A much lower overall earthing resistance.


17.7.2 Coordination of Earthing Systems

It is **POTENTIAL DIFFERENCES** set up between and in systems which cause propagation of surge voltages.

- Direct lightning strikes to structures housing equipment systems will cause potential rises and hence potential differences.
- Entry of lightning currents into the earth will cause Ground Potential Rises (GPR) and hence Ground Potential Differences (GPD).

To reduce/eliminate GPD, we implement **POTENTIAL EQUALIZATION**. This can be achieved by:

- A closed metal box or Faraday cage
- A zero Potential reference grid (ZPRG)
- Bonding between various earth systems.

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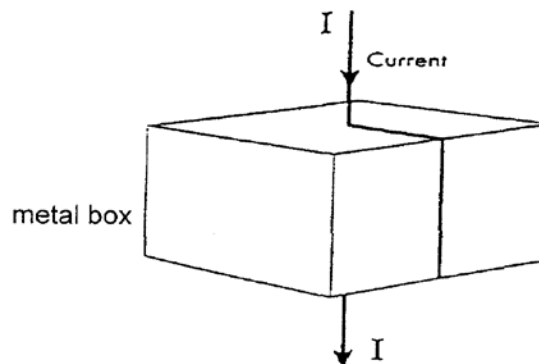
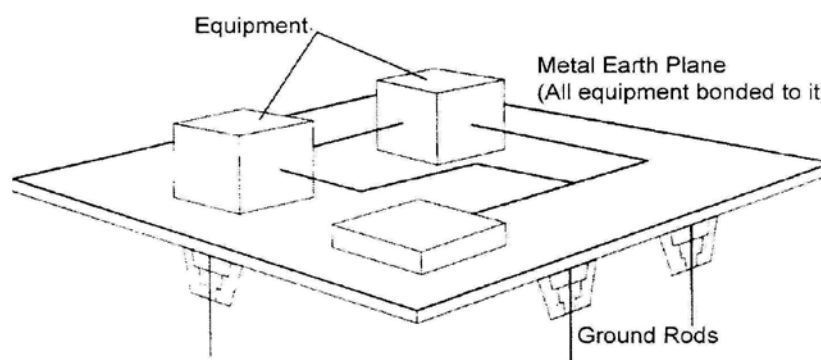


Figure 17.6: A Metal Box Used As A Faraday Cage


17.7.3 The Ideal Earthing System

Salient points / requirements of the ideal system which virtually eliminates problems with surges (next best thing to a closed metal box) are:

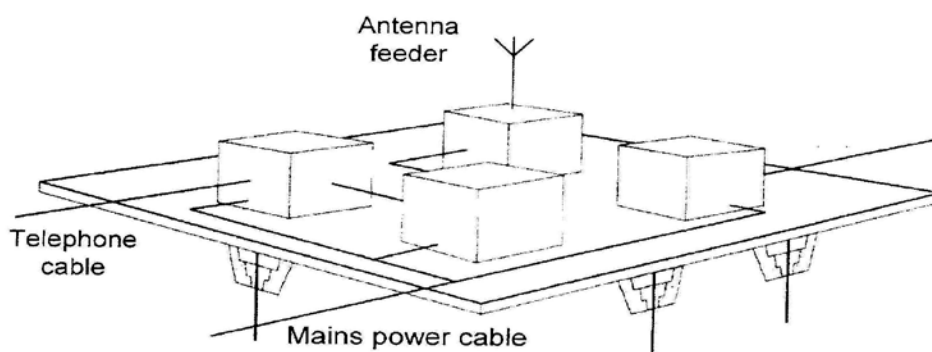
- All equipment is metal-cased
- All equipment sits directly on a metal sheet to which it is electrically bonded.
- Everything shares the same low-impedance zero volt reference.
- For good measure, the metal 'earth plane' is at ground level and connected to ground by a system of rods driven into the soil so that it is at local ground potential.
- There is no connection to other electronic systems.
- The system is physically small; a few square metres at most, so making the likelihood of a direct strike negligible.



The perfect earth – sitting on a metal earth plane

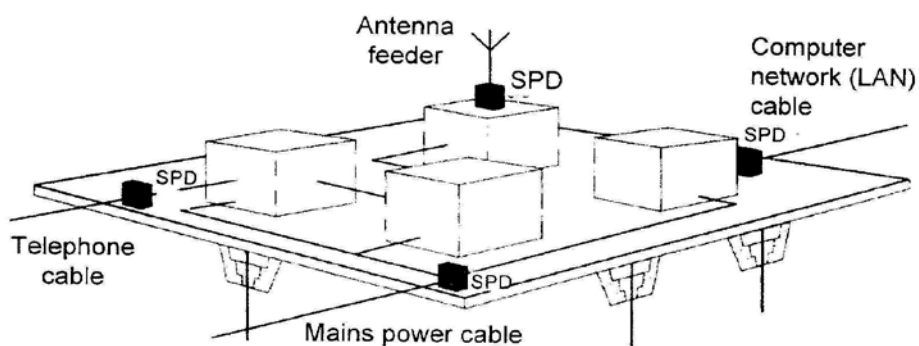
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However, real systems inevitably have cables connected to its systems from the ‘external world’ making a less than ideal system. The connected cables can be mains power, telephone, telemetry, antennas, computer networks, external lighting power cables, etc. Voltage surges can be transmitted to and from the equipment via these cables by potential differences generated.




A less than ideal system – with connections to the external world

Therefore, SPDs are required to limit both COMMON and DIFFERENTIAL mode voltages to the equipment.



Requirement of surge protective devices (SPDs)

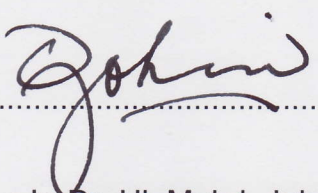
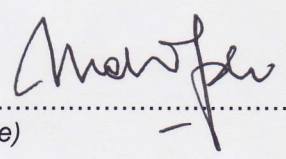
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Refer to Energy Efficiency Guidelines for CKE Design [CKE.GP.04.01.(01).2010]




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CAWANGAN KEJURUTERAAN ELEKTRIK
IBU PEJABAT JKR MALAYSIA**

ENERGY EFFICIENCY GUIDELINES FOR CKE DESIGN

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1.0 Introduction

Energy Efficiency (EE) in the JKR context means the efficient utilization of energy during the operational lifespan of a building where the comfort of its occupants is not compromised nor sacrificed. Initially EE can be achieved by wisely taking various energy saving measures during the design stage of the building. In projects designed by JKR, energy in buildings is associated mainly with electricity. Often this is mistakenly taken to imply that EE is the sole responsibility of electrical engineers. In reality, anything that leads to the eventual end-use of electricity is related to EE in buildings.

1.1 Scope

The guidelines apply to electrical installations for non-residential buildings either it is a conventional design or design and build such as the peak design rate of electrical energy usage for all purposes is greater than 10W/m² of gross floor area.

1.2 Objective

The objective of these guidelines is to ensure that electrical system design comply with the minimum requirements of MS 1525:2007- Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (First Revision).

1.3 Responsibility


Head of Design Team (HODT) is responsible for ensuring adherence to these guidelines.

1.4 Method of Compliance

HODT shall use the EE checklist as in Appendix 3 together with these guidelines. This checklist shall be submitted during Design Verification and attached with JKR.PK Form(O).02-2 (Form Review / Verification / Validation).

2.0 Integrated Design Approach

Integrated building design is a process of design in which multiple disciplines and seemingly unrelated aspects of design are integrated in a manner that permits synergistic benefits to be realized. The goal is to achieve high performance and multiple benefits at a lower cost than the total for all the components combined. This process often includes integrating green design

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strategies into conventional design criteria for building form, function, performance and cost.

EE in JKR constructed building can be achieved by applying both passive and active design strategies.

Passive design strategies includes adopting design measures such as building orientation and shape, site planning, selection of building envelope wall and roof materials with low thermal mass conductivity, building shading design, window type and design, type of glazing, daylight harvesting strategy, using natural ventilation and good landscaping design.

While active design strategies refers to selecting energy efficiency equipment, utilities systems, control system and strategy that result in direct reduction in the building energy running costs. This includes using high efficiency Air Conditioning and Mechanical Ventilation (ACMV) system, such as using Variable Air Volume (VAV) or chilled beam air condition technologies; using high efficiency motors, pumps and fans, Variable Speed Drivers (VSDs) with motor driving pumps and fans with variable loads; use of high efficient lighting system and occupancy sensor and use of effective control system such as Building Automation System (BAS).


Cawangan Kejuruteraan Elektrik focuses mainly on active design strategy which includes electric lighting design. Hence, this guideline is developed to accommodate the strategy.

3.0 Lighting Design

3.1 Types of Lighting

There are many types of lighting products including light bulbs, lamps, ballast, fluorescent lamps and fluorescent fixtures, troffers, track light, emergency fixtures, batteries, incandescent lighting, high intensity discharge (HID) lamps and fixtures, rope lights, mercury lamps, dimmers and other products for area lighting.

For domestic and industrial use, the selection of lighting, in term of wattage and colour rendering, is important in ensuring the right environment for a working area and the efficient utilization of energy, without jeopardizing any visual elements.

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Several Types of Energy Efficient Light

3.2 Electronic Ballast for Fluorescent Lighting

Although electronic ballast saves substantial amount of energy, it is not widely used to replace the relatively energy-inefficient standard electromagnetic ballast because of its higher cost.

Electronic ballast gives significant energy savings with fluorescent lighting, typically reducing power consumption by around 25%. Electronic ballasts are designed to last 10 to 15 years lifetime with long burning times and low switching frequencies. They are more compact and 60% lighter weight than electromagnetic ballasts.

Using electronic ballasts give freedom from the 50Hz lamp flicker, making lighting much easier on the eyes. There is no audible hum and lower heat generation, contributing to improved working conditions. Lamp starting is instantaneous; these ballasts also prevent stroboscopic effects which can be dangerous where rotating machinery is used.

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Several Types of Energy Efficient Electronic Ballasts

3.3 Electromagnetic Ballast

The type of electromagnetic ballast must be energy efficient and energy saving. The Code of Practice has called for fluorescent ballast loss not to exceed 6.0 W in accordance to MS IEC 60929:1995.

3.4 Design Criteria


3.4.1 Luminous Environment

Good lighting practice for workplace is more than just providing good task visibility. It is essential that tasks are performed easily and in comfort. Thus, the lighting must satisfy the quantitative and qualitative aspects demanded by the environment. In general lighting is to ensure:

- i. visual comfort, where the workers have a feeling of well-being
- ii. visual performance, where the workers are able to perform their visual tasks, speedily, and accurately, even under difficult circumstances and during long periods
- iii. visual safety, to see one's way around the detect hazards.

Accordingly, to have a good lighting design, the following criteria should be taken into consideration:

- i. Luminous environment

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- ii. Luminance distribution
- iii. Illuminance
- iv. Glare
- v. Directionality of light
- vi. Colour aspects of light and surfaces
- vii. Flicker
- viii. Daylight
- ix. Maintenance

Design values for the quantifiable parameters of illuminance, discomfort, glare and colour rendering are presented in Appendix 1.

3.4.2 Luminance Distribution

The luminance distribution in the field of view controls the adaptation level of the eyes, which affect task visibility. A well-balanced adaptation luminance is needed to increase:

- i. visual acuity (sharpness of vision)
- ii. contrast sensitivity (discrimination of relatively small luminance differences)
- iii. efficiency of the ocular functions (such as accommodation, convergence, papillary contraction, eye movements, etc.)


Diverse luminance distribution in the field of view also affects visual comfort and should be avoided:

- i. too high luminance can give rise to glare
- ii. too high luminance contrasts will cause visual fatigue due to continuous re-adaptation of the eyes
- iii. too low luminance and too low luminance contrasts results in a dull and non-stimulating working environment
- iv. attention should be given to adaptation in moving from zone to zone within a building

The luminance of all surfaces is important and will be determined by the reflectance of and the illuminance of the surfaces. The range of useful reflectance for the major interior surfaces is given in Table 1 below.

No	Interior Surfaces	Range of Useful Reflectance
1	Ceiling	0.6 – 0.9
2	Walls	0.3 – 0.8
3	Working Planes	0.2 – 0.6
4	Floor	0.1 – 0.5

Table 1: Range of useful reflectance for the major interior surfaces

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3.4.3 Illuminance

The illuminance and its distribution on the tasks areas and the surrounding area have a major impact on how quickly, safely and comfortably a person perceives and carries out the visual task. For spaces where the specific area is unknown, the area where the task may occur is taken as the task area.

All value of illuminance specified in this guideline are maintained illuminance and will provide for visual safety at work and visual performance needs. The details of this can be referred to Appendix 2

3.4.3.1 Recommended illuminance at the task area

The values given in Appendix 2 are the maintained illuminance over the task area on the reference surface which may be horizontal, vertical or inclined. The average illuminance for each task shall not fall below the value given in Appendix 2 regardless of the age and condition of the installation. The values are valid for normal visual conditions and take into account the following factors:

- i. requirement for visual tasks
- ii. safety
- iii. psycho-physiological aspects such as visual comfort and well-being
- iv. economy
- v. practical experience.


The value of illuminance may be adjusted, by at least one step on the scale of illuminance, if the visual conditions differ from the normal assumptions. The illuminance should be increased when:

- i. unusually low contrasts are present in the task
- ii. visual work is critical
- iii. errors are costly to rectify
- iv. accuracy or higher productivity is of great importance
- v. the visual capacity of the worker is below normal.

The required maintained illuminance may be decreased when:

- i. the details are of an unusually large size or high contrast
- ii. the task is undertaken for an unusually short time.

In area where continuous work is carried out, the maintained illuminance shall not be less than 200 lux.

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3.4.3.2 Scale of illuminance

A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminance. In normal lighting conditions, approximately 20 lux of horizontal illuminance is required to just discern features of the human face and is the lowest value taken for the scale of illuminance. The recommended scale of illuminance is:

20 – 30 – 50 – 75 – 100 – 200 – 300 – 500 – 750 – 1000 – 1500 – 2000 – 3000 – 5000 lux.

3.4.3.3 Illuminance of immediate surroundings

The illuminance of the immediate surroundings areas shall be related to the illuminance of the tasks area and should provide a well-balanced illuminance distribution in the field of view. Rapid spatial changes in luminance around the tasks area may lead to visual stress and discomfort.


The maintained illuminance of the immediate surroundings areas may be lower than the tasks illuminance but shall not be less than the values given in the table below.

Task illuminance lux	Illuminance of immediate surrounding lux
≥ 750	500
500	300
300	200
≤ 200	Same as task illuminance

Table 2: Illuminance of immediate surroundings and task illuminance

3.4.3.4 Uniformity

The uniformity of the illuminance is the ratio of the minimum to average value. The illuminance should change gradually. The task area should be illuminated as uniformly as possible. The uniformity of the task illuminance shall not be less than 0.7. The uniformity of the illuminance of the immediate surrounding areas shall be not less than 0.5.

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3.4.3.5 Colour aspects

The colour qualities of a near-white lamp are characterized by two attributes:

- i. The colour appearance of the lamp itself
- ii. Its colour rendering capabilities, which affect the colour appearance of objects and persons illuminated by the lamp.

These two attributes must be considered separately.

Colour Appearance

The variation in the amount of colours within a light mixture affects the appearance of the light in terms of its relative 'warmness' or 'coolness'. To describe this 'warmness' and 'coolness' of the colour of the light sources, the term 'colour temperature' is used.


Colour Temperature or Correlated Colour Temperature (CCT) due to its theoretical basis in the study of 'black body' radiation should apply only to source with a continuous spectrum (such as incandescent lamps and natural

light). However, for light sources with non continuous spectral distribution (such as fluorescent lamps where the spectrum consists of peaks of energy), CCT is used mainly on an empirical sense (i.e. in a very 'near approximate' sense).

Colour Rendering

A more common method of characterizing light sources by its colour is the Colour Rendering Index (CRI). The CRI compares the spectral energy content of a light source to that of a standard reference source with full spectrum. The CRI value is the numerical value and is 100 for full-spectrum natural white-light. Incandescent lights are considered nearly white and have CRI close to 100. Most lights have CRI typically in the range of 20 – 80.

The CRI model is not a perfect model and should only be used to compare light source with the same colour temperature. For example, (about) 6000K daylight fluorescent and clear mercury has CRI of 76 and 22 respectively. The daylight fluorescent will therefore render colours better than clear mercury. The difference between a 3400K tungsten halogen with CRI 99 and an ordinary 2800K incandescent with CRI 92 can usually also be differentiated by most observers. Despite the small difference in CRI values, the tungsten halogen will render colours more vividly compared to the ordinary incandescent. Colour rendering is important especially in the case of (building) façade and monument building.

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3.4.4 Daylight

Daylight may provide all or part of the lighting for visual tasks. Daylight may create a specific modeling and luminance distribution due to its nearly horizontal flow from side windows. Daylight can also be provided by roof lights and other fenestration elements. An automatic or manual switching or dimming of the lamps is required during day time depending on the visual acceptance limit.

3.4.5 General Principles of Efficient Lighting Practice


Lighting must provide a suitable visual environment within a particular space, i.e. sufficient and suitable lighting for the performance of a range of tasks and provision of a desired appearance.

The maintained illuminance levels for general building areas are as given in Appendix 2.

Lighting load shall not exceed the corresponding maximum value as listed in Table 3.

Building Types / Space	Max. lighting power (W / m²)
Restaurants	15
Offices	15
Classrooms / Lecture Theatres	15
Auditoriums / Concrete Halls	15
Hotel / Motel Guest Rooms	15
Lobbies / Atriums / Concourse	20
Supermarkets / Department Stores / Shops	25
Stores / Warehouses / Stairs / Corridors / Lavatories	10
Car Park	5

Table 3: Maximum allowable power (including ballast loss) for illuminance systems

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3.5 Efficiency & Efficacy of Luminance

The efficiency of a light source depends to large extent on how efficient (L.O.R) and performance of the lighting fixtures.

A lamp that produces 20 lumens / watt, when installed, may actually distribute only 10 lumens when covered by dust.

3.6 Lighting Controls

All lighting systems except those required for emergency or exit lighting should be provided with manual, automatic or programmable controls. For lighting loads exceeding 100 kW automatic controls should be provided.

3.7 Lighting Zones Control

All spaces enclosed by wall and ceiling height partitions shall be provided with at least one operated on-off lighting control for each room.

Switch to compacts fluorescent light bulbs, in areas where lights are left on for long periods of time, or in difficult to reach places.

One switch is provided for each task or group of task within an area of 30 m² or less. Lighting switch must possibly next to exit door.


The total number of switches shall be at least one switch for each 1kW of connected load.

Used of a separate circuit where day light can be use and alternate switching to optimize the use of lighting. In typical side lighting design with window along one wall it is best to place the luminaries in rows parallel to the window wall and circuited so that the row nearest the windows will be the first to dim or switch off followed by successive rows.

Automatic 'on' / 'off' control switches are required for areas of infrequent use by using lighting sensors.

For commercial building and offices, lighting in low occupancy area, i.e. M & E plant rooms, store rooms, meeting rooms, and any other identified areas, an automatic control system equipped with sensor shall be placed in order to reduce the energy consumption at that particular area.

For landscaping area in condominiums and apartments, lighting shall be switched of 30% after 12:00 am due to low occupancy in these areas.

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3.8 Guideline for Best Practice

i. Maintenance

Maintained illuminance depends on the maintenance characteristic of the lamp, the luminaire, the environment and maintenance programme. The lighting scheme should be designed with overall maintenance factor calculated for the selected lighting equipment, space environment and specified maintenance schedule. The calculated maintenance factor should not be less than 0.70.

Best practice guideline is established for periodical maintenance and appropriate selection and usage of lighting equipment.

ii. Determination of Lighting Efficiency

Lighting power consumption in term of kWh is determined as follows:

$$\begin{array}{c}
 \boxed{\text{Consumption power per lighting (kW)}} \times \left(\frac{\boxed{\text{Average luminance on working place, E}} \times \boxed{\text{Area, A (m}^2\text{)}}}{\boxed{\text{Luminance flux per one lamp, } \Phi \text{ (m)}} \times \boxed{\text{Criteria for rational use of energy}} \times \boxed{\text{Maintenance rate, M}}} \right) \times \boxed{\text{Operating Hour, T(h)}}
 \end{array}$$

4.0 Sub Metering

Electrical energy meters shall be provided for all energy uses of $\geq 100\text{kVA}$ and shall be installed at strategic load centres to monitor energy consumption of key building services such as the outgoing sub-circuits serving, but not limited to the following:

- Central air-conditioning system
- Lifts
- Major water pumping system
- Plug loads
- Lightings

These sub-meters shall be linked to the Energy Management System (EMS) for monitoring and recording, and control where appropriate, and refer also to Content 8.5.



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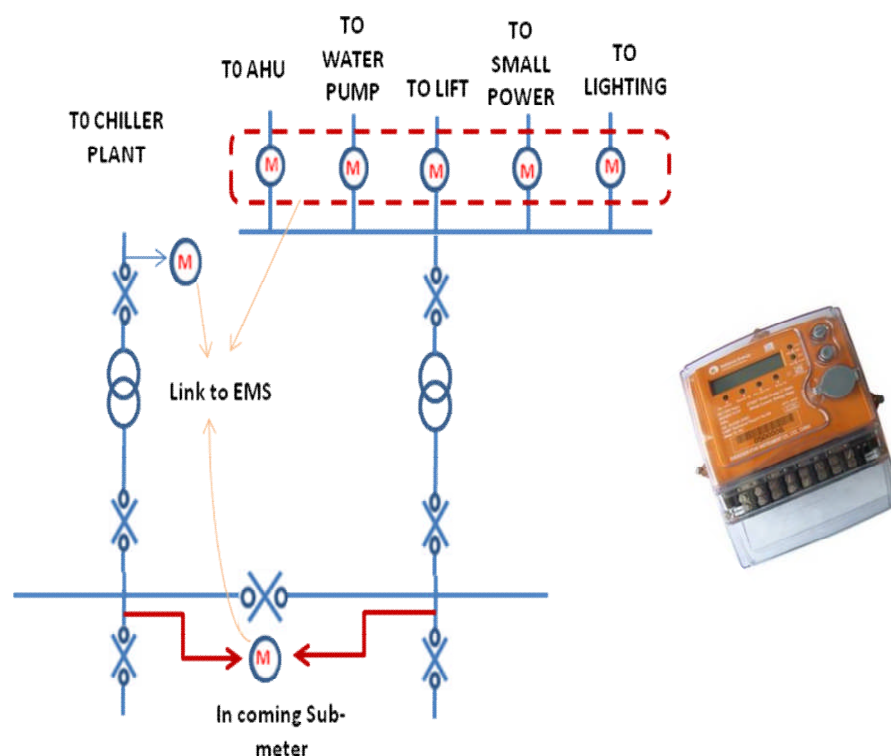
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Example of Sub Metering Schematic Diagram

5.0 Transformers Design


The Electrical Supply Industry (ESI) uses transformers in the generation, transmission and distribution sectors. Decision to purchase what type of transformers is more of economics where one must compare the higher initial capital cost to purchase higher energy efficient transformers with the cost of the losses of lower efficient transformers over time.

Increased cost of energy results in energy conservation and usage of energy-efficient equipment. Improvement of transformer efficiency results in savings from reduction in

losses, which will lead to reduction in the consumption of fossil fuels to produce the electrical energy, thereby resulting in improved conservation of natural resources towards sustainable development.

This guideline sets out the minimum requirements for achieving energy efficient design and installation of power transformer without sacrificing safety,



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reliability and quality. The guideline provides guidance on specification, selection, efficiencies and efficient utilization of liquid-filled transformers. It also provides guidance on best practice in the design, operation and maintenance of power transformers.

5.1 Types of Transformer

A Power Transformer is a static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power.

Transformers are generally classified into two categories as follows:

a) Liquid (Oil) Filled Transformer

A transformer of which the magnetic circuit and windings are immersed in an insulating liquid (for this guideline, it may be any insulating liquid, mineral oil or other product) is regarded as oil-filled transformer.

b) Dry Type Transformer:

A transformer of which the magnetic circuit and windings are not immersed in an insulating liquid is regarded as dry type transformer.

5.2 Parts of Transformer


The transformer essentially consists of the following parts:

- a) Magnetic core
- b) Windings
- c) Insulation
- d) Tank
- e) Cooling system
- f) Bushings
- g) Tap-changers

5.3 Types of Transformers Losses

Transformers losses can be broadly classified into 2 categories as follows:

- a) No-load losses consists of the following components:
 - i) Hysteresis losses in core laminations
 - ii) Eddy current losses

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- iii) I^2R losses due to no load currents
- iv) Stray losses
- v) Dielectric losses

- b) Load losses consists of the following components:
 - i) Losses in windings due to load current flow
 - ii) Conductor eddy current losses
 - iii) Losses at auxiliaries

5.4 Guidelines on Selection of Transformers


The following are the selection criteria:

- a) The type of transformer
- b) Voltage transformation ratio
- c) The winding connection and vector group
- d) The impulse withstand voltage
- e) The impedance voltage
- f) Flux density
- g) The transformer losses and transformer efficiency
- h) The tapping range
- i) Limits of temperature rise
- j) Class of winding insulation
- k) Noise
- l) Design and construction

5.5 Guideline on Efficient Utilization of Transformer

The following are the engineering considerations for the efficient utilization of transformers:

- a) Sizing of capacity
- b) Balanced loading of transformers operating in parallel
- c) Load factor
- d) Transformer impedance
- e) Design and construction
- f) Effects of power quality and harmonics
- g) Choices of transformer core materials
- h) Techno-Economic Life Cycle Costs

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5.6 Location of Distribution Transformers

Location of distribution transformers should comply with table below:

Load fed by Transformers	Distance of Transformer from Load Centres
> 600 A	Not more than 20 meters
300 A to 600 A	Not more than 100 meters

5.7 JKR Specification in Transformers Design

5.7.1 The 33/11kV transformers shall be suitable for conditions operation on a three phase 50 Hz high voltage transmission system at the voltage specified and, unless specifically stated otherwise, the neutral earthing conditions for these systems will be as follows:

0.415kV	Solidly earthed
11kV	Solid or resistance earthed
33kV	Solid or resistance earthed

5.7.2 The transformers shall be of low iron loss and low copper loss cast resin dry type complying with the relevant Malaysian Standard or IEC recommendations.


5.7.3 The air conditioning plus the other mechanical system shall be supplied by its own transformer.

5.7.4 The no-load loss, load loss and total losses shall not exceed the values specified in table below. The tolerance shall be in accordance with MS IEC 60076-1, which allows +10% on total losses, and +15% on no-load and load losses, provided that the tolerance for total losses is not exceeded.

Dry-type

Rated Power (kVA)	No Load Loss (W)*	On-Load Loss (W)*	Total Losses (W)*
400	810	4520	5330
500	840	5350	6190
630	1140	5910	7050
800	1420	5500	6920
1000	1580	6650	8230
1250	1880	8170	10050
1600	2290	9650	11940
2000	2860	12940	15800
2500	3330	14990	18320

(at 120°C)

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Oil-Filled

Rated Power (kVA)	No-Load Loss (W)*	On-Load Loss (W)*	Total Losses (W)*
100	300	1500	1800
300	600	2800	3400
500	1000	4100	5100
750	1200	6000	7200
1000	1400	7000	8400

5.7.5 Power transformer loadings shall not exceed 70% of rated capacity under normal conditions. The choice of power transformer sizes shall take into consideration harmonics as well as current and future fault levels. There shall be provision for forced cooling of the transformer.

5.7.6 The transformer Test to be carried out shall cover but not limited to the following:-

1. Routine Tests


- Induced voltage dielectric test
- Applied voltage dielectric test
- Measurement of no-load losses and the no-load current
- Measurement of the resistance of MV and LV windings
- Measurement of the impedance voltage and load losses
- Measurement of the transformation ratio and verification of the vector group

2. Type Tests

- The temperature rise test
- The lightning impulse test

3. Special Tests

- Measurement of the partial discharge level
- Measurement of the noise level

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5.7.7 Adequate ventilation system shall be provided for the Transformer Room.

6.0 Renewable Energy

Cawangan Kejuruteraan Elektrik shall drive the adoption of renewable energy (RE) in the built environment as an effort to support RE policy in Malaysia and to offer an alternative way to produce energy which is sustainable.

Potential RE project shall be assessed by the availability and reliability of the resources i.e solar, wind, geothermal, low-impact hydro, biomass and others. Generation of renewable electricity using photovoltaic (PV) system is highly

recommended in the Malaysian climate. It can be either grid connected or off-grid system. Solar PV panels can be attached to pitched roofs or flat roofs, fixed vertically onto external walls or located on the ground. They should work efficiently in most locations as long as no part of the panel is shaded from the sun.

If PV system is to consider in the design, as of minimum requirement, it is suggested to estimate the installed power capacity (kWp) where 0.5 % (of total) or 5 kWp (of PV) whichever is the greater, of the total electricity consumption is generated by renewable energy. However, the designers are encouraged to design and install a bigger PV system capacity if it does not cause cost overruns for the whole project.

7.0 Suggested Methods for Energy Efficiency by Others in JKR


7.1 Building Design Specification

The nature of the building environment is an important factor in the design of the lighting system. If dark colours are used on walls, floors and ceilings, the result is decreased light level as more light is absorbed by the dark surfaces. Using light colours instead can allow the removal of lamps in some cases.

7.2 Maximise Daylighting / Natural Lighting Used

In this stage, the electrical designers should coordinate the electrical lighting system with the day lighting design proposed by the architect.

For a place that is opened to the sunlight, there should enclose a lux sensor / light control system to limit the glare entering the workstation to avoid errors, fatigue and accidents.

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Wherever possible, use “natural lighting”. Choose transparent roof material, which is easy to clean and will not darken under the action of sunlight.

Clean the “reflector” portion of the fluorescent light fittings to maintain the available light output.

Task or area lighting may be used in some cases where only a small area of a building needs higher lighting levels. Therefore, an efficient use of lighting is applicable; however it must not compromise the visual aspects of a lighting installation simply to reduce the energy consumption.

Factors such as glare or stray reflections should also be taken into account. They can have an impact on productivity as well as on the energy efficiency of the system.

7.3 Energy Efficient Office Equipment and Plug Loads


Except in Design & Build contracts, the purchase of office equipments and other plug loads are not normally included under JKR 203 contracts. However we should be proactive in advising our clients that they should only purchase energy efficient office equipment in line with our integrated design approach.

Office equipment includes computers, printers, faxes, copying machines and other equipment. Energy consumption of such equipment can represent large portion of the building energy consumption. Using readily available energy efficient and reasonably priced office equipment such as computers with power management functions, laptop, liquid crystal display (LCDs) monitors, multifunction office equipment and others can offer substantial reduction in office equipment energy consumptions.

7.4 Energy Efficient ACMV Systems

ACMV systems are intended to provide adequate cooling comfort, dehumidification and ventilation to occupied spaces at reasonable costs. Some of effective and energy efficient system include:

- Efficient multi zoning air distribution with Variable Air Volume (VAV) and Variable Speed Drives (VSD) to ensure the air conditioning areas are all within the specified comfort zones and to control cooling comfort where you want it.
- Using the motion sensors and occupancy sensors to control the temperature in unoccupied rooms.
- Using effective air infiltration control to prevent the egress of external untreated air.

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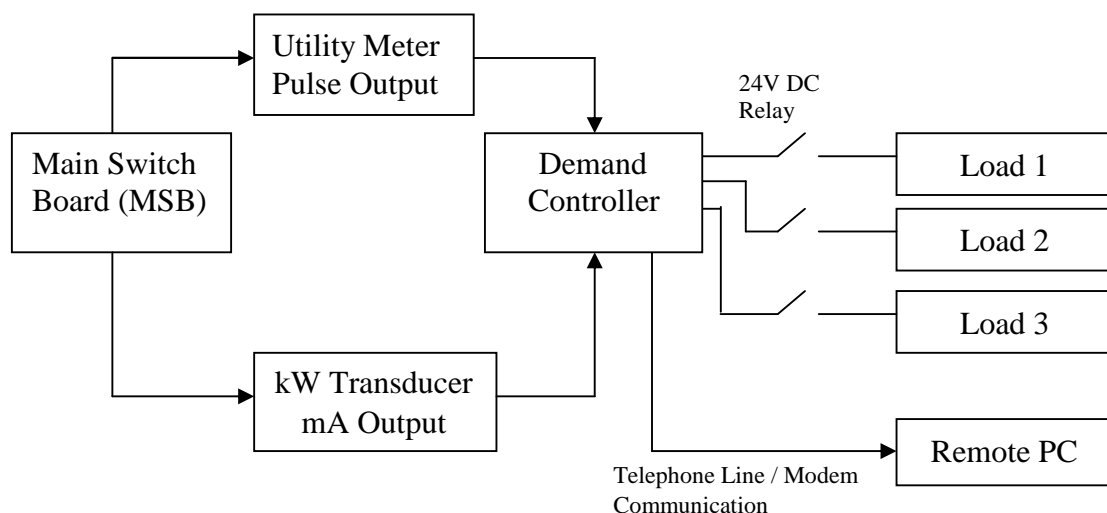
- Using of High Efficiency Motor (HEM) for bigger horse power motor with longer running hours.
- Using of Energy Recovery Wheel to recover energy from exhaust air.
- Better ductworks and pipes insulation to prevent heat loss through condensation.
- Using of high accuracy thermostats for accurate temperature control.

7.5 Energy Management System (EMS)

According to MS 1525, the EMS shall be considered for buildings having area greater than 4000 m² of air-conditioned space where it is a subset of the building automation system function.

For the installations taking supply at 11kV and above from TNB, it is recommended to install the EMS complete with maximum demand (MD) limiting controller for controlling and reducing MD in TNB bill.


Having an effective building monitoring, control, operation, energy management and reporting system can play a critical role in operating and maintaining energy efficient building. This system will ensure that the building operates as efficiently as possible while meeting the occupants' comfort and functional needs not only during testing and commissioning but throughout the life of the building.



Example of Maximum Demand Controller Schematic

7.6 Awareness

An intensive programme of electricity saving awareness for all employees for their cooperation in lighting control.

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Appendix 1

Minimum Allowable Values of Luminous Efficacy for Various Types of Lamp

Factor	Fluorescent	MH	HPS	LPS
Wattage	18 – 95	50 – 400	50 – 400	18 – 180
Output (lumens)	1,000 - 7,500	1,900 - 30,000	3,600 - 4,600	1,800 - 33,000
Efficacy (lumens / watt)	55 – 79	38 – 75	72 – 115	100 – 183
Lumen Maintenance	85 (80)	75 (65)	90 (70)	100 (100)
Lamp Life (hours)	10,000 – 20, 000	10,000 – 20,000	18,000 – 24,000	16,000
CRI	30 – 90	80 – 90	20 – 39	<20

Notes: **Wattage** and **output** refers to the commonly available lamp rating for outdoor lightings.

Efficacy refers to the ratio of the measured light output of a luminaire to its active power, express in lumens per watt.

Lumen Maintenance refers to percent of initial lamp output at 50% of mean lifetime and at end of lifetime (parenthesis).

Lamp Life refers to the approximate mean lifetime of lamp.



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Appendix 2

Item	Area	Illumination Level (Lux)
1	Ruang Laluan (Luar)	50
2	Tempat Letak Kereta	50
3	Bilik Tidur Hotel	100
4	Lif	100
5	Koridor	100
6	Tangga	100
7	Eskalator	150
8	Bilik Persalinan	100
9	Bilik Pencuci	100
10	Pintu keluar & Masuk	100
11	Dewan Masuk	100
12	Lobi	100
13	Bilik Menunggu	100
14	Kaunter Pertanyaan	300
15	Pejabat	300
16	Pejabat Lukisan	300
17	Restoran	150
18	Kantin	200
19	Kafeteria	200
20	Dapur	150
21	Bilik Mandi	150
22	Tandas	100
23	Bilik Darjah	300
24	Perpustakaan	500
26	Muzium	300
27	Bilik Komputer	500
28	Bilik Mesyuarat	300
29	Bilik Pengarah	300
30	Bilik Pegawai	300
31	Bilik Perbincangan	300
32	Stor	100
33	Bilik Cetak	300
34	Bilik Fail	300
35	Bilik Kuliah	300
36	Bilik Makmal	300
37	Bilik Utiliti	100
38	Dewan Serbaguna	300
39	Surau	300
40	Bilik Solat	300
41	Ruang Wuduk	150
42	Bilik Seminar	300
43	Bilik Tukar Lampin	200





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Item	Area	Illumination Level (Lux)
44	Bilik Penyusuan	300
45	Bilik Rawatan	300
46	Bilik Pemeriksaan	300
47	Bilik Analisa	300
48	Farmasi	300
49	Bilik Kebal	300
50	Bilik Pergigian	300
51	Bilik Sterilisasi	300
52	Bilik Pembedahan	500
53	Bengkel	500
54	Ruang Laluan (Dalam)	300
55	Auditorium	150
56	Gimnasium	300
57	Garaj	300
58	Bilik Demontrasi Memasak	100
59	Pantri	100
60	Bilik Penyediaan Makanan	300
61	Bilik Suis/Riser	150
62	Bilik Set Janakuasa	150
63	Bilik Server	300
64	Bilik Mesin	300
65	Bilik AHU	150
66	Bilik MDF	150
67	Rumah Pam	150
68	Bilik Motor Lif	150
69	Bilik Tangki / Mekanikal	150
70	Bilik Tayangan	300
71	Bilik Studio Rakaman	300
72	Bilik Prosedur	300
73	Bilik Gelap	300
74	Bilik Cuci/Dobi	200
75	Hangar	500

Reference: CKE Lux Bulletin dated 23/11/2009




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Appendix 3

Energy Efficiency Checklist (Electrical Aspect Only)


Kumpulan BPR :	Nama PRB :
Nama Projek :	
Kos Projek (Keseluruhan):	Kos Projek (Elektrik):
Kaedah Pelaksanaan: Konvensional Dalam <input type="checkbox"/> Konvensional Perunding <input type="checkbox"/> Reka & Bina <input type="checkbox"/>	
Jumlah Keluasan Lantai (m ²): (berdasarkan luas keseluruhan)	Jumlah Keluasan Lantai (m ²): (berdasarkan luas kawasan berhawa dingin)
Beban Keseluruhan – M.D (kW):	Beban Lampu – M.D (kW): Beban <i>Plug Load</i> – M.D (kW): Beban Mekanikal – M.D (kW):
<i>Lighting Power Density (W/m²):</i> <i>(berdasarkan luas keseluruhan)</i>	<i>Plug Load Density (W/m²):</i> <i>(berdasarkan luas keseluruhan)</i>
<i>*LPD should be $\leq 12\text{W/m}^2$</i>	
<i>Estimated Building Energy Intensity (kWh/m²/year):</i> BEI = <input type="text"/> kW x <input type="text"/> jam x <input type="text"/> hari x 12 bulan = <hr/> <input type="text"/> m ²	
<i>*norma waktu bekerja sehari = 10jam (pejabat)</i>	
Contoh kiraan BEI = $\frac{(\text{Design M.D} \times \text{waktu bekerja sehari} \times \text{jumlah hari bekerja sebulan} \times 12 \text{ bulan})}{\text{Jumlah keluasan keseluruhan lantai (berhawa dingin)}}$	

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No.	Descriptions	√ if Yes x if No	Justify if No
1	Lighting System and Control		
1.1	Use of Energy Efficient Lights:		
	i) Compact Fluorescent Lamp (CFL) c/w Electronic Ballast		
	ii) T5 Lamp		
	iii) LED Lamp		
	iv) Others :		
1.2	All spaces enclosed by wall or ceiling height partitions with an area $\leq 30 \text{ m}^2$ should be provided at least two operated-on-off lighting controls for each room with switch clearly label. If an area $>30 \text{ m}^2$, appropriate numbers of switch shall be provided.		
1.3	One switch for each task or group of tasks (open space) within an area of 30 m^2 or less with switch clearly labels. If an area $>30 \text{ m}^2$, appropriate numbers of switch shall be provided.		
1.4	Lighting switch next to exit door.		
1.5	Separate switch for lighting which parallel to daylight.		
1.6	Photo sensor at building perimeter which receive daylight.		
1.7	Use of occupancy/motion sensor at least 30% of gross floor area.		
1.8	Alternate switching for corridor lighting if $> 10\text{m}$.		
1.9	Two way light switching for internal corridor, stair or other suitable places.		

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No.	Descriptions	√ if Yes x if No	Justify if No
1.10	Dual timer switches with alternate circuit for compound lighting.		
1.11	Illuminance designed according to CKE Room Illumination Level (refer to Appendix 2).		
1.12	LED Exit sign		
2	Transformer		
2.1	Efficiency of Transformer:		
	a. Transformer size : < 1000kVA at full load condition		
	- not lower than 98%		
	b. Transformer size : > 1000kVA at full load condition		
	- not lower than 99%		
2.2	The locations of power transformers and main switchboards sited at their load centre		
	Distance of Transformer from load centre:		
	a. Load fed by Transformers: > 600A		
	- not more than 20 meters		
	b. Load fed by Transformers: 300A to 600A		
	- not more than 100 meters		
2.3	The dry-type and oil-filled transformers should be of low loss type (refer 5.7.4)		
3	Monitoring System		
3.1	Energy Management System (EMS) for building having air-conditioned area > 4000m ² (To monitor and analyse energy consumption)		
3.2	Installation of Digital Electrical Energy Meters at Main Switch Board and sub-switch board serving, but not limited to the following:		
	a. central air-conditioning system		

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No.	Descriptions	√ if Yes x if No	Justify if No
	b. lift and escalator system		
	c. major water pumping system		
	d. general power supply		
	e. lighting supply		
	f. others		
4	Renewable Energy		
4.1	Design (sizing) of renewable energy:		
	Where 1% of the total expected electricity consumption is generated by renewable energy, OR		
	Where 2% of the total expected electricity consumption is generated by renewable energy, OR		
	Where 3% of the total expected electricity consumption is generated by renewable energy, OR		
	Where 4% of the total expected electricity consumption is generated by renewable energy, OR		
	Where 5% of the total expected electricity consumption is generated by renewable energy		

Disediakan oleh:

Disemak oleh:


Disahkan oleh:

.....
Nama:
Jurutera Elektrik

.....
Nama:
Jurutera Elektrik
Penguasa Kanan/
Jurutera Elektrik
Penguasa

.....
Nama:
Ketua Jurutera
Elektrik



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